SOYBEAN AND MAIZE PRODUCTION IN BRAZIL

PRODUCTION PROCESSES & PROFITABILITY COMPARISONS BETWEEN TRANSGENIC AND CONVENTIONAL VARIETIES IN MATO GROSSO AND PARANÁ

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Abstract

This study aims to investigate the changes in production of soybeans and maize in Brazil after the introduction of transgenic crops, by describing all relevant aspects of growing conventional and transgenic soy and maize. Furthermore, using financial analyses of producers of both crops in selected regions, profitability of genetically modified crops versus non-genetically modified crops is described. With sources from literature and experts in the field of soybean and maize production in Brazil, an overview of relevant aspects in soybean and maize cultivation was constructed, followed by a matrix of advantages and disadvantages ascribed to genetically modified varieties. Using data from statistics bureaus *Instituto Mato-Grossense de Economia Agropecuária* (IMEA) and *Centro de Estudos Avançados em Economia Aplicada* (CEPEA), input costs, processing costs and other costs for the harvest year of 2010/2011 were compared between regions in Mato Grosso and Paraná and between genetically modified and conventional varieties. Soybeans, winter maize (safrinha) and summer maize were compared. Then, using selling prices and average land sizes, profitability was compared between Mato Grosso and Paraná and between genetically modified and non-genetically modified crops. Results show that genetically modified herbicide tolerant soybean seeds are more expensive than conventional soybean seeds and that they lower costs for herbicides, compared to conventional soybeans. Genetically modified insect resistant maize seeds are more expensive than conventional seeds, but they show a decrease in costs for insecticides compared to conventional maize. Other costs appear to be comparable and indirect potential advantages and disadvantages of genetically modified crops over non-genetically modified crops, such as reduced machinery cost and increased upstream dependence, were not proven. Only for genetically modified soybeans found in the state of Paraná there appears to be a significant profitability increase compared to non-genetically modified soybeans. No significant difference was found in terms of profitability for all other comparisons between genetically modified and non-genetically modified varieties. This study can provide arguments for the public debate regarding biotechnology in agriculture from a financial perspective. Additionally, these results can be used by producers of soy or maize to help decide on what type of seeds to grow.

Keywords: Soybean and Maize Cultivation, agricultural biotechnology, herbicide tolerant, insect resistant, financial analysis, profitability study

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Abbreviations

Abbreviation	Explanation
BNF	Biological Nitrogen Fixation
BT	Bacillus thuringiensis
CEPEA	Centro de Estudos Avançados em Economia Aplicada
CNPMS	Centro Nacional de Pesquisa de Milho e Sorgo
CONAB	Companhia Nacional de Abastecimento
CPAC	Cerrados Agriculture Research Center
CRC	Cerrado Research Center
CTNBio	Comissão Técnica Nacional de Biossegurança
DNA	DeoxyriboNucleic Acid
EMBRAPA	Empresa Brasileira de Pesquia Agropecuária
EU	European Union
GM	Genetically Modified
GMO	Genetically Modified Organism
Ha	Hectare
HT	Herbicide Tolerant
IAC	Instituto Agronómico de Campinas
IMEA	Instituto Mato-Grossense de Economia Agropecuária
IR	Insect Resistant
IRM	Insect Resistance Management
ISAAA	The International Service for the Acquisition of Agri-biotech Applications
MT	Mato Grosso
NGM	Non-Genetically Modified
PR	Paraná
R$	Real
RR	RoundReady
Sa	Sacks (60 kg)
USA	United States of America
USD	US Dollar

1. Introduction

From 1996 to 2010, the global area of genetically modified (GM) crops grew from 6 countries planting 1.7 million hectares to 29 countries planting over 148 million hectares (James, 2010). Roughly half of all planted biotech crops is soybean *(Glycine max)*, followed by one third for maize *(Zea mays)*, 14% for cotton and 5% for canola. In the near future many new biotech crops will enter the market, of which drought tolerant maize and insect resistant sugarcane are important examples (Hotta et al., 2010). The United States has been market leader in research and distribution of transgenic crops since 1996, but Brazil has been the fastest grower since it introduced herbicide tolerant soybeans in 2005.

The traits added with genetic modification are mostly herbicide tolerance, insect resistance, virus resistance and drought tolerance. Herbicide tolerance is the most popular trait added to crops (61% of all biotech crops) followed by insect resistance (17%) and the combination of these two in so-called stacked crops (22%). Almost all herbicide tolerant crops are resistant to glyphosate, a very broad spectrum herbicide that is normally used to clear large areas of weeds (Duke & Powles, 2008) and the most popular insect resistance trait is known as Bt, an abbreviation for *Bacillus thuringiensis*. Bt toxins are natural insecticides that kill a large variety of insects, such as the European Corn Borer (Vaeck, et al., 1987). With Bt crops farmers have to buy less insecticide and they can still protect their crops. Such an increase globally and more specifically in Brazil must mean biotech crops provide benefits to the actors involved. A few of the direct beneficial effects claimed by producers (Brookes & Barfoot, 2012) for herbicide tolerant crops are for instance: yield increase due to decreased competition (knock-back) from weeds, decreased expenditure on different herbicides, fuel and labor, price premium for higher quality crops (lower level of weed impurities) and production increase due to 'second crops' (e.g. the planting of maize after harvesting HT soy). Indirect beneficial effects include increased management flexibility and sense of security, facilitation of no tillage systems, decreased cost on use of machines and decreased exposure for farmers to harmful herbicides and insecticides (Brookes & Barfoot, 2012). For these beneficial effects however, farmers pay a higher price (a premium) to seed companies and may be more reliant on large companies that have a lot of negotiation power. For example, corn seeds are generally hybrids, meaning they have to be bought annually and premiums may vary considerably between years. Furthermore, many countries still have public acceptance problems and do not support GM crops with favorable regulative frameworks (Qaim, 2009), most notably the European Union. As a result of concerns by European consumers regarding health risks of GM foods (RE Evenson, 2004), the EU applies the strictest GM regulations in the world (Banks, 2005). Few food products are allowed into the EU and if permitted, regulations demand labeling on all food commodities: consisting of, containing or produced from GMOs. Additionally, they enforce a zero-tolerance policy on food products that contain trace amounts of non-approved GMOs (Wager & McHughen, 2010). GMOs for livestock feed products do not require labeling (Bertheau & Davison, 2011). This has split the European market for GM foodstuffs in two; the market that accepts GM products and conventional products that may be contaminated with GM; and the market that accepts only conventional food commodities.

Currently the most cultivated crops in Brazil are soybeans and maize. As of 2011 a total area of 24.2 million hectares was planted with soybeans, with a production of 75.3 million tons (CONAB, 2012a). Maize comes in second with 13.8 million hectares and a production of 57.4 million tons. Mato Grosso and Paraná are the two largest producing states of both commodities. Because the climate in Brazil allows for double harvests, soybean crops are usually followed by maize plantings (Matthey, et al., 2004). Maize and soybeans are also the most dispersed genetically modified crops of Brazil. Since the introduction of transgenic seeds in 2005, many producers have switched to GM crops. As of 2010 approximately 75% of all planted soybeans in Brazil are transgenic, herbicide tolerant soybeans (a total of 17.8 million hectares) and 56% of maize plantings are insect resistant maize (Bt corn) (James, 2010). Cost benefits and yield increases would increase profitability for transgenic soy and maize producers, inviting them to switch from conventional to GM.

There are however also studies that show that the price consumers are willing to pay for Non GM (NGM) crops is higher than for GM crops. The obtained profit from this premium on selling price can outweigh the benefits in production costs from reduced insecticide or herbicide use (Rodrigues & Martines, 2012). Additionally, after the introduction of herbicide tolerant soybeans for instance, the cost of conventional herbicides decreased, making them viable again (Rodrigues, 2013). Finally, there are studies that criticize the kind and magnitude of benefits due to GM in general (Finger, et al., 2011).

1.1 Problem Statement

The adoption of biotech crops in Brazil went so fast there has been little to no research on the actual effects for the individual farmer that has to make the choice on producing GM or NGM. On one side are producers of biotech crop seeds and herbicides that promise yield and profit increases to farmers. On the other side are environmental organizations and critical countries that refuse to accept GM products. In between are farmers that must find a way to survive in an increasingly competitive business, with larger traders that continuously want to pay less for their crops. Summarizing, the following problem statement was defined:

There is little statistical information about GM and NGM production processes and profitability differences for soy and maize producers. Do lower production costs related to transgenic production processes for instance compensate for the GM seed price premium? How have transgenic crops changed soybean and maize production and profitability for farmers in Brazil?

1.2 Research Objectives

This research aims to achieve the following objective:

Investigate how large-scale adoption of transgenic crops in Brazil has changed soybean and maize production processes and analyze yield and profitability differences between transgenic and conventional varieties.

Specific research objectives were defined:

Describe agricultural developments in Brazil and determine relevant factors for growing soybeans and maize, both with and without the use of biotechnology, in terms of input, processes and output.

Use financial analyses to compare production processes and profitability between conventional and transgenic crops.

2. Transgenic Crops in Global Agriculture

2.1 Expansion of Transgenic Crops

After the first successful use of recombinant DNA technology by Cohen and Boyer in 1973 to create a transgenic organism (*E. Coli)* (Cohen, et al., 1973), research on genetically modified organisms took a leap. Research initially focused on bacteria as they were easiest to transform. It took another 13 years until, in 1986, the first field trials began on transgenic crops, featuring a marker gene in tobacco plants. From 1986 to 1995, over 3500 transgenic crop field trials were conducted of which the majority (54%) occurred in the USA, making it by far the largest contributor to research in this area (James & Krattiger, 1996). It was the People's Republic of China however that released the first transgenic plant on the commercial market: virus resistant tobacco (James, 1997). Soon Calgene followed suit in the United States with the release of the Flavr Savr tomato in 1994 (Bruening & Lyons, 2000) and by 1996 major crops such as herbicide tolerant or insect resistant soybeans, maize, cotton and potato were being planted in the USA, China, Canada, Argentina, Australia and Mexico. Since then more countries have approved GM crops and currently Brazil is the second largest in total biotech crop area (Table 1). The most planted biotech crop is soybean, followed by maize, cotton and canola. Most other GM crops such as alfalfa, papaya, squash and potato are fairly new on the market and have less than 1% of total GM plantings. Many new biotech crops are in development by mostly private companies (Hotta, et al., 2010) and the global biotech seed market alone has a value of approximately US$11.2 billion (2010). The largest producers in the biotech seed industry are Monsanto (RoundupReady, YieldGard), Syngenta (VMAX), DuPont (LibertyLink) and Bayer CropScience.

Table 1: Top five countries growing biotech crops, 2010 **(James, 2010)**

Country	Biotech crops area (million hectares)	Percentage of total biotech area (worldwide)
USA	66.8	45 %
Brazil	25.4	17 %
Argentina	22.9	16 %
India	9.4	6 %
Canada	8.8	6 %
Other	14.7	10 %
Total	148.0	100 %

2.2 Beneficial Traits In Biotech Crops

Transgenic crop producers distinguish between single and multiple 'stacks', which describes the amount of traits added to a crop. A single stacked crop has one trait added by genetic modification, which is generally either herbicide tolerance, insect resistance or virus resistance, but double or triple stacked crops with these traits combined are becoming more widespread (mainly in the United States) (James, 2010). Herbicide tolerance is the most popular trait added to crops (61% of all biotech crops) followed by insect resistance (17%) and the combination of these two in stacked crops (22%). Glyphosate became immensely popular because it is a broad spectrum herbicide that kills broadleaf plants and grasses yet, compared to other herbicides, is relatively toxicologically safe. With the development of GM glyphosate tolerant crops, glyphosate containing herbicides became the best-selling herbicides in the world (Duke & Powles, 2008). Herbicide tolerant crops provide farmers with advantages as less different herbicides have to be used: it is easier to apply and allows for no-till practices (Givens, et al., 2009). The most popular insect resistance trait is known as Bt, an abbreviation for *Bacillus thuringiensis*. Some *Bacillus thuringiensis* strains produce a crystal protein that, when ingested by insects from certain species cause the release of *cry* toxins that create pores in cell membranes and lead to the death of the insect. The *cry* toxins specifically target, amongst others, flies, mosquitoes and beetles and have little to no effect on humans or wildlife. Belgian company Plant Genetic Systems was the first to transform a plant with the *bt2* gene. This gene expresses the crystalline inclusion bodies that carry the *cry* toxins and enable the plant to produce its own insecticide (Vaeck, et al., 1987). With Bt crops farmers buy less insecticide and can still keep major pests such as the European Corn Borer away from their crops.

Added up, producers of genetically modified seeds claim the following direct beneficial effects (Brookes & Barfoot, 2012):

Herbicide tolerant crops

- General yields increase because of good quality seeds
- Yield increase due to decreased competition (knock-back) from weeds (HT soybeans – in combination with glyphosate)
- Decreased expenditure on different herbicides, fuel and labor
- Price premium for higher quality crops (lower level of weed impurities)
- Production increase due to 'second crops' (e.g. the planting of maize after harvesting HT soy)

Insect resistant crops

- General yields increase because of good quality seeds
- Yield increase due to resistance to pests
- Decreased expenditure on pesticides, fuel and labor
- Price premium for higher quality crops (less pest damage)

And indirect beneficial effects (Brookes & Barfoot, 2012):

Herbicide tolerant crops

- Increased management flexibility and time due to the ease of use of glyphosate
- Facilitates no tillage systems

Insect resistant crops

- Increased sense of security as crops are standardly protected leading to decreased insurance costs for production risks, or crop losses
- Increased management time as no pest checks have to be done
- Decreased costs of machinery (airplanes, sprayers) in the long run
- Improved health and safety for farmers as they do not come in direct contact with pesticides

2.3 Adoption Of Genetically Modified Crops In Brazil

Even though Brazil currently has the largest area of biotech crops in South-America, the emergence of agriculture biotechnology in the continent started in Argentina. The Secretariat of Agriculture in Argentina started promoting the study of genetically modified crops in 1991 and created a regulative framework to analyze this technology, leading to the first approved GM crop in 1996: glyphosate herbicide-tolerant soybeans. In that same year 370.000 hectares were planted with GM soybeans, 6% of the total amount of soybeans planted in Argentina. In 2004 already 99% of soybeans planted were GM which translates to almost 14.5 million hectares (Trigo, 2011) (James, 2004). Besides Argentina's approach to the regulative process other important factors of the rapid expansion of GM technologies were a strong technology services infrastructure regarding the seed industry and the synergies arising from simplified weed control and no-till practices (Penna & Lema, 2002). Brazil initially lagged in legislature and Embrapa (Empresa Brasileira de Pesquisa Agropecuária), the national agricultural research agency, had only started researching GM soy in 1997 (Embrapa, 2012) and the first application by Monsanto to sell glyphosate herbicide tolerant soybeans was successfully contested in court in 1998. Even though the Comissão Técnica Nacional de Biossegurança (CTNBio) found no scientific reasons to ban the commercial use of HT soybeans, the federal court chose for the precautionary principle and forbade the government to allow commercial production of HT soybeans. This was later extended to all GM crops (Pelaez, 2009).

The release of transgenic crops remained a tough debate until Luiz Inácio Lula da Silva (Lula) won the 2002 election and became President. Initially opposed to transgenic crops, in 2003 he formed a committee to develop legislation on the approval and control over GMO's in Brazil. Reasons for his switch were pressure from his Ministers of Agriculture and Industry & Commerce who were in favor of GMO's and didn't want Brazil to lose competitiveness, and the already widespread use of illegal transgenic soybeans. Since Argentina accepted GMO crops in 1996 and both countries share over 1000 km of border (Central Intelligence Agency, 1999), it comes as no surprise that transgenic crops (mostly soybeans) were being smuggled into Brazil. The Southern regions (predominantly Rio Grande do Sul) planted the most illegal biotech crops and by 2003 an estimated 10% (6 million tons of soybeans) of the national harvest of soybeans was already transgenic (Salvador, 2003). Such an enormous amount of foodstuff that had to, officially, be destroyed would not sit well with President Lula's electorate that relied on his party to provide the lower income population with cheap food. An emergency law was implemented that would allow the harvest of 2003 to be used if labeling of products was employed and the next year no transgenic soybeans would be planted (Pelaez, 2009). It took another temporary law in 2004 and months of debate until in 2005 a new biosafety law was implemented that gave the CTNBio the clearance to set the rules under which GMO risk analysis would be carried out. Since then over 25 different biotech crops have been approved for commercial planting (James, 2010). As of 2010 approximately 75% of all planted soybeans in Brazil are transgenic (a total of 17.8 million hectares), 56% of maize plantings are transgenic and 26% of planted cotton. In the coming years maize, soybean and cotton with more than one trait added, virus resistant beans (Tollefson, 2011) and possibly GM sugarcane (Hotta, et al., 2010) will enter the market in Brazil. Several researches show an increase in income due to GM crops in Brazil. For instance James (2010) indicates a farm income gain of 3.5 billion USD from 2003-2009 related to GM crops and a 2012 study by Brookes & Barfoot indicates a 3.89 billion USD increase from 1996-2010 in income due to herbicide tolerant soybeans alone (Brookes & Barfoot, 2012).

3. Soybean and Maize Production in Brazil

For some time soybeans and maize have been the most cultivated crops in Brazil. For the 2013 harvest a total area of 27.7 million hectares was planted with soybeans, with a forecasted production of 81.5 million tons (CONAB, 2012a). Maize comes in second with 15.8 million hectares and a forecasted production of 79.1 million tons. In 1990 production of soy was 20.1 million tons and maize was 22.3 million tons: this means an approximately 5-fold increase in just over 20 years' time.

One of the reasons agricultural production in Brazil could grow this much was by the increase in area used for crop cultivation. Brazilian agriculture can be divided into roughly two areas: Center-west and South-east. In terms of land condition, farm set-up and climate condition, more regions might exist (such as the North-east and Amazon regions), but the majority of agricultural operations can be found in the Center-west or the South-east. Traditionally production took place in the South-east, in provinces as Paraná, Rio Grande Do Sul and Santa Catarina, because of its favorable climate and fertile lands. Due to this long history of agriculture (dating back to the colonial time), land is more expensive, technology is more advanced and infrastructure is better than in northern parts of Brazil. Consequently, the yields are high and the farms have an average acreage under 100 hectare (Carvalho, 2006). Up until the 1970's, the Center-west was not considered arable land as it consisted of *cerrados*. *Cerrados,* comprising around 20% of Brazilian land area at over 200 million hectares, are tropical savannas with a dry season from April to September (Ratter, et al., 1997). In general these soils were acidic and had little to no nutrients required for crop growth, most importantly lacking phosphorus (Lopes, 1996). States such as Mato Grosso, Mato Grosso Do Sul and Goias therefore showed little agricultural activity compared to the southern provinces of Paraná or Santa Catarina. In 1975 research groups CRC (Cerrado Research Center) and CPAC (Cerrados Agriculture Research Center), among others, began working together to develop suitable soil management approaches for *Cerrado* land. Strategies, including addition of large amounts of lime to decrease acidity, build-up of phosphorus and micro-nutrient fertilization made over 45 million hectares, or almost 25% of *Cerrados,* in the Center-West available for agriculture by 1995 (Lopes, 1996). This development led to a hurried annexation of Center-west land as property was still cheap and showed promise for cultivation. Many producers sold land in the South-east and bought 7 to 8 times larger areas of previously unexploited land in the Center-west. Consequently, the average acreage for producers in the Center-west is almost 900 hectares (Carvalho, 2006) and cultivated area in the Center-west has grown four fold from 1990 to 2012 (CONAB, 2012a).

