Simulating a Storage-Production System with Three Oilseed Crops

by

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Abstract

This work developed a simulation model that is intended to be used for strategic investment decisions by a company that operates in a wide range of activities in the agriculture business in Brazil. Mostly, it is a tool that allows the user, in this case the company management, to quantitatively assess the results of their qualitative expectations for the business environment. I found that the supply of grains is potentially a higher uncertainty factor than demand, that different configurations of crushing capacity and storage impact the results with significant difference, depending on the demand and supply scenarios even in the near future. Knowing that uncertainty is unavoidable and largely impacts the business, I measured it and found that, yield uncertainty alone can impact profits dramatically. The model developed in this paper can easily be leveraged to include more sophisticated crushing rules and up to date market data. It can also be run timely and produce tailored reports.

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Introduction and Motivation

The motivation behind this paper results from the convergence of three forces: Brazilian's Midwest agricultural strength and potential, the search for a healthier diet and willingness of a company to pursue the best growth opportunities that result from the two first forces. In this introduction, I will first introduce these three major forces. Later on, I will briefly explain how I intend to approach the problem and why I believe that this work is a valuable contribution to companies, the public sector or anyone who is willing to understand the intricate cause and effect network of the agricultural supply chain, especially in Brazil.

Three Drivers of Growth

The Power and Potential of Brazilian's Midwest Agriculture

In the next decade, Brazil's agricultural output is estimated to grow by 40%[1]. The country uses only 12% of its arable land, holds over 30% of world's fresh water reserves and has a large and well prepared group of crop scientists, mainly working in the state research company, EMBRAPA[2].

The state of Mato Grosso is the country's leading grain and cattle producer, and given the prospects of new infrastructure projects to be deployed in the region, it is estimated that more than 9 million hectares of land can still switch from cattle to grain in the next decade. One of the largest challenges to Mato Grosso's increase in production is its long distance from consumer markets, as well as a poor logistics network linking the state and these markets. A new governmental plan, the PNLT[3] is being implemented and will significantly

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[1] Ethical Technology: http://ieet.org/index.php/IEET/more/pellissier20100922

[2] Brazilian Institute of Agricultural Research

[3] National Logistics and Transportation Plan

improve the cost efficiency of the region, allowing for an increase in the planted area, at the expense of area that is nowadays used for cattle[4]. Figures 1 and 2 below show how Brazil's transportation matrix compares to other large, commodity producing countries and where the PNLT is planning to take it by 2025.

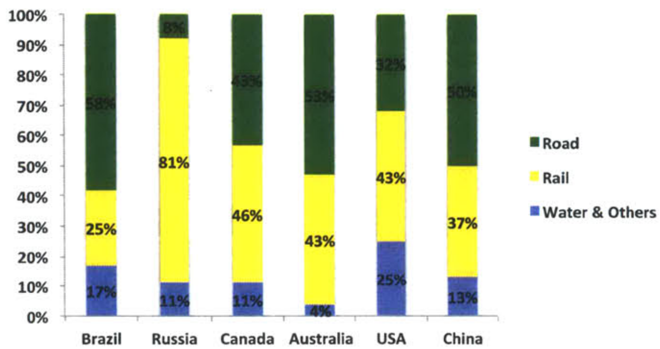

Figure 1: Transportation Mix of Large, Commodity Producing Countries

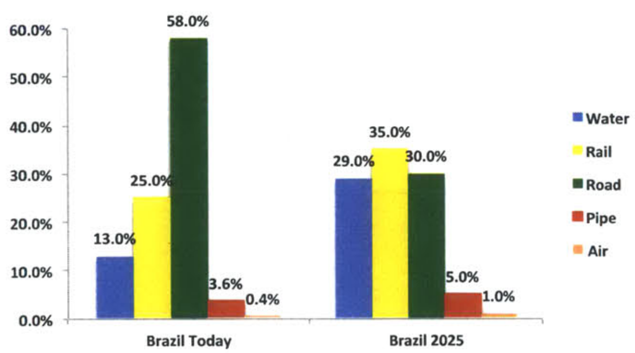

Figure 2: Brazil's Transportation Mix in 2011 and in 2025

Even within Mato Grosso, there are significant differences. As shown in figure 3, producers in Campo Novo do Parecis receive on average 8% less for their soybean grains than those in Rondonopolis, in the south of the State.

[4] With better infrastructure, areas that have historically been used for cattle usually migrate to soybeans in Mato Grosso. The cattle production does not necessarily decrease, but cattle are confined.

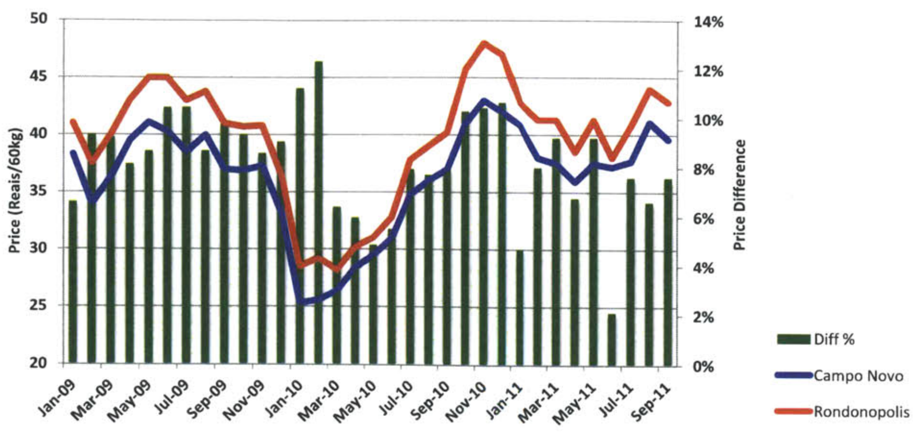

Figure 3: Price Difference in Two Regions of Mato Grosso

For a detailed map of the works that will affect MT and Campo Novo do Parecis, where the company is starting its operations in the Midwest, we added appendix 1. The reader can also refer to the PNLT for a detailed description of each project.

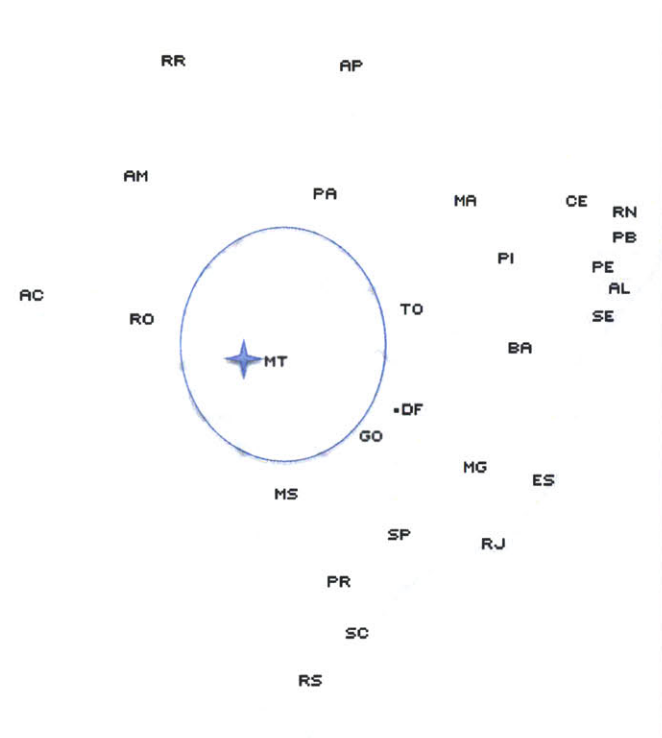

Figure 4: Map of Brazil, with Mato Grosso and Campo Novo do Parecis highlighted.