Figure 1: Cerrados in Brazil **(Simon, et al., 2009)**

Another reason for the increase in production in Brazil is the utilization of second harvests. Since the beginning of the 80's, farmers in Bahia would grow maize in the second part of the season, harvesting in the winter months of June and July. The practice became popular in the southern provinces of Rio Grande do Sul and Paraná in the early 90's to react to corn prices on the international market. When maize harvests failed in the United States for instance, producers would respond by planting maize in the months January and February, to benefit from high prices in June and July. The harvest of winter maize became known as 'safrinha', or little harvest. In the last ten years producers in the Center-west followed the example and started growing maize for a second harvest.

Currently, the state of Mato Grosso is the top producer of soy, followed by Paraná and Rio Grande do Sul (Table 3). Paraná in turn is top producer of corn. The two are often combined in a two crop rotation system, as harvests increase when in rotation, see Table 2. The increase is ascribed to decreased influence of pests and disease and increased nutrients in the soil. During the first growing season from roughly the end of September to February soybeans are grown, followed by maize in the safrinha from January to June.

TABLE 2: EFFECT OF SOYBEAN AND MAIZE CROP ROTATION ON THEIR YIELDS **(EMBRAPA, 2011)**

ROTATION	YIELD (KG HA -1)	
MAIZE AFTER MAIZE	9.680 (100%)	6.160 (100%)
MAIZE AFTER SOY	10.520 (109%)	6.732 (109%)
SOY AFTER SOY	3.258 (100%)	2.183 (100%)
SOY AFTER MAIZE	3.425 (105%)	2.517 (115%)

TABLE 3: TOP FIVE STATES IN SOY AND MAIZE AREA AND PRODUCTION (2010) **(CONAB, 2012A)**

STATE	SOY AREA (MILL. HA)	MAIZE AREA (MILL. HA)	SOY % OF TOTAL	MAIZE % OF TOTAL	SOY PROD. (MILL. TONS)	MAIZE PROD. (MILL. TONS)
MATO GROSSO (MT)	6.398,8	1.898,4	26%	14%	20.412,2	7.619,7
PARANÁ (PR)	4.590,5	2.485,8	19%	18%	15.424,1	12.247,7
RIO GRANDE DO SUL (RS)	4.084,8	1.099,2	17%	8%	11.621,3	5.776,3
GOIAS (GO)	2.605,6	933,9	11%	7%	8.181,6	6.009,8
MATO GROSSO DO SUL (MS)	1.760,1	992,8	7%	7%	5.169,4	3.423,2
TOTAL	19.439,8	7.410,1	80%	54%	60.808,6	35.076,7

3.1 SOYBEAN CULTIVATION

Soybean production in Brazil began when researchers in the Unites States developed varieties of soybeans adapted to lower latitudes (30°) to provide their southern poultry farmers with high-quality protein meals in the 1950s (Goldsmith, 2008). These varieties could also be grown in southern Brazil, which shares a growing climate with southern parts of the United States. From the 1960s and onward the Brazilian government started to support the soybean industry with policies including publicly funded research, subsidies and infrastructure programs. Embrapa further advanced research on soybeans and developed varieties that could grow in the tropics at lowest-latitudes (10°) of the center-west (Schnepf, et al., 2001). Coupled with the development of soil management in *Cerrado* land, millions of hectares became available for soybeans cultivation.

With government support, technology and land available, rising prices in the international market made production of soybeans a profitable business in agriculture. From 1970 to 1990 the soybean area grew from around 2 million hectares to 10 million hectares predominantly in the Center-West provinces of Mato Grosso and Mato Grosso do Sul. Additionally soybean yields grew about 2 percent annually (Schnepf, et al., 2001). In the 90's another surge of reforms hit Brazil and import barriers on agricultural inputs (fertilizer, machinery, etc.) were reduced, spurring on growth of soybean area with an average 2.9% and yield by 3.9% annually. Area growth occurred mostly in the center-west, with a 184% increase from 1990 to 2000 in Mato Grosso alone. In 1994 Cardoso launched the *Real* plan (Schnepf, et al., 2001), depreciating Brazil's currency and consequently lowering export prices of Brazilian products in the world markets. The ability to increase production, coupled with low prices and the availability of demand initiated the largest expansion yet. Area and production grew to 24.1 million hectares and 75.3 million tons in 2010 (Figure 3) and export of soybeans rose from approximately 5 million tons in 1993 to 15 million in 2001 and 30 million tons in 2010 (USDA, 2011) (Cordier, 2012), excluding processed soy products such as soy oil and soymeal. Still, production is growing, and projections for the 2012/2013 harvest indicate a production of over 81 million tons of soybeans in Brazil (USDA, 2013) with a value of $ 104.3 billion (The Crop Site, 2012).

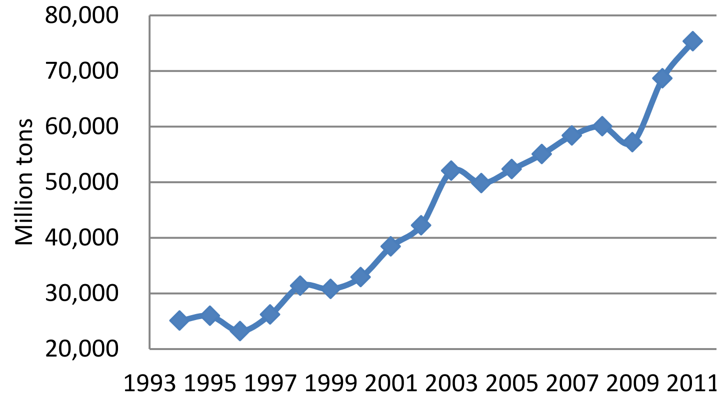


FIGURE 3: NATIONAL PRODUCTION OF SOYBEANS IN BRAZIL **(CONAB, 2013)**

Transgenic soybeans started to appear in Brazil in 2002. At that time transgenic soy was illegal and adoption rates were below 10% (Salvador, 2003). In the 2002/2003 harvest, top producing states Mato Grosso and Paraná grew 4.4 and 3.6 million hectares of soy, with yields of 2930 kg/hectare and 3016 kg/hectare respectively. Using information from national statistics bureau CONAB, cost prices can be found. In Mato Grosso and Paraná, cost prices were 837.51 R$/ha and 846.54 R$/ha respectively (CONAB, 2012b). As mentioned above, in 2010, adoption rate of GM soybeans was already 75% and yields had

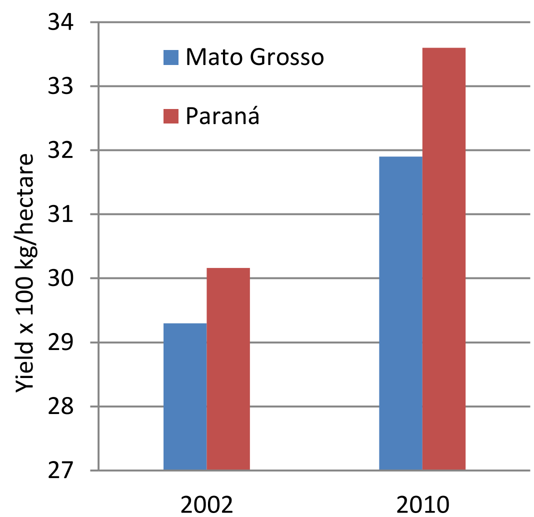


FIGURE 2: SOYBEAN YIELD DIFFERENCE BETWEEN 2002 AND 2010 **(CONAB, 2012B)**

TABLE 4: SOY PRODUCTION COST IN MT AND PR **(CONAB, 2012B)**

LOCATION	R$/KG NGM	R$/KG GM
2002 PRIMAVERA DO LESTE – MT	0,279	-
2002 LONDRINA – PR	0,282	-
2010 SORRISO – MT	0,479	0,530
2010 LONDRINA – PR	0,556	0,556

increased to 3190 kg/ha (9% increase) and 3360 kg/ha (11%) for Mato Grosso and Paraná (Figure 4). Cost prices for non GM soybeans in Sorriso, Mato Grosso, were 1436.01 R$/ha and GM cost prices were 1590.34 R$/ha. In Londrina, Paraná, NGM soy cost 1556.50 R$/ha and GM soy cost 1612.67 R$/ha. Data from national statistics bureaus are not complete on this matter but nonetheless the cost price per kilogram of soy was calculated in Table 4, an annual overview is available in Appendix C. Contrary to what seed producers claim, these data from CONAB show that GM production costs are not significantly lower but may even be higher than NGM production costs and cost prices have doubled in the last eight years. With the current data, increases in yield cannot be attributed to transgenic or conventional varieties. Additionally, no data on selling prices was present and no detailed information was available on the context of these statistics. To find out all relevant aspects of soy production with GM or conventional seeds, in paragraph 3.3 & 3.4 information on the production processes is given.

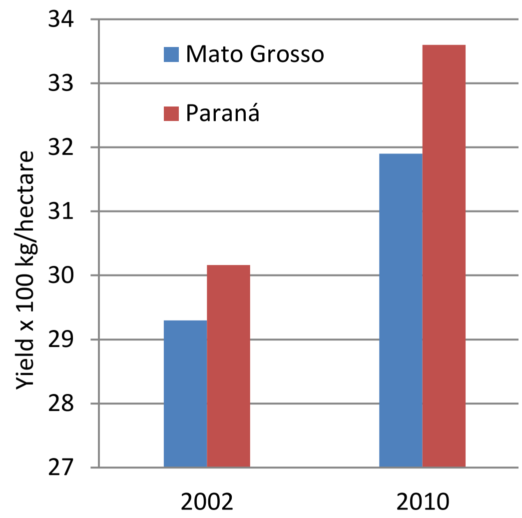


FIGURE 4: SOYBEAN YIELD DIFFERENCE BETWEEN 2002 AND 2010

3.2 MAIZE CULTIVATION

Maize production has been a part of Brazilian agriculture far longer than soybean production. Publicly funded research on maize improvement started in 1932 in the Universidade Federal de Viçosa, in the state of Minas Gerais (Sorj & Wilkinson, 1990). The basics of hybrid seed technology were copied from the United States and adapted to Brazilian latitudes. Hybrid maize, which is the practice of cross-pollinating two inbred plant lines, is higher yielding and stronger than self-pollinating maize (Duvick, 2001), but unable to reproduce. This led to a shift in agriculture as farmers would now buy hybrid seeds annually from seed selling firms, instead of growing their own varieties. Public institutions such as the Instituto Agronómico de Campinas (IAC) in the State of São Paulo took the role of plant breeders and variety improvers and small scale seed businesses marketed the results. In the 1960s public research was restructured and private companies, such as Agroceres and foreign companies Cargill and Pioneer Hi-Bred increased their role in the seed industry. The main role for public institutes was to provide a complementary role on private research. To ensure cooperation between different institutes, Embrapa was founded in 1970 and its maize and sorghum subsidiary Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS) in 1976. CNPMS most important work was developing maize germplasm for low production areas, such as the *cerrados* (López-Pereira & Garcia, 1997). Since the 1970s, public research with Embrapa at its center kept an important role in maize breeding, yet the private sector produced and marketed the varieties. This made the maize seed industry very competitive and in turn lowered seed prices. Together with government incentives such as subsidized credit for farmers and minimum prices for corn: area, quantity and yield kept growing until the 90's. South-east states Minas Gerais, São Paulo and southern states Paraná and Rio Grande do Sul, were the main producers of corn in the 1970's (CONAB, 2012a).

Up until the turn of the century maize did not grow as fast in the center-west as soy. From 1990 to 2000 area increased with approximately 30% against the soy area increase of 90% (CONAB, 2012a). Again, the practice of second harvests in the winter-season became a driving force for growth. Especially in two-crop rotation with soybeans, corn planting area in the center-west alone grew with 90% from 2000 to 2010. Overall maize area in Brazil grew with less than ten percent, meaning production shifted from the south to the center-west. Additionally corn harvests shifted from summer to winter maize, as in 2000 35.8 million tons of corn were harvested in the summer, against 6.4 million in the winter. In 2010 the summer harvest was still approximately 35 million tons, but safrinha corn had increased to 22.4 million tons, giving a total production of 57.4 million tons (CONAB, 2012a). Not only area increases contributed to the increased production of corn, in the last decade yields have improved tremendously. Better production practices, such as water and fertilizer input have contributed to improved yields, as have improved varieties suited to the different climates and for instance shorter growing periods of safrinha (Embrapa, 2011) (see Appendix B). Until recently almost all production was consumed nationally and Brazil had to import corn to cover national demand. Over 80% of corn was used for animal feed in the growing pork and poultry sectors, while the other 20% entered into domestic food channels (Schnepf, et al., 2001). The 2000/2001 harvest marked the first time Brazil became a net exporter of corn. In 2012/2013 corn production is estimated at 72.7 million tons (CONAB, 2012a), export at 19.8 million tons with a value of $ 5.3 billion (CONAB, 2013).

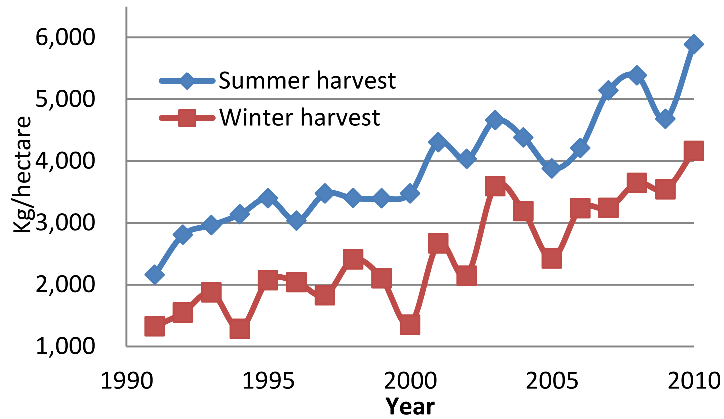


Figure 6: National Maize yields in Brazil **(CONAB, 2012a)**

Transgenic maize was commercially released in 2007 and succeeded conventional maize in use in 2010, with adoption rates of 43% for summer maize and 76% for winter maize (James, 2010). In contrary to maize, CONAB does not supply statistics on production cost differences between GM and conventional maize. Yields (Figure 5) between the growing season of 06/07 and 09/10 for summer maize have increased from 4625 and 6680

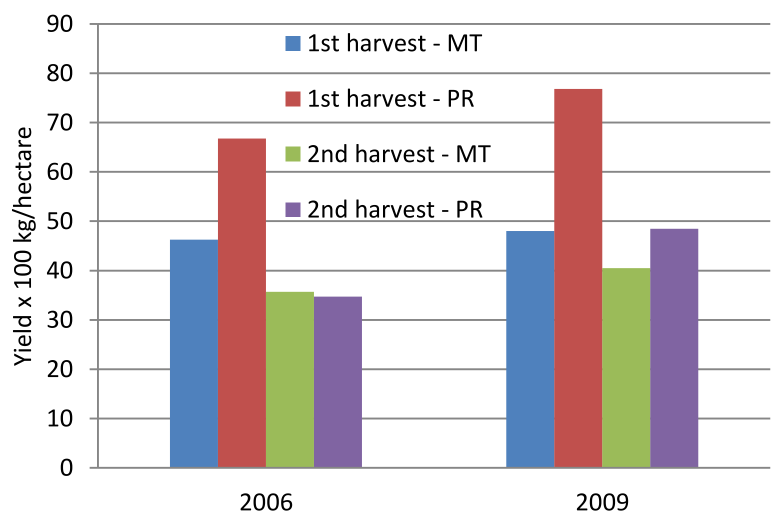


Figure 5: Maize Yield Difference Between 2006 and 2009 **(CONAB, 2012b)**

kg/ha to 4800 (+4%) and 7680 (+15%) kg/ha in Mato Grosso and Paraná respectively. Winter maize yields have grown from 3570 and 3470 kg/ha to 4047 (+13%) and 4850 (+40%) kg/ha for Mato Grosso and Paraná. As with soybeans, increases in yield cannot directly be attributed to transgenic or conventional varieties. Overall production costs are shown in Appendix D, but there is no distinction between biotech and conventional. In the paragraphs 3.5 & 3.6, the production of maize is described to find out all relevant aspects of soy production with GM or conventional varieties.

3.3 Growing Soybeans

To describe soy cultivation practices, the growth is divided into three parts:

- Vegetative growth phase;
- Flowering and pod formation phase;
- Maturing phase

In Brazil soy is usually planted in October, yet some regions in the Central West and specifically Mato Grosso plant as early as September (Soybean and Corn Advisor, Inc, 2011). After four to seven days the seeds sprout and small plants start growing. The growing phase continues for 2 to 3 months until the first flower appears, in November for early plantings and in December for the majority of soybeans in Brazil. From the first to a large part of the second phase the plants grow the organs that absorb nutrients and convert energy from sunlight through photosynthesis. Setback by nutrient/water deficiency due to for instance weed competition or insect damage in this stage seriously decreases yield in the following phases (Egli, 2010).

When the first flower appears, indicating the second phase begins, vegetative growth continues for approximately another month. During the second phase, the flowers grow from the bottom of the plant to the top. Soy is self-pollinating, meaning it can fertilize itself without the need for insects or wind to transfer pollen from other plants. As soon as flowers are pollinated, they begin forming pods, the containers that will hold the actual beans. Not all flowers and/or developing pods develop into mature pods filled with soybeans and many are shed by the plant due to stress induced by external factors or nutrient competition within the plant (Egli & Bruening, 2006). The amount of containers produced is the upper limit of yield and therefore an important part of the plant development. At the end of December nearly all plants have finished setting pods and the final phase begins.

In the maturing phase, the pods are filled with beans. All the photosynthetic capability generated in the previous phases is used to create 2 to 4 green, kidney-like beans per container. After these seeds reach their full size the plant begins maturing. The plant starts to shed leaves and under influence of photoperiod and temperature, the green beans dry to the small round soybeans that are harvested. The last phase is the shortest, lasting about a month and the first harvests in Brazil occur as early as the beginning of January and as late as April (Egli, 2010). Harvested soybeans are either sold by the farm individually or through farmers associations to international traders. From there soybeans are used directly for the food industry or crushed to oil and meal for further processing.