The Search for a Healthier Diet and Renewable Energy

In the last decade, the fight against cholesterol, hydrogenated and trans-fats drove up industry demand for healthier and more stable oils. Consumer awareness led food corporations to develop new fat blends for their products so that they could advertise 0% trans. Palm oil is one of the few vegetable oils that are semi-solid at room temperatures, and is highly stable when frying, thus not requiring hydrogenation. Due to its properties, its consumption increased worldwide. Other oils, such as canola, high oleic sunflower and sunflower, also started to have a place on the consumer's and industry preference list (Matthäus, 2007).

A measure from Brazilian authorities that is about to be approved[5] may provide substantial incentive for oils other than palm to benefit from even more prolonged and sustained growth. In a nutshell, the new regulation forbids companies using oils with high levels of saturated fat to advertise 0% trans-fat. This is a major challenge for the food industry, and large players are already trying to develop products that replace palm for other types of oil, such as canola and high oleic sunflower.

Another demand trend that brings a lot of upside potential to the vegetable oil business is the energy sector. Brazilian regulation requires that 5% of the diesel consumed in the country be blended with biodiesel, which is mostly made with vegetable oil.

Both trends are subject to uncertainties. It is still too early to know if biodiesel is a long term solution to the energy problem, even if partial. The healthy food industry is also

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[5] Public Consultation 21 from April, 6th 2011 (http://portal.anvisa.gov.br/wps/wcm/connect/8899508047458f68988fdc3fbc4c6735/CPN21GGALInovo.pdf?MOD=AJPERES)

always looking for new alternatives and new sources of tasty and healthy ingredients are always a threat to incumbents.

Celena Alimentos

Celena Alimentos, a family-owned company, was created in the south of Brazil, to develop the supply chain for healthy oils that previously had to be imported by major players. Since its inception, the growth has been steady, although compared to soybean, the main Brazilian crop, the volumes are still negligible. The first market the company tackled was canola, a grain that produces oil with very low saturated fat. Brazilian food companies used to import this oil from Canada and Argentina, paying high transportation and transaction costs for it. Celena partnered with cooperatives and farmers in Brazil and Paraguay, bringing the total area harvested in these two countries from less than 10,000 ha in 2000 to over 80,000 in 2011. In the last four years alone, the harvested area more than doubled. Brazilian food companies can now source an important share of their domestic demand for canola oil without clearing customs.

Celena has more recently entered the High Oleic Sunflower and Sunflower markets, where considerable growth has been achieved. The company coordinates the supply chain of oils, from developing and selling seeds to farmers to providing the final products, oil and meal as shown in figure 4 below.

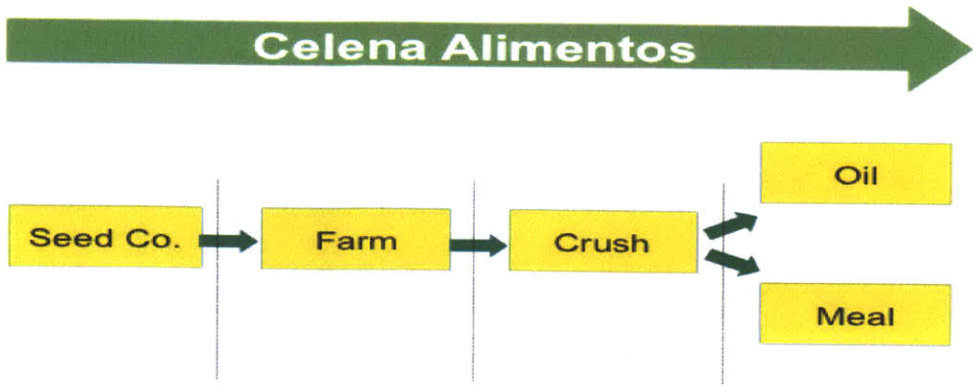

Figure 5: Celena's Range of Operations

Higher demand for healthy oils and renewable energy will potentially drive Celena's business up, and the higher volumes of Canola and other crops that the company expects to see in the future is part of the reason why the company is building a new facility in Campo Novo do Parecis, MT. The reason this region was picked is because it already is a large sunflower producer but the infrastructure of storage and transportation in the municipality and its surroundings are very limited compared to the more developed south of Brazil. This underdevelopment of infrastructure can be seen when we compare the static availability of storage as a percentage of the total amount of grains harvested. While in the Midwest of the USA, this ratio is usually around 2.5 times, it barely passes 1 in Campo Novo do Parecis[6]. The chart below illustrates the amount of storage available and the agricultural output for different distances to Campo Novo do Parecis, where Celena built its first elevators[7].

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[6] Author's estimates used radial distance from Campo Novo do Parecis.
[7] Elevator is a facility that receives and stores grains, usually arriving in trucks or trains.

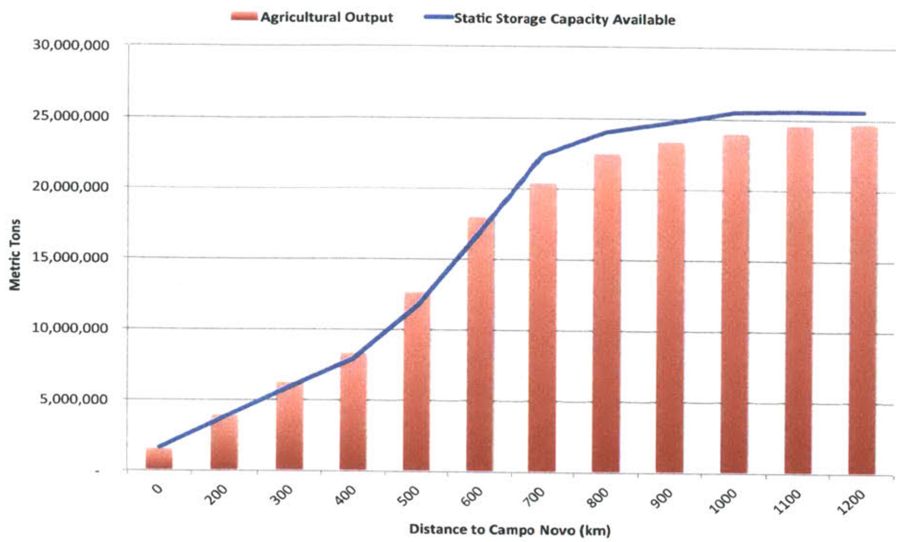

Figure 6: Agricultural Output and Static Storage Capacity within Distances from Campo Novo do Parecis, MT

Another important advantage of expanding geographically is that the Midwest and the South of Brazil follow a complementary crop calendar. Whereas winter crops are harvested in November and December in the South, they are harvested in May and June in the Midwest. This characteristic allows for the company to decrease its capital requirements, have less storage capacity and supply a better quality product year round. The figure below illustrates the calendar for Sunflower in both the South and Midwest of Brazil. Canola and High Oleic Sunflower follow the same calendar.

Sunflower – South (yellow) and MW (green)

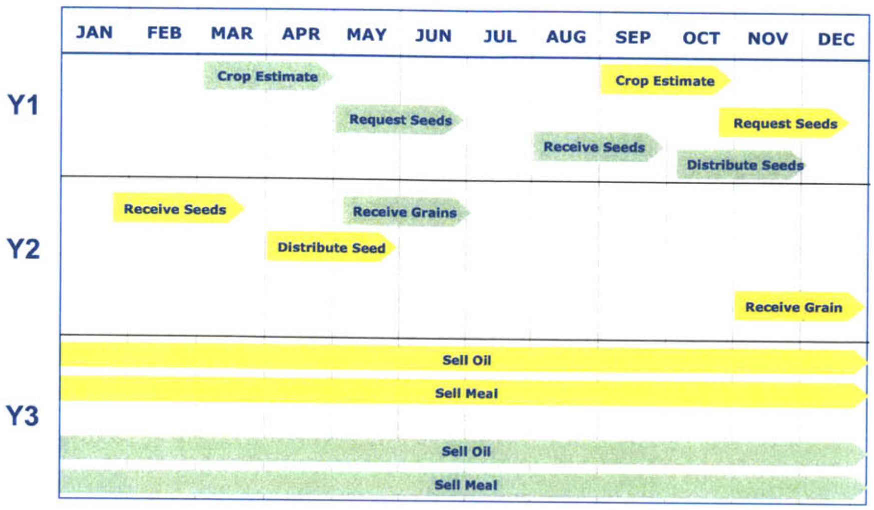

Figure 7: Sunflower Crop Cycle in the South and Midwest.

Contribution

In the company's business, as we discussed, there are many moving parts that ultimately affect the bottom line, and adding to that, there is a lot of uncertainty in the future scenarios. Logistics development and the industry adhesion to the healthy oils for example, will be a function of some variables outside of the company's power.

How should the company configure its network in order to find the best balance between profiting from growth and deploying its capital is a question management is now keen on understanding. There are three main decisions that the company needs to take.

1. How much storage to build for grains, oil and meal?
2. How much of each crop to plant through its farmers network?
3. How to schedule the crushing of grains?

While the first question relates to a setup configuration, the last two decisions are taken on every crop cycle. We can also see that, all these answers are highly dependent in the cost structure, supply and demand of the industry in the years to come. Rather than coming up with a definite answer of what to do, this work aims to develop a system that allows the company to quantify risks and benefits aligned with each decision it takes.

There are a few ways to determine optimal or close to optimal solutions in complex systems. When multiple decisions, steps and uncertainty factors are present, the best way to look for an answer is usually simulation[8].

The first contribution of this work is to allow, through the development of simple possible future scenarios, an assessment of the impacts that the future logistics network configuration in Mato Grosso, the industry adhesion to the healthy oils and the supply of those can affect future profits. This exercise of creating scenarios and analyzing the sensitivity of the overall model is fruitful for the whole industry, as well as policy makers since many of the demand and supply trends are dependent on public action.

A more detailed simulation model is company applied tool, which will allow Celena to take educated decisions according to different scenarios that may roll down. With this model, the company will be able to test different configurations of storage capacity both in-house and in some service providers, assess the costs of outsource crushing activity as opposed to owning their own plant and so on. It is important to stress that we are not willing to guess the future, but rather create a model that allows the company to:

1. Operate efficiently in the scenario that the managers believe to be the most likely.
2. Allow the company no adapt in case structural changes take place in the industry.

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[8] de Neufville, ESD.71, Fall 2012 Class Notes

Literature Review

This literature review focuses on three areas: The first, called "The Agricultural Business," provides a macro view of the agricultural industry in Brazil, using industry reports and papers that describe the agribusiness environment. This paper aims to solve a very specific problem, which is to develop a model to quantify storage and crushing capacity for Celena Alimentos in the wake of logistics and market changes in the edible oils market. A solid background in the flow of goods, the major players and the key points in the grains supply chain is essential for an understanding of the problem and the paper. Since this background information is rather descriptive of the business, the documents used in this part of the analysis take an industry oriented rather than an academic approach.

The second, titled "The Brazilian Agricultural Supply Chain and Its Challenges," discusses documents that describe the Brazilian transportation matrix, including projects that are in the federal and local government's pipelines and how they affect the agriculture supply chain. These papers will mostly help us to build scenarios for our simulation model.

The last section of the literature review, "Simulation Models" presents papers describing simulation models that were used to help build our own model. In this session, we will dedicate special attention to papers and books that tackle the use of simulation as a tool to manage uncertainty and papers that compare different methods for simulating uncertainties.

The Agricultural Business

In this section, we will present papers that describe the mechanism of the Oilseed business, from the seed to the final products, oil and meal.

The first paper in this section, from Soyatech, is a white report named "How the Global Oilseed and Grain Trade Works" (Soyatech, LLC. and HighQuest Partners, 2008)

This report is a primer on the global oilseeds business. It details the flow of seeds, grains and byproducts, specifying how the supply chain works in different nodes, how trade has historically been practiced, and what metrics are most widely used by industry participants. It follows the chronological order of the chain, starting with seed technology, and moving through grain production, processors and finally transportation and end users. It also mentions some of the risk management tools that industry participants use. It pinpoints some market specific data of the larger grain producers, such as Brazil, USA, and Argentina.

Another paper describes the agricultural supply chain (Hodges, Buzby, & Bennett, 2011), but in addition tackle the problem of post-harvest losses. The paper gathers data on losses in each part of the post-harvest distribution: Combining crops, machine threshing, mechanical drying, sealed storage and commercial milling. This information gives the reader an understanding of where the biggest cost savings can be in post-harvest distribution. In total, the authors estimate that the quantity lost from the moment that the crop is harvested to when the end product is consumed account for anywhere between 10% and 30% of the total value of the crops.