3.4 Management Practices in Soybean

This paragraph shows how producers manage soybean crop growth. First eight different types of management practices are distinguished (McWilliams, et al., 1999):

Preparation

- Seedbed preparation
- Variety selection
- Planting rate
- Planting depth
- Row width

Cultivation

- Pest management
    - Insect management
    - Weed control
    - Disease management
- Fertilization

Harvesting

- Harvesting

In the next sub-sections, each practice will be described for conventional soybean cultivation followed by the approach for transgenic varieties. After all practices are described, an overview is presented.

3.4.1 Preparation

Seedbed Preparation

Before cultivation of soy can start the soil must be prepared. Depending on the soil nutrients might have to be added and if soy has been absent from the plot for over three years the soil must be inoculated with nitrogen fixing bacteria *Rhizobium*. Adding nutrients to the soil is particularly important in *Cerrado* regions, where the earth is mostly nutrient poor (Embrapa, 2004). Tilling of the soil used to be a widely used method of preparing soil, but his practice has lost popularity since the 1990's, as it is costly and does not always provide significant yield increases (Kapusta & Krausz, 1993). Tillage is the mechanical disturbance of topsoil to bury weeds, mix organic matter and simplify planting (Duiker, 2011). The practice of reduced- or no tillage is also considered to be more eco-friendly, as it reduces soil erosion, use of fuel and machinery, soil moisture loss and soil compaction (Holland, 2004). The latest figures indicate that over 57% of arable crop land in South-America is not tilled (Friedrich, et al., 2011).

Herbicide tolerant and insect resistant GM crops make no-till practices more accessible to farmers. In South America glyphosate tolerant soybeans in particular may contribute to no-till farming (Brookes & Barfoot, 2006) (Cerdeira, et al., 2011). Benefits for farmers include lower costs in machinery and fuel, and less soil erosion (Thomson, 2007). An additional benefit is the time that can be saved in preparing soil for the following crop. The popularity of soybean-maize crop rotation is for a large part dependent on low preparation times to allow fast planting of maize in January (Possamai, et al., 2001).

Variety Selection

Selection of the right variety is based on several factors, key among them growing climate and photoperiod. Additionally yield potential, pest resistance, protein and oil content and disease resistance play a role in choosing the most suitable variety for the planting region. Embrapa funds several programs that in the past have led to successes in soy cultivation in *Cerrado's* and lower latitude regions (Schnepf, et al., 2001). Continuous research by both public and private institutes leads to higher yields almost every year, see Appendix B. Because of self-pollination most soybeans reproduce with little loss in properties (minimal yield drag) meaning farmers could save seeds from one harvest and use them for the next. The practice of saving seeds used to be an easy method, especially for smaller scale, farmers to reduce costs, as they would not have to rely on companies forcing high prices on them (Murphy, 2006). Currently the saving of RR (RoundupReady) seeds by Monsanto is illegal in Brazil, because of intellectual property rights (Liptak, 2013) (Rodrigues, et al., 2011), illegal use and selling of patent protected seeds is referred to as 'brown bagging'. The appearance of brown bags is not a strange development when looking at the price of GM seeds: RR soybean seeds cost approximately twice as much as conventional seeds (Benbrook, 2009) (GAO, 2000) (Bullock & Nitsi, 2001).

Transgenic seeds offer in the first place resistance to herbicides, insects or diseases. Furthermore, producers claim only varieties with good characteristics in terms of yield and protein content are genetically modified, leading to biotech seeds of high quality (Brookes & Barfoot, 2012) . Prices however are much higher for GM than for NGM.

Planting Practices

Because of a wide difference of available equipment and pest management preferences, different practices for planting are employed. Planting rate and row width determine the amounts of plants on the field and therefore have direct effects on yield. Plant depth is the distance the seed penetrates the earth. Planting depth is related to the type of soil. For sandy soils, soy should be planted up to 5 centimeter deep, but for moist soils half of that is enough (Illinois soybean association, sd). Row spacing is closely related to planting rates. In general narrow rows (narrow is 19 and 38 cm and wide is 76 cm) of soybeans increase yield (Lambert & Lowenberg-Deboer, 2001), as do high planting rates (Cox & Cherney, 2011) (Costa, et al., 1980).

With GM soybeans resistant to glyphosate, producers had to change their approach to row width and planting rate, mainly due to the increased costs of seeds (Bertram & Oplinger, 2004). A cost effective solution was to share planting machines for different types of crops. Soybeans are planted at a wider row width than is optimal in terms of yield, but at the same width as maize and grains, enabling farms or farmers associations to buy only one expensive, high precision seed placement machine instead of several (Pioneer Hi-Bred, 2011). Even though there is a different approach to planting practices between conventional and transgenic soybean production, the difference is expected to be insignificant in cost comparisons.

3.4.2 CULTIVATION

Pest management, or biotic constraints management, is a continuous practice that can be divided into three distinct areas: insect pest management, weed control management and disease (pathogen) management. Following the three paragraphs covering pest management, fertilizer management is described.

INSECT PEST MANAGEMENT

Stink bugs *Piezodurus guildinii* and *Nezara viridula* are common soybean pests in Brazil as is the velvet-bean caterpillar, *Anticarsia gemmatalis*. The most used insect control method is spraying before bugs are found (prophylactic control). From 2004 to 2008 average insecticide use has increased with 70% (Meyer & Cederberg, 2010), endangering long-term sustainability of pest control in Brazil. Alternatives are integrated pest control (IRM), in which for example traps are used to monitor the insect population; insecticide sprays are only applied when a certain threshold is reached. Another alternative is the preservation and propagation of natural enemies of pests (biological control), which could lower insecticide use even more (Bueno, et al., 2011).

In 2010 a commercial soy variety was released for testing in Brazil that confers resistance to, most importantly, *A. gemmatalis* by expressing a Bt gene (James, 2010). Currently this variety is not expected to be very widespread in Brazil, but soybeans with this trait could eventually decrease or replace the use of at least some of the conventional insecticides. Farmers are provided with relatively cheap insecticides (created by the plant) and would have less difficulties responding to insect outbreaks. Furthermore, insect toxins created by Bt crops are more environment friendly when compared to other pesticides (Kumar, et al., 2008) and both farmers and consumers are subjected to less harmful substances.

WEED CONTROL MANAGEMENT

The negative effect of weeds on soybean yields is generally the result of competition. Competition for nutrients, water and sunlight can decrease the development of soybean and ultimately leads to lower yields and lower crop quality. To reduce harmful effects of weeds, four methods of weed control can be applied (Embrapa, 2004). Manual and mechanical: in which weeds are pulled out or destroyed in the field with either laborers carrying small equipment or larger machines driven by laborers. Chemical methods include the application of herbicides and cultural methods are about row distance, fertilizer timing, sowing date and other cultivation techniques that give soy an advantage over weeds. Cultural and specifically chemical methods are very effective and usually cheaper than manual or even mechanical weeding (Callaway & Forcella, 1993) (Teasdale, et al., 2007) (Embrapa, 2004). Yet cultural methods alone do not provide enough protection. And chemical control, or herbicide management, requires a lot of attention and specific knowledge. For instance; herbicide spraying should be done on time to minimize weed competition and maximize effectiveness; it should not adversely affect the soybeans themselves and extraneous variables such as rain might disrupt herbicide effectiveness (Mishra, 2010). Additionally herbicides might be harmful to farmers and/or consumers. Therefore often a combination of more than one method of control is applied.

With the arrival of herbicide tolerant soy, weed management could be simplified. Soybean resistance to broad spectrum herbicide glyphosate meant that farmers could reduce costs, amount (Phipps & Park,

2002) (Hin, et al., 2001) and types of herbicide (Fernandez-Cornejo, et al., 2012) (Nelson, et al., 2001) to get better results. Glyphosate is effective against nearly all weeds that compete with soy and is relatively cheap (Shaner, 2000) (Duke & Powles, 2008). Fewer spraying trips may be required resulting in lower fuel and machinery use (Cerdeira, et al., 2011). Glyphosate works efficiently on leaves, increasing the spraying 'window', or the time between emergence of weeds and the last possibility of effectively applying herbicide. Farmers don't have to identify different weeds and look for specific herbicides anymore and the use of just one herbicide leads to increased standardization, improving risk management (Bullock & Nitsi, 2001). These advantages contribute to important secondary effects, an increase in flexibility for producers and time that can be devoted to other tasks (Qaim, 2009) (Carpenter, 2010).

Disease Management

Embrapa recognizes about 40 diseases in Brazilian soy by nematode, viral, bacterial and fungal pathogens (Embrapa, 2004). The most prominent pathogens for soybean are: Soybean rust, caused by the fungus *Phakopsora pachyrhizi*; Sclerotinia stem rot caused by the fungus *Slerotinia sclerotiorum*; Soybean cyst caused by parasitic nematode *Heterodera glycines* (Hartman, et al., 2011) and foliage diseases caused late in the season by *Septoria glycines* and/or *Cercospora kikuchii*. Fungicides are effective in managing soybean rust and partially effective in stem rot, but future prospects include transgenic host resistance to pathogens (Hartman, et al., 2011). For nematode and foliage diseases host resistance (either through conventional breeding or GM) and crop rotation with for example maize are the most effective means of protection (Westphal, et al., 2009) (Embrapa, 2004).

As of 2010 there are no commercialized GM varieties that provide host resistance (James & Krattiger, 1996), therefore treatment and prevention regarding soybean diseases is expected to be similar between transgenic soybeans and conventional soybeans.

Fertilization

Nutrient and water management are essential in attaining high yields (Stewart, et al., 2005). In most regions soybeans are rain fed and irrigation is not required. In some parts of Brazil dry spells occur frequently and irrigation is important for stable yields. Farmers use rivers and artificial lakes to store water for dry periods (occurring mostly from July to September) (Molan, 2012) or pump water out of the ground. Types of land, climate and cultivar all influence the nutrient needs so samples from the soil and samples from leaves are taken frequently. Depending on any of these factors, land is fertilized before cultivation, during cultivation, at set intervals or by corrective fertilization when necessary. Most abundant nutrients in fertilizers are phosphorus (P), nitrogen (N), Potassium (K), Sulfur (S) and diverse combinations of micronutrients. Embrapa has extensive lists and tables of amounts of nutrients required (Embrapa, 2004). Generally, fertilizer is applied by spraying and in case of nitrogen the plant gets most of its needs from biological nitrogen fixation (BNF) by *Rhizobium* nodules on the roots (Alves, et al., 2003). In high yield situations however, the BNF may become a limiting factor. Especially in parts of the seed filling stages the plant could benefit from added nitrogen (Salvagiotti, et al., 2008). Often seeds are treated before planting and depending on variety and soil, nutrients, fungicides or inoculant for rhizobia may be added. These treatments, combined with so-called adjuvants give seeds optimal conditions to develop shoots (WinField Solutions, 2012). These treatments can be bought separately or they can be provided by the seed supplier, however they are not related to the biotechnological or conventional origin of the seed.

Fertilization practices for modified soybeans and conventional soybeans are expected not to differ.

3.4.3 Harvesting

When soybeans reach full maturity and 90-100% of the pods are brown of color they are ready to be harvested. To be able to store soybeans for longer terms the moisture must be 13% or less (McWilliams, et al., 1999). This is monitored by estimating the pod color or, when applicable, by using combiners that continuously measure moisture. If beans are above 13% moisture they must be dried and if beans are below 10% more losses occur due to shattering. Drying occurs either at the farm or at cooperatives (at a price) that sell the beans. If farmers can harvest early in January they will get a better price for their beans, therefore farmers must consider drying at extra costs, to ultimately increase profit (Molan, 2012). Harvesting is done by combiners that cut the plants off about 3 cm above ground and thresh the beans. The beans are stored in the combiner and later in grain trucks while the crop residue (mulch) is distributed over the land. Partly to protect the soil from erosion and partly to return the nutrients from the remaining biomass (Machado & Silva, 2001). Because of the biological nitrogen fixation, the soil will be rich in nitrogen as well, so when maize is planted right after harvesting the soy, it will need less nutrients. The majority of soybeans are grown in the province of Mato Grosso (CONAB, 2012a). To get the harvests to the harbors of Santos and Paranaguá to be sold internationally, over a thousand kilometers need to be crossed. The majority of transportation takes place by truck over very poor highways and often dirt roads. Annually 51,000 tons of soybeans are being lost just to truck transportation in Mato Grosso alone (Soybean & Corn advisor, 2011). To solve some infrastructural problems, an alternative route north to ports on the amazon is being constructed and investments in improved railways are being done. Nonetheless, in 2011 transportation costs of Brazilian soybeans to Hamburg are 20-28% of the landed costs, compared to 12-13% of the costs of soybeans from the USA to Hamburg (USDA, 2011).

Most Brazilian soybeans are exported to China (58%), followed by the EU (30%) (Brown-Lima, et al., 2010). As a result of strict EU regulation on the import of soybeans, traders offer producers of 100% conventional soybeans that want to export to the EU a premium price per sack, as they have to make extra investments in storage facilities and use more costly means of transport to ensure a completely GMO-free soybean. Otherwise, traders do not make a distinction between GM or NGM produced soybeans. Rather they select the beans on other characteristics, such as oil or protein content (Molan, 2012).

3.5 Growing Maize

Of the cereal staple crops, maize yields are one of the highest in calories per square meter (FAO, 2013). It requires a day mean temperature of at least 18° C and plenty of water, but can grow in many climates (Bondesio, sd) (FAO, sd).

The following four stages were used to describe maize growth (Bell, et al., sd):

- Seedling growth

- Vegetative growth
- Flowering and fertilization
- Grain filling and maturity

Maize seeds are planted twice a year. For the normal harvest maize is planted as early as September and for the second harvest, winter maize or safrinha, planting starts soon as the soy is harvested; usually in January or February (Soybean and Corn Advisor, Inc, 2011). The majority of planted seeds are hybrid; single, double or triple (Embrapa, 2011). Single hybrids are the crossings of two inbred lines. Crossing two inbred lines with two other inbred lines leads to double hybrids and a triple hybrid is the result of one inbred line crossed with a single hybrid.

During the seedling growth stage the seed uses stored starch to germinate. Lateral roots develop and a green shoot appears 5 to 10 days after planting. After the first leaf collar is visible this stage is at an end and the vegetative growth begins (Nielsen, 2000). Vegetative growth is where the plant develops its roots to absorb nutrients and water, leaves to convert sunlight into energy and most visibly, attains altitude. Normally maize can reach up to 2.5 meters but depending on the variety and climate, it can grow much longer (Karl, 2012). During this time the tassel and ears develop and grow. Early planted maize can start pollinating in November–December and safrinha maize in April. The flowering stage starts when the last branch of the tassel, which is the main reproductive structure of the plant, is fully emerged on top of the stalk (Figure 7). The tassel contains flowers that produce pollen and the ears are groups of female flowers that produce fertile ovules with silks at their end. Several days after the tassel has fully emerged, pollen starts to be shed and wind promotes cross fertilization by blowing the pollen to the silks. Pollen germinates when it reaches the silk and grows down the silk to fertilize the ovules, which form kernels, or grains, on the ears. Tassels start shedding pollen one to three days before silks emerge and keep shedding for five to eight days while silks remain fertile for approximately one week (Iowa state university extension, 2004) (Ritchie & Hanway, 1987).

FIGURE 7 (LEFT): TASSEL ON TOP OF MAIZE STALK **(LERNER, 2000)**
FIGURE 8 (RIGHT): SILK ON TOP OF EAR **(LERNER, 2000)**

After fertilization, kernels accumulate carbohydrates and nutrients. For early maize this stage begins in December or January, for winter maize at the end of April or the beginning of May. After ten to twenty days the kernels are filled with a sugary milky fluid, which is suitable for fresh consumption. Another ten days later the fluids sugar content decreases and starch takes its place (Ritchie & Hanway, 1987). The kernels lose water and reach maturity at approximately 30% moisture and after four to five weeks the maize can be harvested; at the end of January or in February. Winter maize is usually harvested in the months May up to July. Moisture content at harvest is often between 23-25%, but for long time storage of grains 13-14% moisture is required so often maize is dried in the field or in storage (Brooker, et al., 1992).

Summer maize is grown from September to February, with a single crop taking 6 to 7 months to grow. Winter maize grows in 5 to 6 months from January to July. Often safrinha consists of early maturing maize cultivars that require less growing days because weather conditions delay sowing or water availability is limited (Soler, et al., 2007). Consequently, yields of safrinha are significantly lower than summer maize yields. Farmers sell their corn directly or through associations to international traders. Due to potential weather problems in for instance the USA, farmers or traders can keep their safrinha grains stocked for a while to increase selling price or market their grains to the Brazilian market. Generally corn is used for direct human consumption, feed for animals or biofuel production (Embrapa, 2011).

3.6 Management Practices in Maize

For maize growing the same eight types of management practices are used that were used for soybean cropping.

3.6.1 Preparation

Seedbed Preparation

The preparation of the seedbed for Maize is mostly comparable to soybean seedbed preparation. Fertilization occurs based on soil samples and forecasted nutrient needs for the crop. Maize does not have a symbiotic relationship with *Rhizobium* like soy does; therefore nitrogen fertilization might be required. Crop rotation with soybeans might increase nitrogen content in the soil, reducing fertilization in this step (Ennin & Clegg, 2001).

The benefits of herbicide tolerant and insect resistant crops in this stage are mainly related to increased accessibility to no-till practices, as explained previously 3.4.1 above. Because Bt-maize is usually the second crop in the year, or the winter crop, it benefits more from the herbicide varieties than vice versa.

Variety Selection

Maize seeds are mostly hybrids from single, double or triple inbred lines. The choice of hybrid is based on available technology. Single hybrids require the most input, are the most expensive but have the highest possible yield. Double and triple are more robust yet less productive. As only first generation hybrids have the hybrid vigor, seeds need to be bought after every harvest. Besides the choice of hybrid, other characteristics are important for variety selection. Like with soybeans, growing climate, soil and photoperiod are important, together with yield potential, pest resistance, disease resistance and functional properties such as protein or sugar content. Because of the huge diversity in seed varieties, generally three categories are distinguished based on their yield potential, which is related to their price. For example, a variety of 'high potential' has a yield of 6,000 kg per ha, whereas a 'medium potential' variety has only 4,800 kg/ha. Because of these differences, prices for high potential seeds are higher, as are required inputs such as fertilizer and pesticides. Therefore high potential seeds are seen as more risky and most producers that start growing maize start with low potential varieties.

In the 2011/2012 season 316 conventional seeds and 173 transgenic seeds were available of which over 80% were hybrid seeds (Embrapa, 2011). The transgenic maize seeds available in Brazil are herbicide tolerant, insect resistant or a combination of both (James, 2010). Besides having the added traits, GM seed producers claim their seeds are also high quality hybrids that perform better than most conventional hybrids (Brookes & Barfoot, 2012).