The Brazilian Agricultural Supply Chain and Its Challenges

Although understanding the macro structure of the agricultural supply chain is an important first step towards tackling the problem, our paper focuses on a specific problem faced by a specific company in a specific region. For that reason, this section concentrates on the regional economics of the agriculture complex of Brazil. The literature in this field is vast. Every time a major infra-structure project is in the pipeline, researchers attempt to understand its effects. In our case, we selected three papers that contribute to the goals of this paper. Makyia (Makyia & Traballi, 2009) analyzes the current distribution and storage network of grains in Brazil, identifying problems and challenges, focusing in the Midwest and South regions, where most of the production is located. The authors also present the main transportation routes of the agricultural activity in the country, comparing them to those of more logistically developed countries, such as USA and Argentina. They show how Brazil has maintained a deficit in storage capacity and attribute it partially to the lack of financing for producers. Because the producers lack storage capacity, they sell most of their grains to cooperatives or elevators belonging to large companies. This situation causes the price of grains to be significantly lower during and right after the harvest.

The authors estimate that, if in-farm storage in Brazil increased from the actual 11% to 50%, soybean prices paid to the farmers would rise by an average of up to 6%, since elevators would lose some of the bargaining power of buying the crops during and right after the harvest . However, they fail to explain how they calculated this value. In addition to that, observing the value of crops along the year it is not clear whether seasonality plays an important role in the pricing of oilseeds and its byproducts.

They also point out challenges in the agriculture supply chain in Brazil by quantifying the effects of a poorly distributed logistics infrastructure in the final cost of grains. Specifically, this paper estimates the impact of freight costs and time for the grains sourced in Campo Novo do Parecis, the region where Celena is planning to install its facility. According to the authors, logistics represent 42% of the landed cost of the grain in the port. This figure is useful for our work, since one of the main reasons to install storage and potentially crushing capacity in the region is to exploit the difference in grain prices in the port or consumer areas and in Campo Novo do Parecis, MT.

Del Carmen et al (del Carmen, Kaufmann, & Nepstad) considers how paving one of the main railroads used for transporting grains in Brazil would affect the supply of grains, the transportation costs and the farming patterns of the region. BR-163 crosses almost the entire states of Mato Grosso and Para, arriving at the port of Santarem, in the Amazon. This is a major port for grain shipments from Brazil to Europe, and part of its capacity is idle because of the difficulties in transporting soybeans through this route.

Del Carmen et al. also estimate that the cost of crossing 1 mile of paved road is three times lower than that of crossing 1 mile of unpaved road and sixty times lower than that of crossing forest. This information is relevant to our work because one of the value drivers of our business is the transportation cost of goods to and from our facilities. In building future scenarios, the main variables we will take into account are different layouts of transportation networks.

The authors conclude that if Brazil could match US average in-land transportation prices, the share of distribution costs in the value of total soybean exports could decrease from around 20% to close to 5%.

Caixeta-Filho (Caixeta-Filho) also addresses the Brazilian grains transportation matrix. He discusses the importance of a more diversified logistics network for Brazil, pointing out non-tangible assets such as the ownership of the network. For example, while railroads and waterways are usually owned by the government and in order to operate in them companies need to overcome a lot of bureaucracy, highway operators are usually very nimble and prices are adjusted much more frequently.

In order to build our simulations, a number of presentations, maps and data were also sourced from the ministry of transportation (Brazilian Ministry of Transportation, 2012), the association of vegetable oil producers (Brazilian Association of Vegetable Oil Industries , 2011), Business Monitor International (Business Monitor International, 2012) and the Food and Agricultural Policy Research Institute (Food and Agricultural Policy Research Institute, 2011). All these resources were obtained online.

Simulation Models

Campuzzano's (Campuzano & Mula, 2011) book on supply chain simulation modeling is a hands-on manual of how to build and simulate a supply chain using the theory of system dynamics. According to the author, when a problem has a complex mathematical representation and building an analytical model will be extremely time consuming and difficult, simulating the supply chain is the best approach because it permits a close representation of reality and a way to visualize the effects of simultaneous transformations in the supply chain. They add that simulation is also preferable to analytical methods when one or several of the following characteristics exist in the supply chain:

- There is no mathematical formulation.
- There is no analytical resolution method.
- Although there is a resolution method, it is very costly.
- The objective is to observe simulation history.
- The purpose is to experiment before configuring the supply chain.
- It is not possible to experiment with the actual supply chain.
- A goal is to observe a slow evolution by manipulating time.

D'Apice (D'Apice, Göttlich, Herty, & Benedetto, 2010), provides a more rigorous mathematical models for supply chain simulation. The concepts were useful in the model description and mathematical representation. De Neufville's Flexibility in Engineering Design (de Neufville & Scholtes, 2011) teaches us to think of uncertainties as an inherent part of our projects, and therefore create a design that is adaptable for a situation of extreme stress. The basic lesson from the book is not to design for average situations. Because the agricultural supply chain is loaded with uncertainties in many aspects, from the yields in the field to the final consumer demand and policy changes, it is very important to understand where we stand in a scenario that is very far from the one we expected.

Kleijnen (Kleijnen, 2005) identifies four types of simulation problems in supply chain: validation and verification, sensitivity analysis, optimization of critical controls and uncertainty analysis. In order to solve the defined problem, Kleijnen and Smits (C. & Smits, 2003), identify four types of simulation: spreadsheet, system dynamics, system dynamic simulation with discrete events, business games. Our problem is to project a business in the future and assess potential threats, opportunities and best strategies. Therefore, according to the framework they provide, we are solving a hybrid problem that includes sensitivity analysis, optimization of critical controls and uncertainty analysis. Due to the complexity of the system, we will also use two different types of simulation, spreadsheet and system dynamics, as we will later specify in the methods section.

Benirschka and Binkley (Benirschka & Binkley, 1995) studied the grain storage markets in Illinois and found that, because prices are lower further from the consuming markets, the opportunity cost of storing grains is lower in further regions. For that reason, they conclude that in a more efficient market, storage should be further from the consumption centers. These findings have important implications for the seasonality of prices, as the authors recognized.

Meyer, Rothkopf and Smith (Meyer, Rothkopf, & Smith, 1979) build a model to measure the reliability in a single stage production-storage system. In their model, demand is predictable, storage capacity is fixed and production is subject to stochastic failures. They analyze the tradeoff between demand satisfaction and inventory levels. The paper is important because it quantifies the reliability of a production storage system for different levels of production and of storage available, allowing to understand the tradeoff curve between these two factors.

Methodology

Overview

The simulation model we built tries to portray the company's activity in a way that is close enough to reality that the insights are useful but not detailed to the point where it loses its usefulness and ability to be recalibrated and run quickly.

In order to perform a realistic business simulation, a number of steps were taken. First, I conducted a series of interviews with the company's management and employees. From these interviews I could develop a detailed view of the business, gather a great amount of financial and operational data and define the variables that should be included in the model and how they relate to each other. I built the model using both Vensim® and Microsoft Excel VBA®.

A system dynamics approach is adequate because instead of focusing on specific data points, it focuses on the relationship between multiple variables and on the combined performance of the system, through feedback loops (Campuzzano and Mula, 2011). On the other hand, spreadsheet-based simulation is usually more intuitive and easier to understand by industry executives. Also, despite a higher set-up time, the results can more easily be customized using VBA®.

While Vensim® already has a number of visual and numerical reports preloaded, Excel® VBA is an industry standard and facilitates the data exchange with company employees. Interfaces between the two programs also allow for data exchange, facilitating the simulation work and focusing in the benefits of each software package, Once I figured out what the operation looks like and identified the variables to work on, attributing values to these variables was challenging. The company's system does not keep track of historical records of many of the variables that we wanted to use. We don't have, for example, the price per transaction, or the daily demand, for more than as little as one month's time. When data was not available, we estimated values. In the next sub sections, we describe the model in details. While most variables will be introduced in the next sections a table with all of them is introduced in appendix 2 to facilitate the reading of the paper.

Summary

The model in a few sentences can be explained as follows:

- Every day, a random amount of each grain crop, $Received_i^t$, is received by the Celena.
- Every day, a random amount of sales, $Sales^j_{i,t}$, t is made of both oil and meal of each crop.
- Once a week, a decision[9] is made on which crop is going to be crushed that week.
  - Every day during this week, the amount crushed is the minimum between the grain inventory of the crop chosen, $Inventory^j_{i,t}$ and the crushing capacity, *CrushCap*.
- In the first day of the following week, the crushing decision is taken again. This happens for 52 weeks.
- Each simulation consists of 100 runs.
- Relevant values are computed for later analysis.

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[9] Refer to "Comparing the Optimal Solution with Feasible Crushing Rules "sub section.

Model Initiation

As previously showed in the crop calendar, the company has to prepare for the coming cycle starting almost one year in advance. These activities include estimating the demand for the coming cycle and the amount of seeds to be bought. These estimates depend on other variables, such as the expected yield. More details are provided in the coming sub-sections.

Crop Size

All company activities derive from the amount of oil that Celena believes it will need to fulfill its clients demand for the cycle. The first set of inputs in the simulation model are therefore the company's estimated oil demand for each oil, $EstOilDemand_i$, the expected yield for each crop, $EstYield_i$, and the Safety multiplier, $SafetyMult_i$, where i = {Canola, HO Sun and Sun} correspond to the crop variety. $EstOilDemand_i$ and $EstYield_i$ are company estimates and are based on historical levels and expected trends[10]. Safety multiplier is the variable that represents the company's risk appetite, where the risk is not to satisfy demand. A $SafetyMult_i$ higher than 1 means that the company prefers to buy more seeds than the necessary to satisfy demand, and a $SafetyMult_i$ lower than 1 that the company is willing to lose sales instead of having excess supply. Later, we will manipulate this variable to generate excess supply. It can be in the company's interest to generate a shortage in the market, if it considers that the price elasticity[11] of the supply is lower than -1. Supply elasticity of soybean in Brazil is estimated in Piketty and Menezes (Piketty & Menezes, 2007) , and vary widely across different models and regions. For our base case, we will

[10] In Building Scenarios section, a detailed description of future scenarios and demand trends can be found.

[11] Price elasticity of supply is represented by $\frac{\Delta Price\%}{\Delta Supply\%}$

consider that the price elasticity, $ElastSupply_i$ of demand is equal to -0.5 for all crops. This means that, for a crop that is 10% lower than what was expected, prices will be on average 5% higher.

$EstOilDemand_i$, $SafetyMult_i$ and $EstYield_i$ are combined to generate the company's seed order, measured in hectares to be planted, $SeedOrder_i$.

$$SeedOrder_i = \frac{SafetyMult_i * EstOilDemand_i}{EstYield_i * \%OilContent_i} \quad (1)$$

Where $\%OilContent_i$ is the amount of oil in the grain, in terms of weight. This value has been extensively measured and its variation is negligible. The oil content is respectively around 40% for Canola, 38% for High Oleic Sunflower and 38% for Sunflower[12].

The actual yield, $ActYd_i$, will be known around six months after the seeds were distributed, and may differ from $EstYield_i$. In our base case, we represent this uncertainty using a normal distribution that has the expected yield as the mean and a standard deviation of 10%, based on data gathered with the company and shown in table below[13] (TOMM, et al., 2009).

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[12] USDA, EMBRAPA and others, see table3.

[13] Only the five last years were used to compute the approximate standard deviation.

Table 1: Harvested Area, Production and Yield for Brazil and Paraguay

	Harvested Area PY (ha)	Harvested Area BR (ha)	Output PY (tons)	Output BR (tons)	Yield PY (tons/ha)	Yield BR (tons ha)
2000	3,000	4,699	3,986	6,496	1.33	1.38
2001	2,000	4,286	3,000	6,444	1.50	1.50
2002	4,000	5,040	6,000	5,085	1.50	1.01
2003	6,000	12,830	10,000	13,493	1.67	1.05
2004	30,000	12,415	45,000	14,379	1.50	1.16
2005	50,000	16,304	75,000	21,035	1.50	1.29
2006	72,000	24,977	80,000	16,977	1.11	0.68
2007	60,000	24,785	72,000	27,033	1.20	1.09
2008	30,000	21,055	36,000	28,389	1.20	1.35
2009	37,055	42,200	40,761	49,297	1.10	1.17
2010	48,500	46,000	72,750	52,641	1.50	1.14
2011	64,500	51,000	80,635	56,328	1.25	1.10

The distribution of the yields can be represented as follows:

$$ActYd_i \sim Normal\left(EstYd_i, \frac{EstYd_i}{10}\right) \quad (2)$$

The actual crop size, *Crop$_i$*, can be defined around six months after the seeds are distributed.

$$Crop_i = SeedOrder_i * ActYd_i \text{ or } \frac{ActYd_i}{EstYd_i} * \frac{EstOilDemand_i}{\%OilContent_i} * SafetyMult_i \quad (3)$$

Figure 7 is a Vensim® diagram showing the process of defining $Crop_i$, *OilPrice$_i$* and the Crush Margin, *CrushMargin$_i$*. Notice that only the price of oil is an output of the model, and depends on the size of the crop. This happens because both the grain and the meal quantities are calculated as a percentage of soybean quantity, and therefore the size of the crop is negligible and does not affect these two markets.