Planting Practices

Planting depth for maize is around 5 cm but in soils low in moisture up to almost 8 cm can occur and for seedbeds with more moisture a minimum of approximately 4 centimeters is common (Farnham, et al., 2001). Plant density is dependent on planting rate (and consequently the germination rate) and row width. High plant densities can negatively influence yield because of internal light competition for instance (Tetio-Kagho & Gardner, 1988a) and can positively influence yield due to a higher kernel per area output (Tetio-Kagho & Gardner, 1988b). Row width fluctuates from 38 cm to almost a meter (Abendroth & Elmore, 2006). Optimal width and planting rate depends on hybrid variety, weed control and on environmental factors such as soil fertility. Narrower widths are becoming more widespread as, like soybeans, yields increase and planting machinery can be used for soybeans as well as maize. The benefits in using the same planter exceed the costs of reduced yield at suboptimal row widths.

Transgenic maize that has traits for insect resistance or herbicide tolerance may be easier to cultivate at higher plant densities because of decreased mechanical pesticide activity. This could lead to benefits in yield related to higher kernel output per area.

3.6.2 Cultivation

Insect Pest Management

The most prevalent insect pests of maize are stem borers and the armyworm. Other pests include corn rootworms, corn earworms and cutworms (James, 2002). Corn borers attack leaves and bore into stems and stalks of the corn plant. This leads to disrupted water and nutrient movement and can cause stalks to break (Iowa state university, sd). Prevalent species in Brazil are the sugarcane borer (*Diatraea saccharalis* and *Eldana saccharina*) and lesser corn borer (*Elasmopalpus lignosellus*). The principal armyworm species in Brazil is *Spodoptera Frugiperda*, which feeds on leaves and developing ears later in the season. Conventional insect control measures are insecticide spraying and biological control (Valicente & Costa, 1995) (Bale, et al., 2007). Difficulties arising in these methods are timing of insecticide spraying which requires constant vigilance (Cruz, et al., 2012) and the possible adverse effects of insecticides on natural enemies (Redoan, et al., 2010). Additionally insecticide sprays may be harmful during use and during consumption.

In 1996 the first Bt maize product in the USA was deployed and Brazil followed in 2008. Bt maize provides resistance to corn borers and suppresses armyworms. This allows farmers to decrease their insecticide output (Cannon, 2000) (Fernandez-Cornejo & McBride, 2000) (Kumar, et al., 2008), decrease attention devoted to insect control (Pray, et al., 2002) and is a more environmental friendly practice (Raybould & Quemada, 2010) (Maagd, et al., 1999). Disadvantages of Bt crops are the ability of insects to evolve resistance against bt-toxins (Tabashnik, et al., 2008), rendering them useless in the long run, and the costs property rights management (Goldsmith, et al., 2003).

Weed Control Management

Negative effects of weeds were described in detail before as were the four different control methods; manual, mechanical, cultural and chemical. GM herbicide tolerant maize is less widespread in Brazil than HT soybeans (James, 2010) and consequently a larger amount of control methods, most notable chemical, are being employed to ensure maize yields. Different compounds are for instance atrazine, mesotrione (Mitchell, et al., 2001) and acetochlor (Armel, et al., 2003).

GM Maize with herbicide tolerant traits will, like soybeans, be easier to use and reduce costs (Gómez, et al., 2012). However, little to no GM HT maize is being cultivated in Brazil.

Disease Management

Maize diseases are caused by nematode, viral, bacterial and fungal pathogens. Diseases caused by fungi and oomycetes are: phaeosphaerialeaf spot (caused by *Phaeosphaeriazeae maydis*); maize rust (*Puccinia spp.*); blotch (*Exserohilum turcicum*); stalk and ear rots (*Gibberella zeae, Fusarium moiliforme, F. subglutinans*) and mildew (*Peronosclerospora sorghi*). Viral diseases are: Rayado fino (*Maize rayado fino virus – MRFV*) and maize mosaic (*Maize Mosaic Virus – MMV*). Finally bacterial pathogens are *Erwinia spp.* that causes Stewart's wilt and *Spiroplasma kunkelii* that causes corn stunt disease (Embrapa, 2011) (Strange & Scott, 2005) (Casela, et al., 1998). Recognized methods to decrease pathogen risk for the producers are: use of resistant cultivars (Strange & Scott, 2005); correct planting time to avoid disease prone moments; proper fungicide management (Costa, et al., 2012); soil management (Ghorbani, et al., 2008) and crop rotation with non-susceptible crops (Strange & Scott, 2005) (Embrapa, 2011). Soy is hardly vulnerable to the above mentioned pathogens and so is maize for soy pathogens, making them effective crops for use in rotation. Embrapa also states that the most successful measure is the use of genetically resistant cultivars. Resistant varieties have little to no extra cost and do not cause a negative impact on the environment or other practices employed by the farmers.

However, currently (2010), no pathogen resistant GM maize varieties have been approved for the Brazilian commercial market (James, 2010). Therefore treatment and prevention regarding diseases is expected to be similar between transgenic and conventional varieties.

Fertilization

The most yield limiting factor for maize is nitrogen, followed by phosphorus and potassium (Embrapa, 2011). To know what to apply farmers can take soil samples and calculate their desired yield, consequently inherent soil fertility and soil reaction must also be taken into account. For instance; based on N sources in the soil, the price of fertilizer and the selling price of corn, producers can choose to add extra nitrogen. In soybean-maize rotations N is usually present in the soil after soybean cultivation, due to the *Rhizobium* activity, and in no-till fields decomposing organic matter can also be a source of N and other nutrients (Shapiro, et al., 2008). In different stages of maize development nutrient requirement varies. Embrapa gives tables and figures on when certain nutrients are required and together with information about availability of fertilizer, climate conditions and soil composition producers can estimate the best time and amount for their crops. Sandy soil for instance, in combination with rain, can lose a lot of nutrients by 'leaching', the flushing of solids from the soil by water. And, like with soy, often seeds are treated before planting. Winter maize (safrinha) generally requires less nutrients because yield is lower (Embrapa, 2011). Maize is very sensitive to droughts (FAO, 1991) and therefore needs a steady water supply. Specifically in the case of maize growth in dry areas or during dry spells (for safrinha for instance) irrigation is vital (Soler, et al., 2007). Methods of irrigation are surface, sprinkler and localized sub irrigation. Each method has its advantages and disadvantages regarding costs, ease-of-use and effectiveness (Embrapa, 2011)

Monsanto is currently producing a drought tolerant maize variety (James, 2010) to be released commercially in 2013 (Humphrey, 2012). This variety is designed to "enhance yield stability when water is limited" (Humphrey, 2012). Maize with these traits will not require less water to obtain the same yields as conventional maize varieties and long dry spells are still detrimental to harvests. But, when short droughts (up to two weeks) occur and water supply returns afterwards, drought tolerant maize will be able to restore some of its yield where conventional maize yield is irreversibly reduced (DiLeo, 2012). This might be beneficial for production in areas with frequent dry spells.

3.6.3 Harvesting

When maize is ready to be harvested several factors need to be considered before actually harvesting. For instance: weather during and length of harvest period; costs for equipment, labor and energy; drying conditions and potential yields and prices. During harvesting combines pick up the stalks and break off the ears. The ears are dragged into the combine and depending on future use the cobs, husks and kernels are separated in the machine. The kernels, or grains, are stored and the rest is returned to the field as mulch. In large areas in for instance Mato Grosso, several combiners can harvest next to each other to keep costs low. The fields are so large that grain trucks wait at the end to pick up grains and leave for storage immediately. Moisture content is important for the harvest timing. Farmers can choose between field drying and drying in storage (Nielsen, 2011). When moisture content is below 20%, losses might occur during harvest, so at times corn is field dried until 20-25% moisture, harvested and then dried further until 13-14% (Brooker, et al., 1992). Farmers sell the grains individually or to cooperation's when they can get the best price.

Maize production in 2010 in Brazil was 76% of the total soy production, and this is divided into 62% for the main harvest and 38% safrinha (Soybean and Corn Advisor, Inc, 2010). This leads to less direct infrastructural challenges when compared to soybean production. Nonetheless post-harvest losses and transportation costs are a significant portion of the production cost, especially in safrinha maize in Mato Grosso (Soybean and Corn Advisor, Inc, 2010).

3.7 Overview

In this subsection, four tables are given that specify the overviews of direct advantages and disadvantages as well as indirect advantages and disadvantages for biotech crops. For the direct overview (Table 5) all eight management practices were listed next to the proposed direct advantages and disadvantages of GM HT soy production.

For every advantage or disadvantage related to GM or NGM, increase or decrease in yield, cost and sales prices are listed as well as sources. In the next phase of the research, these (dis)advantages will be tested using statistical data.

TABLE 5: PROPOSED DIRECT ADVANTAGES AND DISADVANTAGES OF GM HT SOYBEANS, INCLUDING SOURCES

Management practice	Advantage/ Disadvantage	Production/ Profit	Costs	Source
Preparation				
Seedbed preparation	Reduced tillage		Decrease	(Thomson, 2007) (Qaim, 2009) (Cerdeira, et al., 2011)
Variety selection	High quality seeds	Higher yield		(Brookes & Barfoot, 2012)
	More expensive seeds		Increase	(GAO, 2000) (Bullock & Nitsi, 2001) (Benbrook, 2009)
Planting rate	N.A.			
Row width	N.A.			
Cultivation				
Insect control	N.A.			
Weed control	Less herbicide		Decrease	(Hin, et al., 2001) (Phipps & Park, 2002)
	Cheaper herbicide		Decrease	(Shaner, 2000) (Duke & Powles, 2008)
	Fewer spraying trips		Decrease	(Cerdeira, et al., 2011) (Brookes & Barfoot, 2012)
	More secure		Decrease	(James, 2010) (Brookes & Barfoot, 2012)
	Less weed competition	Higher yield		(Hin, et al., 2001) (Brookes & Barfoot, 2012) (Carpenter, 2010)
Disease control	N.A.			
Fertilization	N.A.			
Harvesting				
Harvesting	Higher quality output	Increased profit		(Brookes & Barfoot, 2012)

In Table 6 the same overview is given for GM IR maize.

TABLE 6: PROPOSED DIRECT ADVANTAGES AND DISADVANTAGES OF GM IR MAIZE, INCLUDING SOURCES

Management practice	Advantage/ Disadvantage	Production/ Profit	Costs	Source
Preparation				
Seedbed preparation	N.A.			
Variety selection	High quality seeds	Higher yield		(Gouse, et al., 2006) (Brookes & Barfoot, 2012) (Hellmich & Hellmich, 2012)
	More expensive seeds		Increase	(GAO, 2000) (Benbrook, 2009)
Planting rate	N.A.			
Row width	N.A.			
Cultivation				
Insect control	Less insecticide used		Decrease	(Cannon, 2000) (Fernandez-Cornejo & McBride, 2000) (Fitt, 2008) (Kumar, et al., 2008)
	Fewer spraying trips		Decrease	(Pray, et al., 2002) (Kumar, et al., 2008)
	Standard protection		Decrease	(Huesing & English, 2004)
	Less growth setback	Higher yield		(Fernandez-Cornejo & McBride, 2000) (Qaim & Zilberman, 2003) (Fitt, 2008) (Carpenter, 2010)
Weed control	N.A.			
Disease control	N.A.			
Fertilization	N.A.			
Harvesting				
Harvesting	Higher quality output	Increased profit		(Pray, et al., 2002) (Brookes & Barfoot, 2012) (Hellmich & Hellmich, 2012)

The indirect advantages and disadvantages (Table 7 and Table 8) are those not easily given for a separate phase in the soybean or maize production process. They can be considered more general applicable or may include several aspects that lead to an improvement, or not, for the producer.

TABLE 7: PROPOSED INDIRECT ADVANTAGES AND DISADVANTAGES OF GM HT SOYBEANS, INCLUDING SOURCES

Advantage/ Disadvantage	Production/ Profit	Costs	Source
Simplifies double harvests	Increase		(Possamai, et al., 2001) (Cerdeira, et al., 2011) (Brookes & Barfoot, 2012)
Increased upstream dependence		Increase	(Murphy, 2006) (Benbrook, 2009) (Rodrigues, et al., 2011)
Reduced machinery and fuel cost		Decrease	(Phipps & Park, 2002) (Carpenter, 2010) (Pioneer Hi-Bred, 2011)
Increased management flexibility and availability	Increase		(Qaim, 2009) (James, 2010)
Decreased environmental strain*	N.A.		(Hin, et al., 2001) (Phipps & Park, 2002)

TABLE 8: PROPOSED INDIRECT ADVANTAGES AND DISADVANTAGES OF GM IR MAIZE, INCLUDING SOURCES

Advantage/ Disadvantage	Production/ Profit	Costs	Source
Simplifies double harvests	Increase		(Possamai, et al., 2001) (Ennin & Clegg, 2001) (Brookes & Barfoot, 2012)
Increased upstream dependence		Increase	(Goldsmith, et al., 2003) (Sharma, 2004) (Murphy, 2006) (Benbrook, 2009)
Reduced machinery and fuel cost		Decrease	(Phipps & Park, 2002) (Carpenter, 2010) (Brookes & Barfoot, 2012)
Increased management flexibility and availability	Increase		(Qaim, 2009) (Huesing & English, 2004) (Pray, et al., 2002) (Brookes & Barfoot, 2012)
Decreased environmental strain*	N.A.		(Phipps & Park, 2002) (Maagd, et al., 1999) (Cannon, 2000) (Kumar, et al., 2008) (Raybould & Quemada, 2010)
Increased environmental strain	N.A.		(Tabashnik, et al., 2008) (Kruger, et al., 2009)

*Mentioned in this overview, but outside the scope of this course.

4. Materials and Methods

4.1 Introduction

In this chapter the methods that were used to answer the research questions are described. By means of financial analyses of production costs and sales revenues, the advantages and disadvantages of using GM or NGM seeds described in the first chapters were investigated and discussed. The harvest year in this research was set on 2010/2011, as all information on this year is complete and accessible. The agricultural year in Brazil starts as early as September (2010 in this research) with the summer crops and ends as late as August (2011) with the harvest of winter crops. In this chapter, the data sources will be discussed, followed by the region selection and finally the structure of the analysis.

4.2 Data Sources

Literature and Theoretical Background

Initial information on the agricultural situation of Brazil was provided by Prof. J. G. Martines Filho and his students R.A. Rodrigues and J. Junqueira-Jota. Most cited materials were found in the library at the University of São Paolo or on the internet portal and through other experts that are or have been active in the agricultural sector or seed business. Statistics on Brazilian agriculture were found in the on-line database of CONAB. Founded by the government to provide data for agricultural policy and to ensure a stable market, CONAB is a public company that provides statistics on production, prices and yields of agricultural commodities, both past harvests and future estimations (CONAB, sd). However, the numbers as collected by CONAB are not always complete. Not all regions are present, not all data is complete and often it has a standardized output that lacks the context required to make valid conclusions. Nonetheless, due to its easy accessibility and the large amount of data, CONAB's statistics on national harvest sizes, planting areas and crop productivities were used in the first parts of this research.

Financial analysis

For more detailed data on production costs separated by the different states in Brazil, regional statistics bureaus were approached for the second part of the study, the financial analysis. IMEA, the Mato Grosso Institute of Agricultural Economics, is a private non-profit institute that partners with local farmers' associations to provide information for agribusinesses in the state of Mato Grosso to help in sustainable development (IMEA, sd). For this research their extensive database on production costs and sales prices in the Center-West state of Mato Grosso was used. This database can be found on-line and is accessible free of charge. The final large source of statistical information was CEPEA (Centro de Estudos Avançados em Economia Aplicada). CEPEA is part of the University of São Paulo and as a research center conducts research on agribusiness topics such as management strategies, international trade, production costs and sales prices of commodities (CEPEA, 2007). Access to relevant parts from the database of CEPEA was obtained with assistance of V.Y. Ikeda and D.M. Velazco Bedoya, both employees at CEPEA.

Data from IMEA does not provide background information, therefore the exact methods that IMEA employs to produce the results that were used in this research remain unclear. However, it is assumed to be comparable to the method used by CEPEA, which is survey data collection: Researchers, technicians, consultants and producers are interviewed together in meetings with teams from CEPEA to form a system for production of a commodity and are asked to fill in cost spreadsheets. Together with market prices on interest rates, standard machine costs, fuel consumptions per unit of time, standard pesticide costs, etc. CEPEA determines and combines the production costs in databases (Ikeda, 2013). No information was present on the number and location of farms that cooperated with CEPEA or IMEA.

4.3 Region Selection

The division of Brazilian farming land, as mentioned before, is roughly as follows; large stretches of recently cultivated *cerrado* land in the Center-west and the traditional farming regions in the South-east. Not only climate differs between both regions; also infrastructure, technological input and average farm size varies enormously. Because it is not feasible to research all different agricultural regions in Brazil that produce soy and maize, representative regions were found. The state Mato Grosso, as the largest producer of soy and second in maize, was chosen to be representative for agriculture in the Center-west and Paraná was chosen for North-east agriculture because it is the leading producer in maize.

Mato Grosso

Mato Grosso, with 900.000 km^2 the size of France and Germany combined, is split into seven regions which are further divided into numerous counties (IMEA, 2010). Both IMEA and CEPEA have data from several of these counties, so a selection was made based on two criteria. One is the availability of comparable information from both databases: Sorriso for example was selected because it is present in both IMEA and CEPEA databases, enabling a good source comparison. The second criterion was based on quality comparison: counties that compare NGM and GM were picked with relatively little distance between them to keep production (geography, infrastructure, available technology) differences minimal. In Figure 9 **FIGURE** a table and a map show what counties were used in Mato Grosso and for what part of the research.

Figure 9: Regions Used For Data Analysis in Mato Grosso **(IMEA, 2008)**

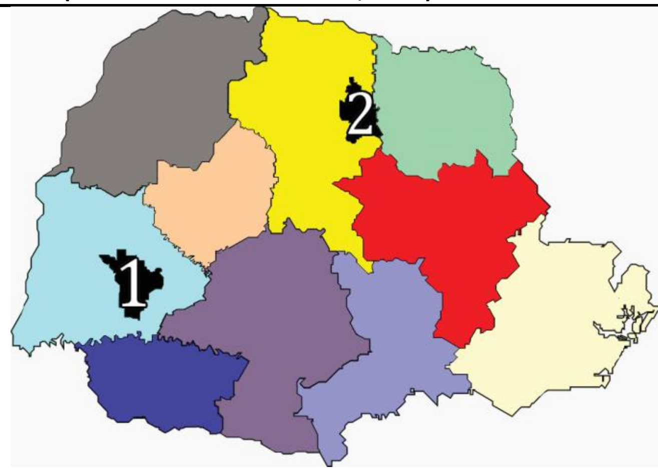
Type of Data	Region	Source	Map
Soy			
GM	Campo Verde	IMEA	1
	Canarana	IMEA	2
	Sorriso	CEPEA	3
NGM	Diamantino	IMEA	4
	Sorriso	IMEA	3
	Sorriso	CEPEA	3
Maize			
GM	Sorriso	IMEA	3
	Sorriso	CEPEA	3
Maize safrinha			
GM	Rondonópolis	CEPEA	5
	Sorriso	CEPEA	3
NGM	Diamantino	IMEA	4
	Sorriso	IMEA	3
	Sorriso	CEPEA	3

Paraná

Paraná is slightly smaller than Great Britain with an area of approximately 200.000 km^2. No regional institutes, like IMEA, could be approached and consequently all data was taken from CEPEA, which has a broad database of Paraná. The counties with the most comparable data between GM and NGM were selected, namely Cascavel and Londrina (Figure 10).