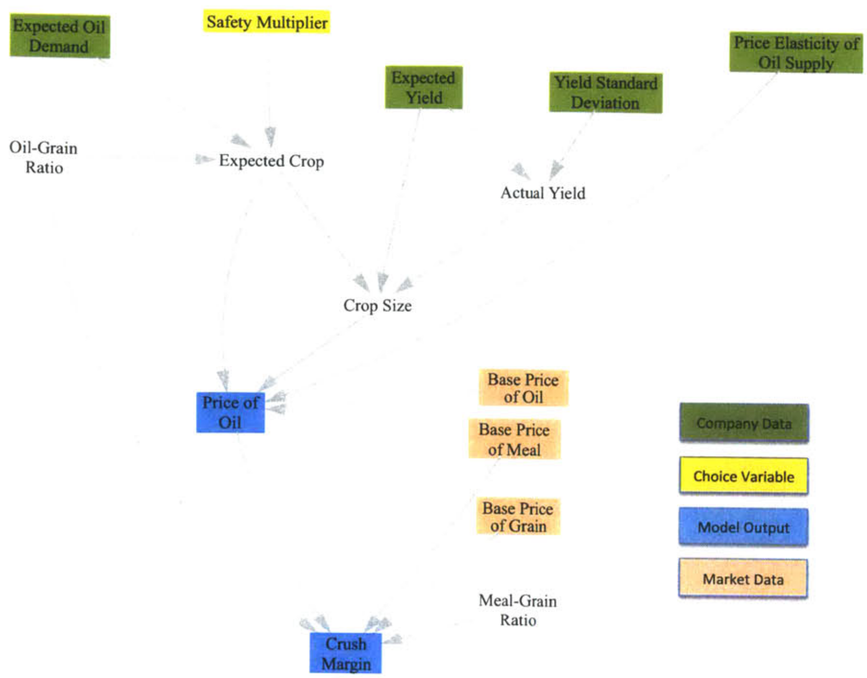

Figure 8: Price and Crush Margin Creation System on Vensim.

Price

The price of oil is a function of the difference between the sizes of the actual and the predicted crop and the price elasticity of supply. Specifically, we represent its expected value as:

$$ActOilPrice_i = BaseOilPrice_i + BaseOilPrice_i * \left(\frac{ActYd_i}{EstYd_i * SafetyMult_i} - 1\right) * ElastSupply_i (4)$$

$ActOilPrice_i$ follows a normal distribution with a standard variation of 15% of the estimated value.

From (3), we know that the size of the crop is a function of the amount of seeds planted and the yield, which is random. From (1) we obtained the amount of seeds planted, which by its turn is a function of the safety multiplier and the expected oil demand. The same process applies for HO Sunflower and Sunflower. Since the company's bottom line is impacted by the relation between the price of grain, meal and oil rather than the levels, we will fix grain and meal prices and let only the oil prices vary in our model. This is correct because we do not consider cost of capital in our model, In which case, the levels of these variables, not just their relations would matter.

Other Costs

Other variables are part of the model and affect the expenses of Celena. The two main operational expenses are storing in third party storage facilities and crushing. Third party storage of grain, oil and meal for each crop are set in our base case according to the table below.

Table 2: Overdraft Cost in USD/(ton-day) for Each Crop, 2011 Rates.

$Overdraft^j_i$	Canola	HO Sun	Sun
Grain	0.12	0.15	0.15
Oil	0.2	0.2	0.2
Meal	0.15	0.15	0.15

Crushing cost, according to company data varies from 40 to 55 usd per ton of grain crushed, as shown below:

Table 3: Canola, HO Sunflower and Sunflower Crushing Cost (USD/ton)

Variable	Canola	HO Sun	Sun
$CrushCost_i$	40	55	55
$\% \, Oil \, Content_i$	40%	38%	38%
$\% \, MealContent_i$	58%	60%	60%

The total expense with crushing and storing in third parties will depend on the amount of grains received and on sales thus they can only be known after the model is initiated, as shown in the next section.

Recurrence – System Dynamics

Provided that the company signs exclusivity agreements with farmers that plant the seeds they sell, we assume that the entire crop will eventually be delivered to Celena within the 370 days cycle. The company provided a table of the expected share of the crop to be received each month.

Table 4: Percentage of crop received each month in the South and MW

	MW			South		
	Canola	HO Sun	Sun	Canola	HO Sun	Sun
Jan	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Feb	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Mar	20.0%	20.0%	20.0%	3.3%	3.3%	3.3%
Apr	35.0%	35.0%	35.0%	3.3%	3.3%	3.3%
May	15.0%	15.0%	15.0%	3.3%	3.3%	3.3%
Jun	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Jul	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Aug	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%
Sep	3.3%	3.3%	3.3%	20.0%	20.0%	20.0%
Oct	3.3%	3.3%	3.3%	35.0%	35.0%	35.0%
Nov	3.3%	3.3%	3.3%	15.0%	15.0%	15.0%
Dec	3.3%	3.3%	3.3%	3.3%	3.3%	3.3%

We use this schedule and add a component of uncertainty regarding the daily deliveries of grains. Since we also know *Crop_i*, we generate the daily grain delivers using a random distribution where the mean is the expected demand for that day and the daily standard deviation is 20%, or:

$$Received_i^t \sim Normal\left(Crop_i * \frac{TableIndex}{30.5}, 20\%\right) (5)$$

This receiving schedule contrasts with a rather homogeneous sales schedule. Both in receiving grains and in the sale of byproducts, there is uncertainty in the daily volumes. More specifically, we model the sale of oil and meal in the system as the minimum of the demand for oil and meal in that day and what the company had in inventory.

Since we consider that sales are homogeneous and all the grain will be converted to oil and meal, we estimate the daily demand of oil, *OilDemand$_i$*, as the following normal distribution:

$$OilDemand_i^t \sim Normal\left(\frac{Crop_i * \%OilContent_i}{365}, \frac{Crop_i * \%OilContent_i}{365 * 5}\right) (6)$$

Meal demand, *MealDemand$_i$*, follows a similar distribution:

$$MealDemand_i^t \sim Normal\left(\frac{Crop_i * \%MealContent_i}{365}, \frac{Crop_i * \%MealContent_i}{365 * 5}\right) (7)$$

In both distributions, the standard deviation is 20% of the daily expected volume, as the right term shows.

Crushing Rules

We considered two different possibilities of crushing rules. These rules take into account the manageability of the crushing plant. For example, it is not acceptable, from a managerial standpoint, to choose a different crop to crush every day, due to the idle time and the inefficiencies of constantly switching the machinery for a different crop. These crushing rules do not represent actual policies, but hypothetical ones. The idea is to show how the model allows us to compare between two different crushing schedules. These two crushing rules can easily be manipulated and changed in the future: $Inventory^{j}_{i,t}$

1. Every Sunday, grain inventory, $Inventory_{i,t}^j$, is checked for all crops and that one with highest inventory is going to be the sole seed crushed that week. The amount crushed per day, $Crush_{i,t}$, will be the smallest of the daily inventory and the plant capacity.

2. Every Sunday, oil inventory is checked for all crops, and the seed that has smallest oil inventory will be crushed that week. The daily crushing amount is also the minimum between plant capacity and the grain inventory of that crop.

More complex rules will be developed when the model is put into use at Celena Alimentos. Every strategy will be measured in relation to the profit that it generates, but other metrics may also be relevant, such as maximum inventory at any given time, and others.

Building Scenarios

Scenarios are an important tool to analyze the company operations in light of possible major changes. The idea behind building scenarios is not to predict the exact way the future will be but to create an edge in the reaction time and the ability to adapt in case structural changes happen. They can also compensate for decision making errors, by identifying basic trends and uncertainties (Schoemaker, 1995).