Figure 10: Regions Used For Data Analysis in Paraná **(AGROECOLOGIA PARANÁ , 2011)**

Type of Data	Region	Source	Map
Soy			
GM	Cascavel	CEPEA	1
	Londrina	CEPEA	2
NGM	Cascavel	CEPEA	1
	Londrina	CEPEA	2
Maize			
GM	Cascavel	CEPEA	1
	Londrina	CEPEA	2
NGM	Cascavel	CEPEA	1
	Londrina	CEPEA	2
Maize safrinha			
GM	Cascavel	CEPEA	1
	Londrina	CEPEA	2
NGM	Cascavel	CEPEA	1
	Londrina	CEPEA	2



4.4 Production Costs

The production costs compiled of data from IMEA and CEPEA are given in Table 10, Table 11, Table 12, Table 13 and Table 14. The currency used is the Real (R$, €0,34). Table 10 and Table 11 show the full production costs of GM and NGM soybeans, respectively, for the harvest year of 2010/2011. Table 12 and Table 13 show the full production costs for GM and NGM winter maize and Table 14 shows the production costs for GM and NGM summer maize. The tables are divided into four cost groups to maintain a clear overview (Table 9). First there are the agricultural product costs, second are the agricultural processes, third are other overhead costs and the fourth group consists of the fixed costs. To research both the direct and indirect advantages and disadvantages, the cost groups were explored in depth by dividing them into actual cost inputs. The following pages show the tables, after that each of the cost groups and their cost inputs will be described.

Table 9: Overview of Cost Groups Used (R$/ha)

1. Agricultural products
2. Agricultural processes
3. Other costs
4. Fixed costs
Total Costs (A+B)

TABLE 10: TOTAL PRODUCTION COSTS OF GM SOYBEANS, 2010/2011 HARVEST

REGION:	CAMPO VERDE/ CANARANA	SORRISO	CASCAVEL	LONDRINA
INPUT COSTS:	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)
1. AGRICULTURAL PRODUCTS (R$)	**805.72**	**746.42**	**734.52**	**542.56**
- SEEDS (R$)	**114.32**	**112.13**	**165.08**	**128.10**
SOY SEEDS (R$)	114.32	112.13	165.08	128.10
- FERTILIZERS (R$)	**420.94**	**469.01**	**346.36**	**249.34**
SOIL CORRECTORS/SEED TREATMENT (R$)	36.34	24.24	57.29	34.55
MACRONUTRIENTS (R$)	384.60	444.78	289.07	214.79
- APPLICATIONS (R$)	**270.47**	**165.28**	**223.08**	**165.12**
FUNGICIDES (R$)	99.19	57.42	106.64	77.27
HERBICIDES (R$)	70.94	40.29	35.51	27.48
INSECTICIDES (R$)	84.99	58.86	74.92	52.85
ADJUVANTS (R$)	15.35	8.70	6.00	7.52
2. AGRICULTURAL PROCESSES (R$)	**167.10**	**137.84**	**223.07**	**356.76**
LABOR (R$)	23.06	51.71	62.76	153.60
SOIL PREPARATION AND SEEDING (R$)	81.26	35.48	46.36	44.49
APPLICATIONS (R$)	26.12	13.21	52.93	18.99
HARVESTING (R$)	36.67	37.43	61.02	139.67
3. OTHER COSTS (R$)	**197.50**	**220.75**	**231.04**	**223.48**
TECHNICAL ASSISTANCE (R$)	8.34	18.55	20.31	19.06
TRANSPORT OF PRODUCE (R$)	54.60	43.40	57.85	53.72
STORAGE AND PROCESSING (R$)	*57.66*	*0.00*	*0.00*	*0.00*
TAXES (R$)	58.70	73.95	54.95	52.20
INSURANCE (R$)	4.95	6.22	11.21	6.34
FINANCING (R$)	70.91	78.63	86.72	92.16
ADMINISTRATIVE COSTS (R$)	*88.21*	*0.00*	*0.00*	*0.00*
A - VARIABLE COSTS (1+2+3) (R$)	**1,170.31**	**1,105.01**	**1,188.63**	**1,122.80**
4. FIXED COSTS (R$)	**235.85**	**272.51**	**593.49**	**483.71**
DEPRECIATION OF MACHINERY AND EQUIPMENT (R$)	37.85	73.25	120.95	62.06
COST OF LAND (R$)	198.00	199.25	472.54	421.65
INTEREST ON CAPITAL INVESTED (R$)	0.00	57.30	93.31	45.83
B - FIXED COSTS (4) (R$)	**235.85**	**272.51**	**593.49**	**483.71**
TOTAL COSTS (A+B) (R$)	**1,406.16**	**1,377.52**	**1,782.13**	**1,606.52**
SOURCE:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

TABLE 11: TOTAL PRODUCTION COSTS OF NGM SOYBEANS, 2010/2011 HARVEST

REGION:	CAMPO VERDE/ CANARANA	SORRISO	CASCAVEL	LONDRINA
INPUT COSTS:	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)
1. AGRICULTURAL PRODUCTS (R$)	**762.89**	**739.08**	**805.59**	**582.82**
- SEEDS (R$)	**86.78**	**80.00**	**133.47**	**102.48**
SOY SEEDS (R$)	86.78	80.00	133.47	102.48
- FERTILIZERS (R$)	**397.96**	**469.01**	**346.36**	**249.34**
SOIL CORRECTORS/SEED TREATMENT (R$)	26.75	24.24	57.29	34.55
MACRONUTRIENTS (R$)	371.21	444.78	289.07	214.79
- APPLICATIONS (R$)	**278.16**	**190.07**	**325.76**	**231.01**
FUNGICIDES (R$)	89.84	57.42	106.64	77.27
HERBICIDES (R$)	76.99	62.04	138.20	89.60
INSECTICIDES (R$)	95.20	58.86	74.92	52.85
ADJUVANTS (R$)	16.13	11.75	6.00	11.28
2. AGRICULTURAL PROCESSES (R$)	**171.69**	**137.84**	**223.07**	**356.76**
LABOR (R$)	24.43	51.71	62.76	153.60
SOIL PREPARATION AND SEEDING (R$)	84.75	35.48	46.36	44.49
APPLICATIONS (R$)	22.40	13.21	52.93	18.99
HARVESTING (R$)	40.12	37.43	61.02	139.67
3. OTHER COSTS (R$)	**177.53**	**219.98**	**238.53**	**228.18**
TECHNICAL ASSISTANCE (R$)	7.86	18.41	21.73	19.87
TRANSPORT OF PRODUCE (R$)	36.40	43.40	57.85	53.72
STORAGE AND PROCESSING (R$)	*60.59*	*0.00*	*0.00*	*0.00*
TAXES (R$)	55.66	73.95	54.95	52.20
INSURANCE (R$)	4.52	6.22	11.21	6.34
FINANCING (R$)	73.10	78.01	92.79	96.05
ADMINISTRATIVE COSTS (R$)	*72.14*	*0.00*	*0.00*	*0.00*
A - VARIABLE COSTS (1+2+3) (R$)	**1,112.11**	**1,096.90**	**1,267.20**	**1,167.76**
4. FIXED COSTS (R$)	**224.53**	**272.51**	**593.49**	**483.71**
DEPRECIATION OF MACHINERY AND EQUIPMENT (R$)	35.56	73.25	120.95	62.06
COST OF LAND (R$)	188.97	199.25	472.54	421.65
INTEREST ON CAPITAL INVESTED (R$)	0.00	57.30	93.31	45.83
B - FIXED COSTS (4) (R$)	**224.53**	**272.51**	**593.49**	**483.71**
TOTAL COSTS (A+B) (R$)	**1,336.63**	**1,369.41**	**1,860.69**	**1,651.48**
SOURCE:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

TABLE 12: TOTAL PRODUCTION COSTS OF GM WINTER MAIZE, 2010/2011 HARVEST

REGION:	**SORRISO**	**RONDONÓPOLIS**	**CASCAVEL**	**LONDRINA**
INPUT COSTS:	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)
1. AGRICULTURAL PRODUCTS (R$)	**565.96**	**500.96**	**826.16**	**735.57**
- SEEDS (R$)	**220.00**	**250.00**	**368.18**	**392.56**
MAIZE SEEDS (R$)	220.00	250.00	368.18	392.56
- FERTILIZERS (R$)	**267.44**	**152.36**	**317.81**	**247.72**
SOIL CORRECTORS/SEED TREATMENT (R$)	26.78	42.36	56.90	38.42
MACRONUTRIENTS (R$)	240.66	110.00	260.91	209.30
- APPLICATIONS (R$)	**78.52**	**98.60**	**140.17**	**95.29**
FUNGICIDES (R$)	12.00	28.80	42.15	31.82
HERBICIDES (R$)	40.60	67.70	60.45	47.31
INSECTICIDES (R$)	17.92	0.00	32.93	12.40
ADJUVANTS (R$)	8.00	2.10	4.65	3.76
2. AGRICULTURAL PROCESSES (R$)	**157.12**	**137.82**	**239.37**	**246.44**
LABOR (R$)	42.61	57.01	45.66	73.23
SOIL PREPARATION AND SEEDING (R$)	51.25	24.72	57.99	55.62
APPLICATIONS (R$)	5.50	12.17	40.37	9.50
HARVESTING (R$)	57.76	43.92	95.35	108.10
3. OTHER COSTS (R$)	**238.47**	**177.61**	**297.81**	**241.26**
TECHNICAL ASSISTANCE (R$)	16.26	13.57	23.23	20.76
TRANSPORT OF PRODUCE (R$)	90.00	39.60	96.00	56.20
STORAGE AND PROCESSING (R$)	*108.00*	*63.00*	*0.00*	*0.00*
TAXES (R$)	29.50	27.60	44.16	35.22
INSURANCE (R$)	7.03	6.90	12.85	6.05
FINANCING (R$)	95.68	89.95	121.57	123.03
ADMINISTRATIVE COSTS (R$)	*0.00*	*0.00*	*0.00*	*0.00*
A - VARIABLE COSTS (1+2+3) (R$)	**961.55**	**816.39**	**1,363.34**	**1,223.27**
4. FIXED COSTS (R$)	**253.27**	**225.67**	**465.30**	**375.02**
DEPRECIATION OF MACHINERY AND EQUIPMENT (R$)	91.46	85.70	143.61	56.76
COST OF LAND (R$)	89.83	72.47	210.10	276.70
INTEREST ON CAPITAL INVESTED (R$)	71.98	67.50	111.59	41.56
B - FIXED COSTS (4) (R$)	**253.27**	**225.67**	**465.30**	**375.02**
TOTAL COSTS (A+B) (R$)	**1,214.82**	**1,042.06**	**1,828.64**	**1,598.29**
SOURCE:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

TABLE 13: TOTAL PRODUCTION COSTS OF NGM WINTER MAIZE, 2010/2011 HARVEST

REGION:	SORRISO	RONDONÓPOLIS	CASCAVEL	LONDRINA
INPUT COSTS:	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)
1. AGRICULTURAL PRODUCTS (R$)	**524.60**	**506.88**	**740.02**	**707.01**
- SEEDS (R$)	**150.00**	**150.00**	**256.61**	**289.26**
MAIZE SEEDS (R$)	150.00	150.00	256.61	289.26
- FERTILIZERS (R$)	**287.64**	**152.36**	**317.81**	**247.72**
SOIL CORRECTORS/SEED TREATMENT (R$)	46.98	42.36	56.90	38.42
MACRONUTRIENTS (R$)	240.66	110.00	260.91	209.30
- APPLICATIONS (R$)	**86.96**	**204.52**	**165.60**	**170.04**
FUNGICIDES (R$)	0.00	28.80	42.15	31.82
HERBICIDES (R$)	40.60	67.70	60.45	47.31
INSECTICIDES (R$)	40.96	105.92	58.35	87.15
ADJUVANTS (R$)	5.40	2.10	4.65	3.76
2. AGRICULTURAL PROCESSES (R$)	**160.92**	**145.03**	**272.46**	**262.61**
LABOR (R$)	44.74	61.75	47.21	83.07
SOIL PREPARATION AND SEEDING (R$)	50.72	24.72	57.99	55.62
APPLICATIONS (R$)	7.70	14.64	71.92	15.83
HARVESTING (R$)	57.76	43.92	95.35	108.10
3. OTHER COSTS (R$)	**233.93**	**179.62**	**291.20**	**240.01**
TECHNICAL ASSISTANCE (R$)	15.51	13.83	22.17	20.52
TRANSPORT OF PRODUCE (R$)	90.00	39.60	96.00	56.20
STORAGE AND PROCESSING (R$)	*108.00*	*63.00*	*0.00*	*0.00*
TAXES (R$)	29.50	27.60	44.16	35.22
INSURANCE (R$)	7.14	7.05	12.85	6.50
FINANCING (R$)	91.78	91.54	116.02	121.56
ADMINISTRATIVE COSTS (R$)	*0.00*	*0.00*	*0.00*	*0.00*
A - VARIABLE COSTS (1+2+3) (R$)	**919.45**	**831.52**	**1,303.68**	**1,209.63**
4. FIXED COSTS (R$)	**255.59**	**228.77**	**465.30**	**390.21**
DEPRECIATION OF MACHINERY AND EQUIPMENT (R$)	92.75	87.42	143.61	65.17
COST OF LAND (R$)	89.83	72.47	210.10	276.70
INTEREST ON CAPITAL INVESTED (R$)	73.02	68.88	111.59	48.34
B - FIXED COSTS (4) (R$)	**255.59**	**228.77**	**465.30**	**390.21**
TOTAL COSTS (A+B) (R$)	**1,175.04**	**1,060.29**	**1,768.98**	**1,599.84**
SOURCE:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

TABLE 14: TOTAL PRODUCTION COSTS OF SUMMER MAIZE, 2010/2011 HARVEST

	GM		NGM	
REGION:	**CASCAVEL**	**LONDRINA**	**CASCAVEL**	**LONDRINA**
INPUT COSTS:	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)	Cost (R$/ha)
1. AGRICULTURAL PRODUCTS (R$)	**1,111.27**	**1,040.95**	**1,029.23**	**1,033.06**
- SEEDS (R$)	**433.88**	**392.56**	**309.92**	**309.92**
MAIZE SEEDS (R$)	433.88	392.56	309.92	309.92
- FERTILIZERS (R$)	**581.96**	**524.17**	**581.96**	**524.17**
SOIL CORRECTORS/SEED TREATMENT (R$)	63.22	37.19	63.22	37.19
MACRONUTRIENTS (R$)	518.74	486.98	518.74	486.98
- APPLICATIONS (R$)	**95.42**	**124.21**	**137.35**	**198.97**
FUNGICIDES (R$)	0.00	31.82	0.00	31.82
HERBICIDES (R$)	86.50	76.24	86.50	76.24
INSECTICIDES (R$)	8.93	12.40	50.85	87.15
ADJUVANTS (R$)	0.00	3.76	0.00	3.76
2. AGRICULTURAL PROCESSES (R$)	**284.67**	**326.28**	**305.41**	**332.49**
LABOR (R$)	60.13	101.93	63.22	103.80
SOIL PREPARATION AND SEEDING (R$)	58.33	55.62	58.33	55.62
APPLICATIONS (R$)	30.00	16.26	47.64	20.59
HARVESTING (R$)	136.21	152.48	136.21	152.48
3. OTHER COSTS (R$)	**440.00**	**380.42**	**435.43**	**380.49**
TECHNICAL ASSISTANCE (R$)	31.75	30.24	30.52	30.20
TRANSPORT OF PRODUCE (R$)	191.47	144.63	191.47	144.63
STORAGE AND PROCESSING (R$)	*0.00*	*0.00*	*0.00*	*0.00*
TAXES (R$)	86.88	68.19	86.88	68.19
INSURANCE (R$)	16.20	6.59	16.78	6.82
FINANCING (R$)	113.70	130.77	109.78	130.65
ADMINISTRATIVE COSTS (R$)	*0.00*	*0.00*	*0.00*	*0.00*
A - VARIABLE COSTS (1+2+3) (R$)	**1,835.94**	**1,747.65**	**1,770.06**	**1,746.04**
4. FIXED COSTS (R$)	**806.15**	**536.89**	**825.80**	**544.49**
DEPRECIATION OF MACHINERY AND EQUIPMENT (R$)	187.02	66.13	197.90	70.33
COST OF LAND (R$)	472.54	421.65	472.54	421.65
INTEREST ON CAPITAL INVESTED (R$)	146.58	49.11	155.36	52.50
B - FIXED COSTS (4) (R$)	**806.15**	**536.89**	**825.80**	**544.49**
TOTAL COSTS (A+B) (R$)	**2,642.09**	**2,284.54**	**2,595.87**	**2,290.52**
SOURCE:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

Agricultural products

Agricultural products consist of costs of seeds, fertilizers and pesticides required for production of soy and/or maize, see Table 18. Both sources sometimes have different methods of calculating production costs. For instance, IMEA includes the costs of cover crops in the costs of seeds and CEPEA does not. To simplify, cover crop costs were omitted in this research. In calculating fertilizer costs, IMEA works with soil correctors where CEPEA uses seed treatments, even though in principal they are the same: pesticides and inoculant before seed is sown (Ikeda, 2013). Additionally, IMEA divides nutrients in macro- and micronutrients, whereas CEPEA uses just fertilizer. The distinction is more important in Mato Grosso because of the large amounts of nutrients added to *Cerrado* land, but in this research, IMEA's macro- and micronutrients are added up to the simple term 'nutrients'. Both sources handle pesticides the same way. Adjuvants are compounds used to improve activity of pesticides such as surfactants or emulsifiers, which are not active pesticides on their own.

Table 15: Agricultural Products

-	**Soy or Maize Seeds**
-	**Fertilizer**
	Soil Correctors/ Seed Treatments
	Nutrients
-	**Pesticides**
	Fungicides
	Herbicides
	Insecticides
	Adjuvants

Agricultural processes

The costs associated with agricultural processes were divided into labor, soil preparation and seeding, applications and harvesting, see Table 16. The term soil preparation and seeding is approached differently by IMEA and CEPEA. IMEA gives the mechanical costs of plowing, land leveling and fertilizing (before planting) and seeding separately whereas CEPEA groups them in the term 'soil preparation and seeding'. In this research, CEPEA's approach is used by adding up the values from IMEA into the simplified term soil preparation and seeding. The other cost inputs are treated the same by both sources. Application costs are costs associated with applying pesticides or fertilizers (after planting) to the land.