Our scenarios will be based on three major drivers that are mostly independent from each other: Demand trends, supply availability and infrastructure developments. Each scenario can be represented therefore as a vector of three dimensions, *Scenario (Demand, Supply, Infrastructure)*. In order to have a manageable number of possible scenarios, we will lay two possibilities for each of the dimensions, thus allowing for eight scenarios in total. All scenarios were compared over the same base case.

Infrastructure developments are somehow correlated to supply availability, but in our scenarios, we will disregard this fact. It is up to the manager to decide how to combine the three scenarios. A representative scheme of the possible scenarios is in figure below.

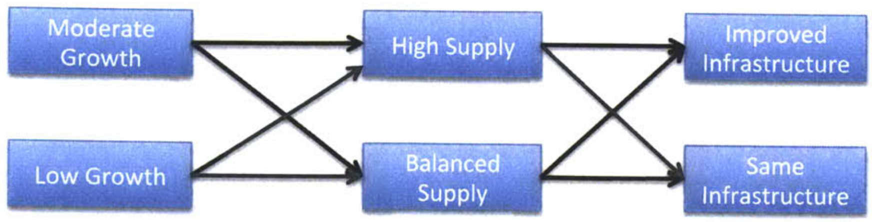

Figure 9: Possible Scenarios

Demand Scenarios

Conservative Growth - Growth

The healthy oils market is growing worldwide[14]. The penetration of Canola and Sunflower oils in Brazil are still low. While in 2011 Canola and Sunflower represented 13.3% and 6.9% of the world production of oil meals[15], in Brazil their market share is still lower than 2% each[16]. Furthermore, new regulation will require that some of the food companies replace palm oil for other varieties. Since palm oil production and imports in Brazil account for more than 300,000 tons per year, of which more than 70% is used in the food industry, replacing 20% of palm for food uses in 5 years would represent an increase of around 55,000 tons per year in Canola and Sunflower demand. Contrasting with today's market this is an increase of about 90%. This will be our conservative growth scenario. Because we are spreading the growth in 5 years, this scenarios represents an annual average growth of approximately 14% a year[17]. In the next subsections, we detail each of the scenarios that were built over the base case. The growing demand is represented by an annual demand growth of 12% in Canola, 15% in High Oleic Sunflower and 10% in Sunflower.

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[14] Oil World Annual 2011
[15] Oil World Annual 2011
[16] Company Estimates
[17] $1.9^{1/5} - 1 = 1.137 - 1 = 0.137 \cong 14\%$

Low Growth - NoGrowth

The low growth scenario assumes that there is no legislation and there is a halt in the trend for healthier oils. Even in this scenario, Celena believes that it can grow the business since it has new facilities in Mato Gross, which increases its geographic footprint and allows for them to be competitive in areas where they usually were not. Therefore, the low growth scenario will consider a 5% annual increase for 5 years for each crop, totaling an increase of little over 27% in demand values from our base case. The expected values in each scenario for $EstOilDemand_{i,t}$ are:

Table 5: Estimated demand in 5 years for each oil in growth or no growth scenarios

$EstOilDemand_{i,t}$	Canola	HO Sun	Sun
Growth	26,435	14,080	3,221
NoGrowth	19,144	8,934	2,553

Supply Availability

Supply Availability is contingent on new varieties being introduced by other companies, which would harm the competitiveness of Celena and generate a reduction in their margins. Because the market is at an early stage, and the development of a seed is a very costly process[18] there is no reason to think that this is a high risk. Availability of land is also a risk in the business, but one that we consider to be minor. Winter crops like canola and sunflower still represent a minor part of farmer's income, and an undersupply of land would probably be dealt with an increase in the price paid for the grains, which is up to Celena and its competitors to manage. A more detailed view of the land availability issue in

[18] According to our conversations with industry experts, around USD 10 million and 10 years of research.

Brazil and especially in Mato Grosso can be seen in Arvor et al. (Arvor, Meirelles, Dubreuil, Béguée, & Shimabukurof).

High Supply - Oversupply

In our model, oversupply will be represented by a safety multiplier of 1.2 and a price elasticity of supply of -0.5. In this scenario, the company is hurt by an average decrease in the price of oil of 10%, with prices of grain and meal unchanged. It is a direct impact on the crush margin.

Balanced Supply - Balanced

Our balanced supply scenario means that the industry does a good job managing the supply and demand of Canola. It is represented by a safety multiplier of 1. From $Crop_i =$

$$SeedOrder_i * ActYd_i \text{ or } \frac{ActYd_i}{EstYd_i} * \frac{EstOilDemand_i}{\%OilContent_i} * SafetyMult_i (8)$$

We conclude that if $SafetyMult_i = 1$ and $ActYd_i = EstYd_i$,

$Crop_i * \%OilContent_i = EstOilDemand_i$ (9), or supply equals demand. This scenario implies that the margins in five years will be on par with todays.

Infrastructure

In our model, infrastructure deployment will be represented by a premium in the crush margins. Today, Celena and its clients need to share the high costs of logistics from the farm to the elevators to the client's premises. If better highways are implemented, new railroads are deployed, it is likely that the cost of transportation will go down. The freight incurred by Celena from its elevators in MT to the client is represented below:

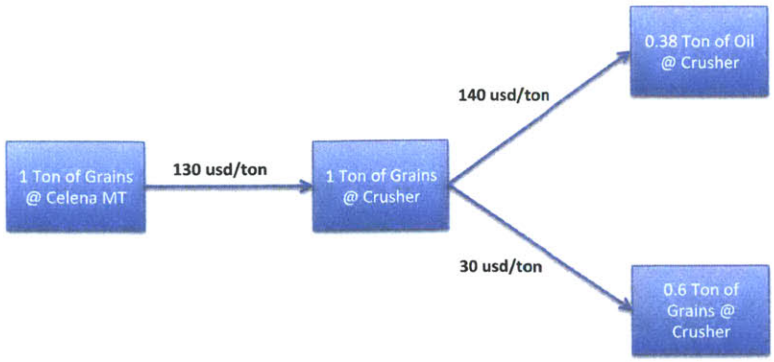


Figure 10: Transportation Costs, 2011

Improved Infrastructure

In our improved infrastructure scenario, we assume that that Celena and its clients share in a 50-50 basis the cost improvements of the new logistics costs. A study conducted by the Inter-American Development Bank from 2011 (Guasch, 2011) estimates that the cost improvement of asphalting a road is about 20%. Considering that nowadays, the total freight cost from Celena MT to the crusher and finally to the client is estimated at 201 usd per ton of grain processed, a 20% cost reduction represents 40 usd per ton of premium considering an homogeneous improvement in all roads the company operates. This premium may be underestimated because it considers cost improvements in the same road. New projects may enable grains to travel a large part of the distance in rails or in newly build roads. A more detailed examination of the projects with estimated cost improvements can be seen in the appendix 1.