Table 16: Agricultural Processes

-	**Labor**
-	**Soil Preparation and Seeding**
-	**Applications**
-	**Harvesting**

Other Costs

The third subdivision (Table 17) is made up of non-agricultural costs such as technical assistance, transport of produce, storage and processing, taxes, insurance, financing and administration. With the exception of storage and processing costs and administration costs, both sources have the same approach to the different cost drivers. CEPEA does not include storage and processing or administration costs in the production costs and to be able to compare data from both sources, both storage and processing and administration costs as calculated by IMEA were not used in this research.

Table 17: Other Costs

-	**Technical Assistance**
-	**Transport of Produce**
-	**Storage and Processing**
-	**Taxes**
-	**Insurance**
-	**Financing**

Fixed Costs

These three subdivisions combined make up all variable operating costs. The fourth subdivision consists of all fixed costs: the costs of depreciation of machinery & equipment, the costs of land and the interest on capital invested (Table 18). Interest on capital invested also covers interest on loans. IMEA and CEPEA both calculate the first two, but IMEA does not include the interest on capital invested.

TABLE 18: FIXED COSTS

-	**DEPRECIATION OF MACHINES & EQUIPMENT**
-	**COSTS OF LAND**
-	**INTEREST ON CAPITAL INVESTED**

4.5 SALES PRICES

Sales prices for every region were provided in the data from CEPEA. Sales prices for regions from IMEA were calculated by taken the average of soy prices in that region from February to March, the months were the majority of soybeans are harvested and sold (IMEA, 2011). See Appendix E for the data used.

4.6 FINANCIAL ANALYSIS

The financial analysis is used to find the most profitable system, either the one that uses transgenic seeds or the one that uses conventional seeds. To this end different production costs, selling prices and yields in conjunction with the average sizes of farms in each region to compare profits and/or losses were calculated, see Table 19. Table 19 can be seen as a summarized result of all data that was found and used for this research. Three units are used in all calculations found in the results. Brazil's national currency; the Real (R$, €0,34), is used as currency. For units of area and quantity, hectares (Ha, 10.000 km^2) and sacks (Sa, 60kg) were used. The average area is taken from the average farm size in a particular region. In the Center-west the average was 897 Ha and the average in the South-east was 92 Ha (Carvalho, 2006).

TABLE 19: TEMPLATE USED FOR PROFIT/LOSS CALCULATION (R$/HA)

YIELD	SC/HA	-
AVERAGE AREA	HA	-
AVERAGE PRODUCTION	SC	AVERAGE AREA * YIELD
TOTAL COSTS	R$	AVERAGE AREA * PRODUCTION COSTS
TOTAL SALES	R$	AVERAGE AREA * AVERAGE SELLING PRICE
TOTAL PROFIT	R$	TOTAL SALES – TOTAL COSTS
COST PRICE	R$/SA	TOTAL COSTS / YIELD
AVERAGE SELLING PRICE	R$/SA	-
PROFIT MARGIN	R$/SA	SELLING PRICE – COST PRICE

The profit margins will be further compared in the results using tables, to link the profit margins between GM and NGM and the Center-west and South-east. With these tables an easy overview is given that can pinpoint whether or not GM or NGM is more profitable and if this is related to region. Following the profit analysis in the results, the production costs will be described in more detail as well. Tables are given that highlight where the production costs differ and what is the most likely cause.

4.7 SIGNIFICANCE

To ensure a useful analysis, results that have an absolute difference of less than 5% compared to the lower value will not be seen as significant. For example, the absolute difference between R$ 70.94 and R$ 76.99 is R$ 6.05, or 8.53% of R$ 70.94. In this situation the difference is significant, as it is above the value of R$ 3.55, which is 5% of R$ 70.94. Another example is the difference between R$ 297.81 and R$ 291.20 is R$ 6.61. The difference is 2.27% of R$ 291.20, so it will not be seen as a significant difference nor will it be described as such in the results.

5. Results

In the following paragraphs the results from the financial analyses on soy, maize and winter maize are shown. For each crop the profit/loss analysis will be shown first and then the production costs will be described in more detail.

5.1 Profit/Loss Analysis On Soybean Production

All the production cost price data obtained from IMEA, CONAB and CEPEA can be found in paragraph 4.4 above, all data on prices can be found in Appendix E. Below are the profit/loss calculations for soybeans from the summer harvest of 2010. Colored highlights are used to indicate rows of interest.

Table 20: Profit/Loss Calculations for GM soybeans, per Region (R$/ha)

	Campo Verde/ Canarana	Sorriso	Cascavel	Londrina
Yield (sc/ha)	52.00	62.00	57.85	53.72
Average area (ha)	897	897	92	92
Average production (sc)	46,644	55,614	5,322	4,942
Total Costs (R$)	1,261,326	1,235,635	163,956	147,799
Total Sales (R$)	1,862,961	1,786,322	219,807	208,806
Total Profit (R$)	601,636	550,687	55,851	61,006
Cost Price Per Sack (R$)	27.04	22.22	30.81	29.91
Average selling Price Per Sack (R$)	39.94	32.12	41.30	42.25
Profit Margin Per Sack (R$)	12.90	9.90	10.49	12.34
source:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

Table 21: Profit/Loss Calculations for NGM soybeans, per Region (R$/ha)

	Diamantino/ Sorriso	Sorriso	Cascavel	Londrina
Yield (sc/ha)	52.00	62.00	57.85	53.72
Average area (ha)	897	897	92	92
Average production (sc)	46,644	55,614	5,322	4,942
Total Costs (R$)	1,198,957	1,228,357	171,184	151,936
Total Sales (R$)	1,799,526	1,786,322	219,807	208,806
Total Profit (R$)	600,568	557,964	48,623	56,870
Cost Price Per Sack (R$)	25.70	22.09	32.16	30.74
Average selling Price Per Sack (R$)	38.58	32.12	41.30	42.25
Profit Margin Per Sack (R$)	12.88	10.03	9.14	11.51
source:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

The yields were taken from the same sources as the production costs from Table 10 and Table 11. They are different for each region but identical across GM and NGM varieties, suggesting no significant yield difference between GM and NGM soybeans was obtained by the institutes that did the field work.

Because of the differences between the Center-west and the South-east, the average area per farm differs with a factor ten. This has a direct effect on total costs and profits, as producers that own land in the Center-west have a larger production and thus a larger profit or loss. Therefore the cost price per sack and average selling price per sack are more useful for analysis and both will be described in the next paragraph. The easiest way to compare overall profits is by connecting the profit margins per sack, as this takes out the differences between the regions in Mato Grosso (Campo Verde, Canarana, Diamantino, Sorriso) and the regions in Paraná (Cascavel, Londrina). To this end, the profit margin per sack in Table 20 and Table 21 were combined in Table 22, with the regions combined in states:

The table compares two variables: region and whether the bean is GM or not. The differences indicate that NGM varieties in the Center-west are slightly more profitable, at 5 cents per sack, whereas GM varieties in the South-east are vastly more profitable than NGM varieties, at R$ 1.10 per sack, almost 10% of the entire profit margin.

TABLE 22: PROFIT MARGINS PER SACK OF SOY

STATE	GM (R$/SA)	NGM (R$/SA)	DIFFERENCE (R$/SA)
MATO GROSSO (CENTER-WEST) (R$)	11.40	11.45	**- 0.05**
PARANÁ (SOUTH-EAST) (R$)	11.42	10.32	**1.10**

5.2 DETAILED SOYBEAN PRODUCTION AND SELLING PRICE

To clearly pinpoint differences in production costs, Table 23 and Table 25 show cost summaries. The costs are grouped in agricultural products, processes, other variable costs and fixed costs. Variations in absolute cost between GM and NGM are most pronounced for agricultural products, a full comparison is shown in Table 24 and Table 26. Input costs 2, 3 and 4 do not differ much in absolute costs between GM and NGM, mainly because CEPEA averages most of these costs. The differences between regions are more prominent and clearly show a division between the Center-west and South-east. Especially for the fixed cost, which includes the prices of land (Table 10 and Table 11), a large deviation is present: in Mato Grosso fixed costs are 17-20% of total costs while in Paraná this is between 29 and 33%. This difference explains most of the higher cost price per hectare in the South-east.

TABLE 23: SUMMARIZED PRODUCTION COSTS FOR GM SOYBEANS, PER REGION (R$/HA)

INPUT COSTS:	CAMPO VERDE/ CANARANA		SORRISO		CASCAVEL		LONDRINA	
1. AGRICULTURAL PRODUCTS (R$)	805,72	57%	746,42	54%	734,52	41%	542,56	34%
2. AGRICULTURAL PROCESSES (R$)	167,10	12%	137,84	10%	223,07	13%	356,76	22%
3. OTHER COSTS (R$)	197,50	14%	220,75	16%	231,04	13%	223,48	14%
4. FIXED COSTS (R$)	235,85	17%	272,51	20%	593,49	33%	483,71	30%
TOTAL COSTS (R$)	1.406,16		1.377,52		1.782,13		1.606,52	
SOURCE:	*IMEA*		*CEPEA*		*CEPEA*		*CEPEA*	

Table 25: Summarized Production Costs for NGM soybeans, per Region (R$/ha)

Input Costs:	Diamantino/ Sorriso		Sorriso		Cascavel		Londrina	
1. Agricultural Products (R$)	762,89	57%	739,08	54%	805,59	43%	582,82	35%
2. Agricultural Processes (R$)	171,69	13%	137,84	10%	223,07	12%	356,76	22%
3. Other Costs (R$)	177,53	13%	219,98	16%	238,53	13%	228,18	14%
4. Fixed Costs (R$)	224,53	17%	272,51	20%	593,49	32%	483,71	29%
Total Costs (R$)	1.336,63		1.369,41		1.860,69		1.651,48	
Source:	*IMEA*		*CEPEA*		*CEPEA*		*CEPEA*	

Agricultural Products

To take a closer look at the differences between GM and NGM in the agricultural products, the full comparison is shown below. GM seed prices per hectare are between R$ 25.62 and R$ 32.13 more expensive than NGM prices per hectare, with little variance across both states. A higher cost price for GM seeds should be countered with lower expenditures on herbicides: this is only partly visible in Table 24 and Table 26. In Mato Grosso, the herbicide costs per hectare for cultivating NGM varieties of soy are R$ 6.05 and R$ 21.75 higher than the costs for GM varieties. This is different in regions in Paraná, where the variance is more distinct; R$ 102.69 and R$ 62.12 are spent more per hectare. At first glance this would make GM seeds worth the investment in Paraná regions Cascavel and Londrina, but not in Diamantino or Sorriso (Mato Grosso). Another prominent cost driver is highlighted in blue, the macronutrient costs per hectare. There is little to no variance between GM and NGM varieties, but between Mato Grosso and Paraná regions the costs differ over R$ 150. This difference can be linked to the large amounts required to make *Cerrado* land fertile enough for cultivation.

Table 24: Agricultural Product Costs for GM soybeans, per Region (R$/ha)

Input Costs:	Campo Verde/ Canarana	Sorriso	Cascavel	Londrina
- Seeds (R$)	**114.32**	**112.13**	**165.08**	**128.10**
Soy seeds (R$)	114.32	112.13	165.08	128.10
- Fertilizers (R$)	**420.94**	**469.01**	**346.36**	**249.34**
Soil correctors/Seed treatment (R$)	36.34	24.24	57.29	34.55
Macronutrients (R$)	384.60	444.78	289.07	214.79
- Applications (R$)	**270.47**	**165.28**	**223.08**	**165.12**
Fungicides (R$)	99.19	57.42	106.64	77.27
Herbicides (R$)	70.94	40.29	35.51	27.48
Insecticides (R$)	84.99	58.86	74.92	52.85
Adjuvants (R$)	15.35	8.70	6.00	7.52
Total Agricultural Product Costs (R$)	**805.72**	**746.42**	**734.52**	**542.56**
source:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

TABLE 26: AGRICULTURAL PRODUCT COSTS FOR NGM SOYBEANS, PER REGION (R$/HA)

INPUT COSTS:	DIAMANTINO/ SORRISO	SORRISO	CASCAVEL	LONDRINA
- SEEDS (R$)	**86.78**	**80.00**	**133.47**	**102.48**
SOY SEEDS (R$)	86.78	80.00	133.47	102.48
- FERTILIZERS (R$)	**397.96**	**469.01**	**346.36**	**249.34**
SOIL CORRECTORS/SEED TREATMENT (R$)	26.75	24.24	57.29	34.55
MACRONUTRIENTS (R$)	371.21	444.78	289.07	214.79
- APPLICATIONS (R$)	**278.16**	**190.07**	**325.76**	**231.01**
FUNGICIDES (R$)	89.84	57.42	106.64	77.27
HERBICIDES (R$)	76.99	62.04	138.20	89.60
INSECTICIDES (R$)	95.20	58.86	74.92	52.85
ADJUVANTS (R$)	16.13	11.75	6.00	11.28
TOTAL AGRICULTURAL PRODUCT COSTS (R$)	**762.89**	**739.08**	**805.59**	**582.82**
SOURCE:	*IMEA*	*CEPEA*	*CEPEA*	*CEPEA*

Soybean traders and price watchers make no difference between GM and NGM soybeans for the main market. As mentioned before, a price premium exists for certified NGM soybeans. Whenever a load of certified soybeans is sold, it can be tested to ensure no GM soybeans are present, meaning producers have to certify that they indeed sell 100% NGM beans. To prevent contamination, these soybeans are stored in separate facilities, transported in clean trucks and handled independently from GM products (Varacca, et al., 2013). The guarantee that no GM products are present allows for a price premium. In this research the main market is studied as 100% GM free products can be seen as a niche market, and price premiums were not taken into account.

5.3 PROFIT/LOSS ANALYSIS ON MAIZE PRODUCTION

The full overview of cost price data can be found in Table 12, Table 13 and Table 14, together with all data on sales prices. Below are the the profit/loss calculations for corn from the harvests of 2010/2011. Over 96% of corn in Mato Grosso is winter maize – safrinha. Because so little summer maize is grown in the Center-west, statistics bureaus do not have enough data to make a useful comparison between GM and NGM summer maize. Therefore only summer maize from Paraná is used. The distinction in data between GM and NGM maize is relatively new, as GM maize was first cultivated in 2007, nevertheless, enough data was present to compare the 2010/2011 winter maize harvests.

Yields of corn differ much more between varieties than soybean yields do; this is related to the amount of risk a producer is willing to take as external factors play a larger role. High potential seeds are more expensive, require more input and climate factors have a larger effect on yield. Producers therefore choose maize seeds based on what they can safely expect to produce in a particular region, hence the differences between Rondonópolis and Sorriso for instance. Like with soybeans, there is no difference in yields between GM and NGM, again signifying that possible yield improvements for GM varieties are not significant.

TABLE 27: SUMMARIZED PROFIT/LOSS CALCULATIONS FOR GM WINTER MAIZE, PER REGION (R$/HA)

	SORRISO	RONDONÓPOLIS	CASCAVEL	LONDRINA
YIELD (SC/HA)	90,00	60,00	80,00	70,25
AVERAGE AREA (HA)	897	897	92	92
AVERAGE PRODUCTION (SC)	80,730	53,820	7,360	6,463
TOTAL COSTS (R$)	1,186,569	991,240	168,235	147,043
TOTAL SALES (R$)	1,150,403	1,076,400	176,640	140,889
TOTAL PROFIT (R$)	-36,166	85,160	8,405	-6,154
COST PRICE PER SACK (R$)	14.70	18.42	22.86	22.75
AVERAGE SELLING PRICE PER SACK (R$)	14.25	20.00	24.00	21.80
PROFIT MARGIN PER SACK (R$)	-0.45	1.58	1.14	-0.95

TABLE 28: SUMMARIZED PROFIT/LOSS CALCULATIONS FOR NGM WINTER MAIZE, PER REGION (R$/HA)

	SORRISO	RONDONÓPOLIS	CASCAVEL	LONDRINA
YIELD (SC/HA)	90,00	60,00	80,00	70,25
AVERAGE AREA (HA)	897	897	92	92
AVERAGE PRODUCTION (SC)	80,730	53,820	7,360	6,463
TOTAL COSTS (R$)	1,150,891	1,007,595	162,746	147,185
TOTAL SALES (R$)	1,150,403	1,076,400	176,640	140,889
TOTAL PROFIT (R$)	-489	68,805	13,894	-6,296
COST PRICE PER SACK (R$)	14.26	18.72	22.11	22.77
AVERAGE SELLING PRICE PER SACK (R$)	14.25	20.00	24.00	21.80
PROFIT MARGIN PER SACK (R$)	-0.01	1.28	1.89	-0.97

TABLE 29: SUMMARIZED PROFIT/LOSS CALCULATIONS FOR SUMMER MAIZE, PER REGION (R$/HA)

	GM		NGM	
	CASCAVEL	LONDRINA	CASCAVEL	LONDRINA
YIELD (SC/HA)	174.07	144.63	174.07	144.63
AVERAGE AREA (HA)	92	92	92	92
AVERAGE PRODUCTION (SC)	16,014	13,306	16,014	13,306
TOTAL COSTS (R$)	243,072	210,178	238,820	210,728
TOTAL SALES (R$)	347,507	272,769	347,507	272,769
TOTAL PROFIT (R$)	104,435	62,591	108,687	62,040
COST PRICE PER SACK (R$)	15.18	15.80	14.91	15.84
AVERAGE SELLING PRICE PER SACK (R$)	21.70	20.50	21.70	20.50
PROFIT MARGIN PER SACK (R$)	6.52	4.70	6.79	4.66

What is remarkable about the total profit or loss for each region are the losses for the regions of Sorriso and Londrina. Due to climate instability and lower demands on the market, planting in the off-season is associated with more risk and some producers will not make a profit. In both regions that fail to make a profit, the losses are associated with lower selling prices per sack than in the regions that do make a profit. This could indicate that the demand for corn was lower than expected. The cost price per sack and average selling price per sack will be described in the next paragraph. The profit margins per sack in Table 27, Table 28 and Table 29 were combined in Table 30 and Table 31:

The negative differences between GM and NGM suggest that, for maize, both the summer and winter varieties of non-biotech crops have higher profit margins than their biotech counterparts.

TABLE 30: PROFIT MARGINS PER SACK OF WINTER MAIZE

STATE	GM (R$/SA)	NGM (R$/SA)	DIFFERENCE (R$/SA)
MATO GROSSO (CENTER-WEST) (R$)	0,57	0,64	**- 0,07**
PARANÁ (SOUTH-EAST) (R$)	0,09	0,46	**- 0,36**

TABLE 31: PROFIT MARGINS PER SACK OF SUMMER MAIZE

STATE	GM (R$/SA)	NGM (R$/SA)	DIFFERENCE (R$/SA)
PARANÁ (SOUTH-EAST) (R$)	5,61	5,72	**- 0,11**

5.4 DETAILED MAIZE PRODUCTION AND SELLING PRICE

The summarized costs are shown in Table 32, Table 33 and Table 36. The costs are grouped in agricultural products, processes, other variable costs and fixed costs. Like with soybeans the variations in absolute costs between GM and NGM varieties are most pronounced for agricultural products and only marginal for the other cost groups. The input costs will be fully examined in Table 34, Table 35 and Table 37. As expected, regions from Paraná once more show larger fixed costs than regions from Mato Grosso when taking the prices of land into account.

TABLE 32: SUMMARIZED PRODUCTION COSTS FOR GM WINTER MAIZE, PER REGION (R$/HA)

INPUT COSTS:	SORRISO		RONDONÓPOLIS		CASCAVEL		LONDRINA	
1. AGRICULTURAL PRODUCTS (R$)	565.96	43%	500.96	45%	826.16	45%	735.57	46%
2. AGRICULTURAL PROCESSES (R$)	157.12	12%	137.82	12%	239.37	13%	246.44	15%
3. OTHER COSTS (R$)	346.47	26%	240.61	22%	297.81	16%	241.26	15%
4. FIXED COSTS (R$)	253.27	19%	225.67	20%	465.30	25%	375.02	23%
TOTAL COSTS (R$)	1,322.82		1,105.06		1,828.64		1,598.29	

TABLE 33: SUMMARIZED PRODUCTION COSTS FOR NGM WINTER MAIZE, PER REGION (R$/HA)

INPUT COSTS:	SORRISO		RONDONÓPOLIS		CASCAVEL		LONDRINA	
1. AGRICULTURAL PRODUCTS (R$)	524.60	41%	506.88	45%	740.02	42%	707.01	44%
2. AGRICULTURAL PROCESSES (R$)	160.92	13%	145.03	13%	272.46	15%	262.61	16%
3. OTHER COSTS (R$)	341.93	27%	242.62	22%	291.20	16%	240.01	15%
4. FIXED COSTS (R$)	255.59	20%	228.77	20%	465.30	26%	390.21	24%
TOTAL COSTS (R$)	1,283.04		1,123.29		1,768.98		1,599.84	

TABLE 36: SUMMARIZED PRODUCTION COSTS FOR SUMMER MAIZE, PER REGION (R$/HA)

	GM				NGM			
INPUT COSTS:	**CASCAVEL**		**LONDRINA**		**CASCAVEL**		**LONDRINA**	
1. AGRICULTURAL PRODUCT (R$)	1,111.27	42%	1,040.95	46%	1,029.23	40%	1,033.06	45%
2. AGRICULTURAL PROCESSES (R$)	284.67	11%	326.28	14%	305.41	12%	332.49	15%
3. OTHER COSTS (R$)	440.00	17%	380.42	17%	435.43	17%	380.49	17%
4. FIXED COSTS (R$)	806.15	31%	536.89	24%	825.80	32%	544.49	24%
TOTAL COSTS (R$)	2,642.09		2,284.54		2,595.87		2,290.52	

AGRICULTURAL PRODUCTS

The green highlighted areas below show that GM seed prices per hectare are significantly higher than NGM seed prices. In case of Sorriso a R$ 70.00 difference, for the other regions over R$ 100 per hectare. This is not limited to winter maize, the GM summer maize varieties in Cascavel and Londrina are also R$ 100 more expensive than NGM varieties.

TABLE 34: AGRICULTURAL PRODUCT COSTS FOR GM WINTER MAIZE, PER REGION (R$/HA)

INPUT COSTS:	**SORRISO**	**RONDONÓPOLIS**	**CASCAVEL**	**LONDRINA**
- SEEDS (R$)	**220.00**	**250.00**	**368.18**	**392.56**
MAIZE SEEDS (R$)	220.00	250.00	368.18	392.56
- FERTILIZERS (R$)	**267.44**	**152.36**	**317.81**	**247.72**
SOIL CORRECTORS/SEED TREATMENT (R$)	26.78	42.36	56.90	38.42
MACRONUTRIENTS (R$)	240.66	110.00	260.91	209.30
- APPLICATIONS (R$)	**78.52**	**98.60**	**140.17**	**95.29**
FUNGICIDES (R$)	12.00	28.80	42.15	31.82
HERBICIDES (R$)	40.60	67.70	60.45	47.31
INSECTICIDES (R$)	17.92	0.00	32.93	12.40
ADJUVANTS (R$)	8.00	2.10	4.65	3.76
TOTAL AGRICULTURAL PRODUCT COSTS (R$)	**565.96**	**500.96**	**826.16**	**735.57**

TABLE 35: AGRICULTURAL PRODUCT COSTS FOR NGM WINTER MAIZE, PER REGION (R$/HA)

INPUT COSTS:	**SORRISO**	**RONDONÓPOLIS**	**CASCAVEL**	**LONDRINA**
- SEEDS (R$)	**150.00**	**150.00**	**256.61**	**289.26**
MAIZE SEEDS (R$)	150.00	150.00	256.61	289.26
- FERTILIZERS (R$)	**287.64**	**152.36**	**317.81**	**247.72**
SOIL CORRECTORS/SEED TREATMENT (R$)	46.98	42.36	56.90	38.42
MACRONUTRIENTS (R$)	240.66	110.00	260.91	209.30
- APPLICATIONS (R$)	**86.96**	**204.52**	**165.60**	**170.04**
FUNGICIDES (R$)	0.00	28.80	42.15	31.82
HERBICIDES (R$)	40.60	67.70	60.45	47.31
INSECTICIDES (R$)	40.96	105.92	58.35	87.15
ADJUVANTS (R$)	5.40	2.10	4.65	3.76
TOTAL AGRICULTURAL PRODUCT COSTS (R$)	**524.60**	**506.88**	**740.02**	**707.01**

TABLE 37: AGRICULTURAL PRODUCT COSTS FOR SUMMER MAIZE. PER REGION (R$/HA)

	GM		NGM	
INPUT COSTS:	**CASCAVEL**	**LONDRINA**	**CASCAVEL**	**LONDRINA**
- SEEDS (R$)	**433.88**	**392.56**	**309.92**	**309.92**
MAIZE SEEDS (R$)	433.88	392.56	309.92	309.92
- FERTILIZERS (R$)	**581.96**	**524.17**	**581.96**	**524.17**
SOIL CORRECTORS/SEED TREATMENT (R$)	63.22	37.19	63.22	37.19
MACRONUTRIENTS (R$)	518.74	486.98	518.74	486.98
- APPLICATIONS (R$)	**95.42**	**124.21**	**137.35**	**198.97**
FUNGICIDES (R$)	0.00	31.82	0.00	31.82
HERBICIDES (R$)	86.50	76.24	86.50	76.24
INSECTICIDES (R$)	8.93	12.40	50.85	87.15
ADJUVANTS (R$)	0.00	3.76	0.00	3.76
TOTAL AGRICULTURAL PRODUCT COSTS (R$)	**1,111.27**	**1,040.95**	**1,029.23**	**1,033.06**

Insect resistant maize varieties need less insecticide spraying, which is visible in lower expenses on insecticide. For winter maize in Sorriso and Cascavel this difference is minimal at respectively R$ 23.06 and R$ 25.43 per hectare but for Rondonópolis and Londrina this difference is more pronounced at R$ 105.92 and R$ 74.75. For summer maize the difference between GM and NGM in Cascavel and Londrina is R$ 41.92 and R$ 74.75 per hectare respectively. Based on only the differences between decreased costs of insecticide and increased costs of seeds, GM varieties seem profitable only for the region of Rondonópolis. This could be related to pests that require additional insecticides besides BT-toxins, causing GM producers to spray other insecticides as well.

In the soybean comparison of macronutrient costs per hectare between Mato Grosso and Paraná, the difference between Center-west and South-east was clearly visible. This does not seem to be the case for maize. Sorriso macronutrient costs for example are on the same level as Cascavel and Londrina macronutrient costs and Rondonópolis is even below that. This may be related to the fact that soybean is shown as the first harvest and corn as the second. Soil preparations have already been done and maize is planted as fast as possible.

As with soybeans, no price premiums were taken into account.

5.5 Soybean Overview

In the following two tables (Table 38 & Table 39), the proposed direct and indirect advantages and disadvantages from paragraph 3.7 are given again for soybeans, and whether or not they are supported by the results from the financial analysis.

Table 38: Validity of Direct Advantages and Disadvantages of GM HT Soybeans

Management practice	Advantage/ Disadvantage	Production/ Profit	Costs	Result
Preparation				
Seedbed preparation	Reduced tillage		Decrease	Unsupported
Variety selection	High quality seeds	Higher yield		Unsupported
	More expensive seeds		Increase	Supported
Cultivation				
Weed control	Less herbicide		Decrease	Unsupported
	Cheaper herbicide		Decrease	Supported
	Fewer spraying trips		Decrease	Unsupported
	More secure		Decrease	Not visible
	Less weed competition	Higher yield		Unsupported
Harvesting				
Harvesting	Higher quality output	Increased sales		Unsupported

Table 39: Validity Indirect Advantages and Disadvantages of GM HT Soybeans

Advantage/ Disadvantage	Production/ Profit	Costs	Results
Simplifies double harvests	Increase		Unsupported
Increased upstream dependence		Increase	Not visible
Reduced machinery and fuel cost		Decrease	Unsupported
Increased management flexibility and availability	Increase		Not visible

Seedbed Preparation

No support was found for a decrease in costs related to an easier adoption of double harvests or easier adoption of reduced tillage. Reduced or no tillage decreases costs, but the financial analyses do not indicate that producers of GM varieties have significant lower costs than producers of NGM varieties in this aspect. Whether or not double harvests are simplified for producers that cultivate GM over producers that cultivate NGM, is not proven based on the financial analyses. Profit is not increased for GM producers, nor are their costs decreased for seedbed preparation of maize. According to producers of NGM beans, the most important prerequisites for second harvests are varieties that can grow and produce faster than regular crops (Rodrigues, 2013). For example, a soy variety that can be harvested in February, is followed by a maize variety that needs only five to six months to grow, so it can be harvested before the dry season starts. These characteristics can be found in GM or NGM crops, so the advantage of GM crops that it simplifies double harvests is seen as unsupported.

Variety Selection

The higher yields for GM soybeans based on the proposed higher quality of the seeds were not proven. The yields are the same across GM and NGM, suggesting that the differences are not significant enough for CEPEA and IMEA to mention. The quality of seeds differs for every producer but it seems that GM and NGM seeds only vary in the trait for herbicide tolerance, all other aspects are just as likely to be found in either variety. The price of GM seeds is proven to be higher than the price of conventional seeds. In the data from this research, the difference varies between R$ 25.62 and R$ 32.13 per hectare. The dependence of GM soybean producers on multinationals that sell seeds is difficult to measure with just the financial data. No comparison is present that takes the practice of saving seeds into account, for example, or the pressure on producers to choose GM or not. Therefore this aspect is noted as not visible.

Weed Control

The price difference for seeds is roughly compensated by the visible cost decrease of herbicides for GM crops. The cost decrease for herbicides is however based on the type and price of the herbicide: amount of spraying trips, machinery and fuel costs are not significantly different between GM and NGM. This indicates that indeed a different and/or cheaper herbicide is used. Should GM HT soybeans require less trips because of their resistance to glyphosate, results show that this is not the case in reality. The lack of difference between spending on machinery and fuel, indicate that producers have, on average, an equal amount of spraying trips. This could be related to the fact that glyphosate containing herbicides are cheap or that they are not harmful to the crops, encouraging producers to spray more than might be necessary. A higher yield as a result of lowered weed competition related to HT soybeans was not supported based on the analyses made. Both GM and NGM have the same yield, indicating that different types of weed control can be equally effective.

Additionally, no cost/benefit data exists on the management flexibility and availability related to the use of GM HT soybeans. During discussions with producers of both GM an NGM, this aspect was a recurring benefit for the GM producers. The spraying window of HT soybeans is larger, the sprayings are standardized and the herbicides are seen as less harmful to their employers. This makes the use of glyphosate containing herbicides easier than regular herbicides which some producers consider a deciding benefit in favor of GM. They can spend less time on defining the ideal moment for spraying and they feel more secure about their ability to handle sudden weed outbreaks (Molan, 2013). This does not show in a visible cost decrease for labor, however, because some producers consider it an important benefit, this indirect advantage is not shown as unsupported, but as not visible.

Harvesting

Differences in harvest quality were also found to be insignificant; soybean traders do not differentiate between GM and NGM, rather they look at the overall quality of the beans. They only provide premiums for certified NGM soybeans, a niche market. The rest of the beans are judged by the same criteria and GM soybeans do not seem to stand out. Important characteristics such as protein content, oil content, etc. are different across all varieties and whether or not one is GM or NGM makes no difference.

5.6 Maize Overview

For maize the same tables of proposed direct and indirect advantages and disadvantages from paragraph 3.7 are given (Table 40 & Table 41), and whether or not they are supported by the results from the financial analysis.

Table 40: Validity Direct Advantages and Disadvantages of GM IR Maize

Management practice	Advantage/ Disadvantage	Production/ Profit	Costs	Result
Preparation				
Variety selection	High quality seeds	Higher yield		Unsupported
	More expensive seeds		Increase	Supported
Cultivation				
Insect control	Less insecticide used		Decrease	Supported
	Fewer spraying trips		Decrease	Unsupported
	Standard protection		Decrease	Unsupported
	Less growth setback	Higher yield		Unsupported
Harvesting				
Harvesting	Higher quality output	Increase sales		Unsupported

Table 41: Validity Indirect Advantages and Disadvantages of GM IR Maize

Advantage/ Disadvantage	Production/ Profit	Costs	Results
Simplifies double harvests	Increase		Unsupported
Increased upstream dependence		Increase	Not visible
Reduced machinery and fuel cost		Decrease	Unsupported
Increased management flexibility and availability	Increase		Not visible

Seedbed Preparation

The results found for maize are almost identical to the results found for soybeans. As winter maize is the second crop, differences in costs between GM and NGM should've been visible. But no significant cost decreases or increases are present, indicating again that the characteristics required for two annual harvests are not related to GM. Therefore the statement that GM IR maize simplifies double harvests is shown as unsupported.

Variety Selection

Again, comparable to soybeans, the higher yields for GM maize based on the proposed higher quality of the seeds were not proven. The only true difference between GM and NGM is the trait for insect resistance, other characteristics can be found across both types of maize seeds, depending on the producers. The price however, was shown to be higher for GM maize seeds, namely between R$ 70.00 and R$ 123.96 per hectare. Dependence on and market power of seed suppliers is difficult to describe with just financial data. Due to the hybrid nature of maize seed, producers have to buy seeds annually, regardless of the seeds being GM or NGM. Nevertheless, the influence of seed producers on farmers cannot be measured, so this statement is considered to be not visible.

Insect Control

Yields across GM and NGM maize are equal, suggesting no increased yields related to decreased growth setback. Prices for IR maize seeds are high because they provide producers with an alternative to costly insecticides; the plant produces them on its own. The results indeed show a decrease in costs for insecticides compared to NGM crops, but in most cases GM producers still have costs for insecticides. This indicates they still need to control their crops and apply insecticide. The costs for agricultural processes also do not decrease significantly for GM maize, so even though the BT-corn decreases the amount of insecticide required, it does not obsolete the use, nor does it markedly decrease spraying trips. Therefore the statement that GM maize decreases insecticide use is supported, but that it decreases spraying trips is not. Arguable is the statement that crops are standardly protected; the fact that producers have to buy occasional insecticides suggests that they have to react to pests that are immune to the crystals from the BT-plants. However, producers indicate that having the BT corn decreases the time involved with checking for pests, finding suitable pesticides and that it decreases exposure of insecticides to employees. Therefore, the standard protection was considered to be unsupported, but the increased management flexibility is noted as not visible.

Harvesting

Equal to soybeans, traders do not distinguish between GM and NGM, but instead focus on the overall quality. Therefore no price differences are offered unless the corn is truly 100% NGM.

6. Conclusion & Discussion

6.1 Conclusion

The use of a financial analysis to compare production processes and profitability of transgenic and conventional varieties was the second objective. In this chapter the overall conclusions will be given, followed by a discussion of limitations and possible follow-ups on this research.

6.1.1 Agricultural Developments

The first objective of this research was to describe the adoption of transgenic soybeans and maize in Brazil, with an in-depth account of agricultural processes for both GM and NGM varieties. After the approval of GM crops in 1996 in the United States and Argentina, Brazil initially lagged in legislature that allowed biotech crops in Brazil, but governmental policy changed in 2003. Brazilian soy and maize producers made up the lost time and by 2010, over 25 million hectares of GM crops were grown in Brazil, which is 17% of the worldwide (150 million) total. This number will likely grow over the coming years, indicating producers see benefits in biotech seeds. The majority of GM crops in Brazil are herbicide tolerant soy, with 75% of total soy grown in 2010 being GM, and insect resistant maize, with an adoption rate of 56% in 2010. Herbicide tolerant soy allows producers to spray with a single, cheaper, type of herbicide at regular intervals. Insect resistant maize makes many insecticides obsolete as the plant produces its own, which decreases costs for insecticide. Both GM soy and GM maize seeds are however more expensive than their conventional counterparts.

Brazilian agriculture is characterized by an additional winter harvest, or safrinha. The first season is from approximately August to February and the second from as early as December to May. This practice of double harvests is made possible by the fact that many producers do not till their lands and have developed faster growing varieties for the, shorter, second season. Another important characteristic of Brazilian agriculture is the contrast between the more fertile and technologically developed south-east regions and the large stretches of tropical savannah called *Cerrados* in the Center-west.

The agricultural procedure is split into preparation, cultivation and harvesting. These are further divided and described in the following sections (for preparation): Seedbed preparation, Variety selection, Planting rate, Planting depth and Row width. Cultivation is divided into: Pest management, Insect management, Weed control, Disease management and Fertilization. Harvesting was not divided. All sections of agriculture are described with emphasis on differences between GM and NGM varieties and are used in the analysis part of the research.

6.1.2 Financial Analysis

Soybeans

The only real measurable differences between transgenic soy and conventional soy are the price of seeds and the use of a glyphosate containing herbicides. The GM seeds cost significantly more and consequently a much lower price can be paid for herbicides, as glyphosate is relatively cheap. NGM producers spend less on seeds, but more on herbicides. In the Center-west, this difference is hardly visible in profitability, as NGM soy displays only a small increase in profitability. This shows that, for just the financial aspects of producers, GM and NGM are alternatives for each other that do not give either of them a significant advantage, unlike GM seed producers often claim. In the South-east, the difference between profit margins is more pronounced in favor of GM crops; results show that they are more profitable than NGM soy. The difference may be attributed to the fact that both regions differ in technological advancement, land structure and infrastructure. Cost in the South-east are larger and agricultural product costs, such as herbicides, are a smaller part of the total because of higher fixed costs. Price differences between glyphosate containing herbicides and more conventional herbicides may be more pronounced in the South-east than they are in the Center-west. Additionally, farms operate at smaller scale and tend to work more efficient, thus keeping variable costs, such as the application of herbicides as low as possible. Weed control with GM soybeans is more straightforward and can be done at any time weeds are found, but conventional weed control may incorporate more preventive spraying, leading to higher costs. The GM producers that were approached during the course of this study however, stated that the indirect benefits were a deciding factor for them. Ease of use, spraying window flexibility and good results of glyphosate herbicides provide them with more assurance that risks are minimized, even though this may not be proven to lead to lower costs/higher profits.

Maize

GM maize is produced differently from NGM maize in only one aspect, the amount of insecticide required. NGM producers have to keep an eye on their fields and spray as soon as pests are spotted above an acceptable concentration, whereas GM producers can rely on their BT-corn dealing with the majority of pests on its own. Whether exposure induced or indigenous resistance to BT-crystals is present in insects is not known, but to some extent BT-maize needs insecticides against pests as well. The prices of GM seed reflects the decreased insecticide us; they are significantly higher than the prices of conventional seed. And in return, expenditures on insecticides are lower for GM producers than for NGM producers. When the profit margins are compared however, the NGM corn seems to be more profitable per sack than the GM corn. Because of the low profit margins (in some regions producers made losses on winter maize) the differences between GM and NGM profit margins are relatively large in favor of NGM, but this time larger for the South-east than for the Center-west regions. A possible reason for this difference might be the presence of a pest that was resistant to Bt-crystals, or the possible presence of such a pest, leading farmers to spray in advance. For summer maize the variance between profit margins is hardly significant. This leads to the same conclusion made with soybeans, namely that the difference between GM and NGM maize, based on the financial data of producers, is as such that they are alternatives for each other. Indirect benefits however, such as increased management flexibility or security cannot, with this analysis, be expressed in increased profit or decreased losses. Even though this increased sense of confidence is a reason for producers to choose transgenic crops.

6.2 Discussion

Limitations

Some of the limitation found in doing this research are given below:

- Financial analysis can only describe the direct effects on the producers involved, it is much harder to take long-term effects into account, or effects that are not directly described in money. Environmental issues are the most heard arguments in debate regarding GMO´s, yet they are not in the limelight of this study. Mainly because this research tries to take the perspective of the farmer, who may not be overly concerned with regulations, as long as they are approved. Long term effects of GMO's are not only important for the well-being of people that work with them, they are also vital to the environment as a whole. Costs arising from potential long term adverse or beneficial effects of GMO's were not taken into account.
- Not all cited material is from impartial sources, meaning some information will be preconceived; benefits for GM crops might therefore be exaggerated by some and understated by others. Most benefits for GM crops are given by proponents that focus on increased yield, quality and profits for biotech crops, generally institutions funded by large players in the agricultural biotech. Several works cited in this research were produced for the ISAAA (James, 2010) or PG Economics (Brookes & Barfoot, 2012) who are funded by, among others, Monsanto, the largest multinational in agricultural biotechnology (Melton, 2013) (ISAAA, 2013). Opponents of biotech crops, whether out of principle against the technique or the execution of genetic modification, largely emphasize adverse long term effects on the environment and excessive market power of large biotech corporations. This study looks at the situation for farmers from a financial perspective, which does not deal with the environment as much, but tends to focus on financial aspects such as yield, quality and profits. Therefore the information in the first part of the research was taken largely from proponents of agricultural biotechnology, promising better results with GMO's.
- By choosing different regions in different states that show both opposites of Brazilian agriculture, an attempt was done to give the best results for Brazil as a whole. This inevitably leads to lower focus on the separate regions.
- Because of the limited time and budget, only one harvest year is described, which means the results are seen from an isolated perspective. Agriculture is dependent on many variables that can or cannot be foreseen and a study of just one harvest cannot be generalized over several years. Different climate conditions, different market conditions, different cost prices, etc. can make one year totally different from the next. For example, if this research had been done two years after the introduction of GM crops in 2002, different conclusions would have been found. Mainly because following growing interest for HT soybeans, the market for conventional herbicides decreased and consequently prices dropped.
- Another limitation is the triangulation of data. All data was taken from regional and national statistics bureaus, no actual producers gave their figures. This is difficult, not only due to the language barrier, but also because producers are not very open to given their financial information and because they don´t specify their expenditures. Therefore the only usable

information was from CEPEA and IMEA, who average many values. Besides that, finding the origin of their data is near to impossible, which makes fact checking difficult.

Based on these limitations, the data presented in this study can show some inaccuracies compared to the real situation. The conclusions are still relevant.

Future research

Follow-ups of this research could be centered on the limitations of this study. Long term costs of the use of GM crops are hard to find but important. Whether these are agricultural issues that deal with the cost related to the increase of herbicide resistant weeds, or environmental issues that arise from crossover of GM traits into other species, long term effects and accompanying costs are important in the debate on biotechnology in agriculture.

Another direction for follow up can be found in the widening of research data. An option would be to research more data from different regions and conclude based on similarity of growing conditions. This would lead to conclusions filtered on comparable situations and not just the two regions in this study. Another option regarding increase of data is doing a case study with several comparable producers. This would increase the knowledge on motivations for a specific course of action, give a more specific cost picture and would increase error detection and correction. Additionally, a study on profitability over time could give important insights for farmers. Such studies might show how new developments affect cost prices and could provide producers with an idea of what they can expect when new innovations enter the market.

Alternatively, a survey among producers might give insights on motivations for choosing GM or NGM and could help chart the advantages and disadvantages that producers experience.

Recommendations

For farmers in Brazil it will be difficult to recommend a certain course of action. The differences between GM and NGM are small, meaning not a clear ‘winner’ is present. The best method will probably revolve around finding what is best for every particular situation, taking infrastructure and local accommodations into account. For instance, when local seed suppliers provide low cost conventional seeds and glyphosate containing herbicides are expensive, a GM variety that shows excellent growing potential might not give best profits compared to a good growing conventional variety.

Considering European agriculture, the Brazilian situation may not be very applicable, yet some elements might be useful. The European Union’s attitude towards genetic modification is going to be increasingly difficult to maintain, especially as more and more interesting developments occur in agricultural biotechnology. This study, to some extent, shows that GM are not always beneficial from a financial perspective. However, the one case in which GM crops showed strong profit increases compared to NGM, was in a situation most comparable to European agriculture. A highly technologically advanced agricultural region, with good infrastructure and extensive use of available land can benefit from efficient use of resources. As with herbicide tolerant soybeans in Paraná, efficiency can be increased by having a powerful herbicide such as glyphosate available, leading to lowered costs and possibly increased food security. Besides the possible benefits of GM crop traits, the market for GM seeds is steadily increasing across the world. This is a large potential industry for seed developers in the Netherlands and Europe as a whole. Even though few current benefits of GM crops are supported in this study, the majority of producers still use them and will probably do so in the future, indicating that the demand is only growing. It would be a waste not to explore this market when the European Union has the facilities to do so.

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Appendix

Appendices A to D were summarized using statistics from CONAB (CONAB, 2012a).

Appendix B: Total Soybean Area, Yield and Production in Brazil Since 1976/77 Harvest

Year	Area (1000 ha)	Yield (kg/ha)	Production (1000 tons)
1977	6.949,00	1.748	12.145,00
1978	7.780,00	1.250	9.726,00
1979	8.151,00	1.251	10.200,00
1980	8.755,90	1.700	14.887,40
1981	8.693,40	1.781	15.484,80
1982	8.393,20	1.536	12.890,90
1983	8.412,00	1.728	14.532,90
1984	9.162,90	1.674	15.340,50
1985	10.074,00	1.808	18.211,50
1986	9.644,40	1.369	13.207,50
1987	9.221,70	1.851	17.071,50
1988	10.706,60	1.693	18.127,00
1989	12.252,80	1.953	23.929,20
1990	11.551,40	1.740	20.101,30
1991	9.742,50	1.580	15.394,50
1992	9.582,20	2.027	19.418,60
1993	10.717,00	2.150	23.042,10
1994	11.501,70	2.179	25.059,20
1995	11.678,70	2.221	25.934,10
1996	10.663,20	2.175	23.189,70
1997	11.381,30	2.299	26.160,00
1998	13.157,90	2.384	31.369,90
1999	12.995,20	2.367	30.765,00
2000	13.622,90	2.414	32.890,00
2001	13.969,80	2.751	38.431,80
2002	16.386,20	2.577	42.230,00
2003	18.474,80	2.816	52.017,50
2004	21.375,80	2.329	49.792,70
2005	23.301,10	2.245	52.304,60
2006	22.749,40	2.419	55.027,10
2007	20.686,80	2.823	58.391,80
2008	21.313,10	2.816	60.017,70
2009	21.743,10	2.629	57.165,50
2010	23.467,90	2.927	68.688,20

Appendix B: Total Maize Area, Yield and Production in Brazil Since 1976/77 Harvest

Year	Area (1000 ha)	Yield (kg/ha)	Production (1000 tons)
1977	11.797,34	1.632	19.255,73
1978	10.985,06	1.276	14.017,06
1979	11.304,81	1.461	16.513,83
1980	11.669,88	1.665	19.435,32
1981	12.147,14	1.752	21.283,81
1982	12.771,05	1.692	21.604,81
1983	11.658,19	1.631	19.014,96
1984	12.205,63	1.735	21.178,20
1985	11.940,16	1.773	21.174,70
1986	13.083,45	1.549	20.264,77
1987	14.610,35	1.832	26.758,96
1988	13.411,10	1.881	25.224,27
1989	12.974,24	2.025	26.267,59
1990	12.092,70	1.841	22.257,83
1991	13.451,40	1.791	24.096,10
1992	14.027,10	2.194	30.771,20
1993	12.436,30	2.349	29.207,70
1994	14.151,70	2.344	33.173,70
1995	14.282,20	2.622	37.441,90
1996	13.756,70	2.356	32.404,70
1997	13.798,80	2.588	35.715,60
1998	11.391,10	2.650	30.187,80
1999	12.513,00	2.589	32.393,40
2000	12.757,90	2.480	31.640,50
2001	12.972,50	3.260	42.289,70
2002	12.297,80	2.868	35.266,80
2003	13.226,20	3.585	47.410,90
2004	12.783,00	3.291	42.128,50
2005	12.208,20	2.867	35.006,70
2006	12.963,90	3.279	42.514,90
2007	14.054,90	3.655	51.369,90
2008	14.765,70	3.972	58.652,30
2009	14.171,80	3.599	51.003,80
2010	12.993,90	4.311	56.018,10

Appendix C: Production Prices of NGM and GM Soy in Paraná and Mato Grosso

NGM				GM			
Londrina - PR				Londrina - PR			
YEAR	YIELD	COST/HA	COST/KG	YEAR	YIELD	COST/HA	COST/KG
2002/03	3.000	846,54	0,282	2002/03	-	-	0,000
2003/04	3.000	1.139,04	0,380	2003/04	-	-	0,000
2004/05	3.000	1.238,21	0,413	2004/05	-	-	0,000
2005/06	3.000	1.307,84	0,436	2005/06	-	-	0,000
2006/07	3.000	1.319,66	0,440	2006/07	-	-	0,000
2007/08	3.000	1.269,86	0,423	2007/08	2.800	1.415,71	0,506
2008/09	2.800	1.645,24	0,588	2008/09	2.800	1.616,86	0,577
2009/10	2.800	1.882,99	0,672	2009/10	2.900	1.743,00	0,601
2010/11	2.800	1.556,50	0,556	2010/11	2.900	1.612,67	0,556

NGM				GM			
Primavera do Leste - MT				Sorriso - MT			
YEAR	YIELD	COST/HA	COST/KG	YEAR	YIELD	COST/HA	COST/KG
2002/03	3.000	837,51	0,279	2002/03	-	-	0,000
2003/04	3.000	1.143,60	0,381	2003/04	-	-	0,000
2004/05	3.000	1.293,91	0,431	2004/05	-	-	0,000
2005/06	3.000	1.457,72	0,486	2005/06	-	-	0,000
2006/07	3.000	1.316,81	0,439	2006/07	-	-	0,000
2007/08	3.000	1.405,06	0,468	2007/08	3.000	1.181,28	0,394
2008/09	3.000	1.885,09	0,628	2008/09	3.000	1.858,44	0,619
2009/10	3.000	1.847,01	0,616	2009/10	3.000	1.792,49	0,597
2010/11	3.000	1.611,41	0,537	2010/11	3.000	1.590,34	0,530

Appendix D: Production Prices of Summer and Winter Maize in Paraná and Mato Grosso

Summer				**Winter**			
Londrina - PR				Campo Mourão - PR			
year	yield	cost/ha	cost/kg	year	yield	cost/ha	cost/kg
1998/99	6.000	838,87	0,140	1998/99	-	-	0,000
1999/00	6.000	970,48	0,162	1999/00	-	-	0,000
2000/01	6.000	987,13	0,165	2000/01	-	-	0,000
2001/02	6.000	1.102,65	0,184	2001/02	-	-	0,000
2002/03	6.000	1.248,73	0,208	2002/03	-	-	0,000
2003/04	6.000	1.674,69	0,279	2003/04	-	-	0,000
2004/05	6.000	1.941,66	0,324	2004/05	3.000	892,73	0,298
2005/06	6.000	2.004,00	0,334	2005/06	3.000	869,41	0,290
2006/07	6.000	1.810,23	0,302	2006/07	3.000	931,71	0,311
2007/08	6.000	1.921,64	0,320	2007/08	3.000	1.144,33	0,381
2008/09	6.750	2.321,43	0,344	2008/09	3.000	944,06	0,315
2009/10	6.750	2.397,38	0,355	2009/10	3.000	980,30	0,327

Summer				**Winter**			
Primavera do Leste - MT				Primavera do Leste - MT			
year	yield	cost/ha	cost/kg	year	yield	cost/ha	cost/kg
1998/99	6.000	729,88	0,122	1998/99	-	-	0,000
1999/00	6.000	866,03	0,144	1999/00	-	-	0,000
2000/01	6.000	888,34	0,148	2000/01	-	-	0,000
2001/02	6.000	884,46	0,147	2001/02	-	-	0,000
2002/03	6.000	1.072,24	0,179	2002/03	-	-	0,000
2003/04	6.000	1.499,98	0,250	2003/04	-	-	0,000
2004/05	6.000	1.709,10	0,285	2004/05	3.900	1.053,78	0,270
2005/06	6.000	1.862,96	0,310	2005/06	3.900	1.092,72	0,280
2006/07	6.000	1.604,93	0,267	2006/07	3.900	1.106,52	0,284
2007/08	6.000	1.764,18	0,294	2007/08	3.900	1.161,72	0,298
2008/09	6.000	2.022,90	0,337	2008/09	3.900	1.379,42	0,354
2009/10	6.000	2.207,04	0,368	2009/10	3.900	1.360,10	0,349

APPENDIX E: SELLING PRICES OF SOYBEANS IN MATO GROSSO **(IMEA, 2011)**

SOY PRICES 2010/2011 HARVEST			**SOY PRICES 2010/2011 HARVEST**		
	CAMPO VERDE	CARANARA		DIAMANTINO	SORRISO
DATE	PRICE (R$)	PRICE (R$)	DATE	PRICE (R$)	PRICE (R$)
30-3	R$ 39.50	R$ 38.00	30-3	R$ 38.00	R$ 37.30
29-3	R$ 39.80	R$ 38.50	29-3	R$ 38.60	R$ 37.80
28-3	R$ 39.00	R$ 38.20	28-3	R$ 38.00	R$ 36.80
25-3	R$ 40.00	R$ 38.70	25-3	R$ 38.80	R$ 37.50
24-3	R$ 40.00	R$ 38.70	24-3	R$ 38.50	R$ 37.00
23-3	R$ 40.00	R$ 38.70	23-3	R$ 38.50	R$ 37.00
22-3	R$ 40.30	R$ 39.00	22-3	R$ 38.90	R$ 37.00
21-3	R$ 40.10	R$ 39.00	21-3	R$ 38.00	R$ 37.00
18-3	R$ 40.00	R$ 39.00	18-3	R$ 38.00	R$ 37.00
17-3	R$ 39.50	R$ 38.20	17-3	R$ 38.20	R$ 36.50
16-3	R$ 38.00	R$ 37.00	16-3	R$ 36.50	R$ 35.60
15-3	R$ 37.10	R$ 36.00	15-3	R$ 35.90	R$ 34.60
14-3	R$ 39.20	R$ 38.00	14-3	R$ 38.00	R$ 36.80
11-3	R$ 39.00	R$ 37.80	11-3	R$ 37.50	R$ 36.50
10-3	R$ 39.50	R$ 38.00	10-3	R$ 38.50	R$ 37.00
9-3	R$ 39.50	R$ 37.80	9-3	R$ 38.30	R$ 36.50
4-3	R$ 40.50	R$ 38.90	4-3	R$ 39.80	R$ 38.30
3-3	R$ 40.50	R$ 38.90	3-3	R$ 39.80	R$ 38.30
2-3	R$ 40.20	R$ 38.70	2-3	R$ 39.40	R$ 38.00
1-3	R$ 39.90	R$ 38.30	1-3	R$ 39.00	R$ 37.70
28-2	R$ 39.50	R$ 38.30	28-2	R$ 39.00	R$ 37.00
25-2	R$ 39.50	R$ 38.50	25-2	R$ 39.00	R$ 37.20
24-2	R$ 38.40	R$ 37.30	24-2	R$ 37.50	R$ 35.50
23-2	R$ 38.60	R$ 37.50	23-2	R$ 37.50	R$ 35.50
22-2	R$ 39.60	R$ 37.80	22-2	R$ 38.00	R$ 36.00
21-2	R$ 41.00	R$ 39.80	21-2	R$ 39.40	R$ 38.00
18-2	R$ 41.00	R$ 39.80	18-2	R$ 39.40	R$ 38.00
17-2	R$ 41.60	R$ 40.70	17-2	R$ 39.80	R$ 38.60
16-2	R$ 41.20	R$ 40.60	16-2	R$ 39.40	R$ 38.40
15-2	R$ 41.30	R$ 40.80	15-2	R$ 39.50	R$ 38.50
14-2	R$ 42.30	R$ 41.30	14-2	R$ 41.00	R$ 39.50
11-2	R$ 42.80	R$ 41.50	11-2	R$ 41.40	R$ 40.20
10-2	R$ 43.00	R$ 41.80	10-2	R$ 41.60	R$ 40.50
9-2	R$ 43.20	R$ 41.90	9-2	R$ 41.80	R$ 40.70
8-2	R$ 43.00	R$ 42.70	8-2	R$ 41.70	R$ 40.40
7-2	R$ 42.70	R$ 41.40	7-2	R$ 41.50	R$ 40.20
4-2	R$ 42.80	R$ 41.50	4-2	R$ 41.50	R$ 40.30
3-2	R$ 42.80	R$ 41.60	3-2	R$ 41.50	R$ 40.50
2-2	R$ 43.00	R$ 41.80	2-2	R$ 41.80	R$ 40.70
1-2	R$ 43.00	R$ 41.50	1-2	R$ 41.70	R$ 40.50
AVERAGE	R$ 40.55	R$ 39.34	AVERAGE	R$ 39.26	R$ 37.91
TOTAL AVERAGE		R$ 39.94	TOTAL AVERAGE		R$ 38.58