Same Infrastructure

In the case new infrastructure is not deployed, today's cost remain for the future. Notice that the transportation cost is implied in the crush margin in our model, therefore there is a premium of 0 in the same infrastructure case.

Scenarios Summary

We can finally summarize the eight scenarios in terms of demand, infrastructure and supply, for the reader's convenience:

Table 6: Scenarios Summary

Scenario	Demand	InfraStructure	Supply
Scenario1	NoGrowth	Same	Balanced
Scenario2	Growth	Same	Balanced
Scenario3	NoGrowth	Improved	Balanced
Scenario4	Growth	Improved	Balanced
Scenario5	NoGrowth	Same	OverSupply
Scenario6	Growth	Same	Oversupply
Scenario7	NoGrowth	Improved	Oversupply
Scenario8	Growth	Improved	Oversupply

Simulating Scenarios and Rules

Because there are randomly generated variables in our model, we can't draw conclusions looking at just one cycle of operations. For that reason, we simulated, for each given scenario and rule, one hundred cycles. The simulation was programmed in VBA®, and the code is in the appendix. Because the crushing is defined every week, and this decision affects the inventory and sales for the following week, there are two loops. The first loop refers to the operations within a cycle. Every week a decision is made, one of the crops is crushed. This happens 52 times, as it is the cycle time in weeks. The other loop refers to the number of simulations that we are doing. We chose to do one hundred simulations to limit the processing time of the program. For illustrative purposes, a summary of the VBA® program is shown in appendix 3.

In order to compare results yielded by different sets and scenarios, we computed, for different variables, in each scenario and setting: maximum value, minimum value, average value, standard deviation, and 25th and 75th percentiles. The variables we analyze are: annual grain buying expense; annual crush expense; annual overdraft expense with grain, oil and meal; each crop's annual revenue with oil and meal sales; ending inventory of each crop in grain, oil and meal; annual volume crushed of canola, HO sunflower and sunflower; annual quantity received of grains per crop; annual quantity sold of oil and meal per crop; total revenues, expenses and profits in the year; overdraft quantity and cost for grain, oil and meal; overdraft days for grain, oil and meal, lost sales of oil and meal; average crush margin for each crop; prices for each crop in grains, oil and meal.

Finding the Optimal Crushing Schedule

The optimal crushing schedule is the one that allows the company to generate the highest profits. Since once the crop is harvested, both daily grain deliveries and byproducts demand are outside of the company's control, the best way to leverage the profit's is through an optimal crushing schedule. A balanced crushing schedule will find the optimal tradeoff between product availability and crushing and storage costs. The daily fluctuations of prices will add uncertainty to the model, and is also outside of the company's control.

The optimal crushing schedule is a utopia, since it defines the profit maximizing amount of crushing each day after sales in that and future dates are already known. The only objective of an optimal crushing schedule is to create a benchmark against which to compare other crushing policies.

Finding the optimal crushing schedule can be mathematically defined as follows:

$$\max_{wrt\ Crushing} \sum_i \sum_j \sum_{t=0}^{365} (SalesOil_i^t * PriceOil_i^t + SalesMeal_i^t * PriceMeal_i^t - Received_i^t * PriceGrain_i^t - OverdraftCost_{i,j}^t - CrushingCost_i^t) \quad (10)$$

subject to:

$$SalesOil_i^t = \min(OilDemand_i^t, OilInventory_i^t) \quad (11),$$

$$OverdraftCost_i^t = Inventory_{i,j}^t - Capacity_{i,j} \quad (12) \text{ and}$$

Inventory Balance Equations:

$$\text{Grain: } Inventory_{i,j}^t = Inventory_{i,j}^{t-1} - Crushing_i^t + Received_i^t \quad (13)$$

$$\text{Oil: } Inventory_{i,j}^t = Inventory_{i,j}^{t-1} + Crushing_i^t * \%OilContent - Sales \quad (14)$$

$$\text{Meal: } Inventory_{i,j}^t = Inventory_{i,j}^{t-1} + Crushing_i^t * \%MealContent - Sales \quad (15)$$

Non-negativity Constraints:

$$All\ variables \geq 0, \forall\ t, i\ and\ j \quad (16)$$

Where $PriceGrain_i^t$, $PriceOil_i^t$ and $PriceMeal_i^t$ are the prices of oil and meal of a certain grain at a certain time, $CrushingCost_i^t$ is the crushing expense for a certain crop in a certain time and $OverdraftCost_{i,j}^t$ is the cost that the company incurs when it stores grains, oil or meal, denoted by the j subscript, outside its own facilities. This happens because sometimes the storage capacity that the company owns, $Capacity_{i,j}$ is not enough to handle the entire inventory.

The company can directly influence this profit function in three ways:

1. Choosing the configuration of $Capacity_{i,j}$ a priori.
2. Changing the value of $SafetyMult_i$.
3. After the harvest, through scheduling $Crushing_i^t$.

We will measure how much the best possible crushing schedules for each of the different scenarios and rules, using our base case values of $Capacity_{i,j}$, would yield on profits over our pre-determined crushing rules.

Data Analysis

In this section, I discuss the results obtained. It is the objective of this work that the model is useful for the company for strategic planning, so the contribution of this section is more to show the type of results that can be obtained than the results themselves. The company will be able to adapt the model and change the parameters anytime. Later, I describe the sources of uncertainty in the business and quantify them. We also discuss how the possible decisions that the company take affect the results, through multiple sensitivity analysis from the simulations. Lastly, we discuss how the recent developments and future prospects for Mato Grosso may affect the company's operations and suggest a framework for taking decisions going further.

Model Layout – Base Case

Remembering the methodology section, the inputs of the model are of three types: decisions, historical values and technical coefficients. For every simulation a scenario is picked and a set of variables is input by the user. The interface with illustrative values can be seen in appendix 4. The set of variables that we are going to use to compare our eight different scenarios constitute the Base Case. On top of the scenarios, I considered two storage capacity networks to show how storage affects the business.

Table 7: Static Storage Capacity (Tons)

Storage Capacity	Grain	Oil	Meal
High	16,560	6,500	10,000
Low	10,560	2,500	6,000

In the future, these values can be changed and new simulations executed.

Quantifying Uncertainty

The sources of uncertainty in the business were quantified and the results are presented in this section. Uncertainty is anything that the company can't predict and affect the results. To illustrate the importance of uncertainty, the histogram of profits below represent one hundred simulations where the company's set of decisions was the same. In other words, it shows what the profit in one year of operations is likely to be given a certain set of decisions taken. It is an effective way to see the aggregate effect of uncertainty in the model. Figure 10 below shows the profit distributions in a high storage capacity scenario and growth scenarios. The red line represents the cumulative distribution function of the profit. As can be seen in the picture, the profits varied widely in every configuration. In Scenario 2, for example, it went from negative 27 million to positive 29 million USD and the standard deviation of 71% in the annual profit makes uncertainty a major issue for the managers to deal with.

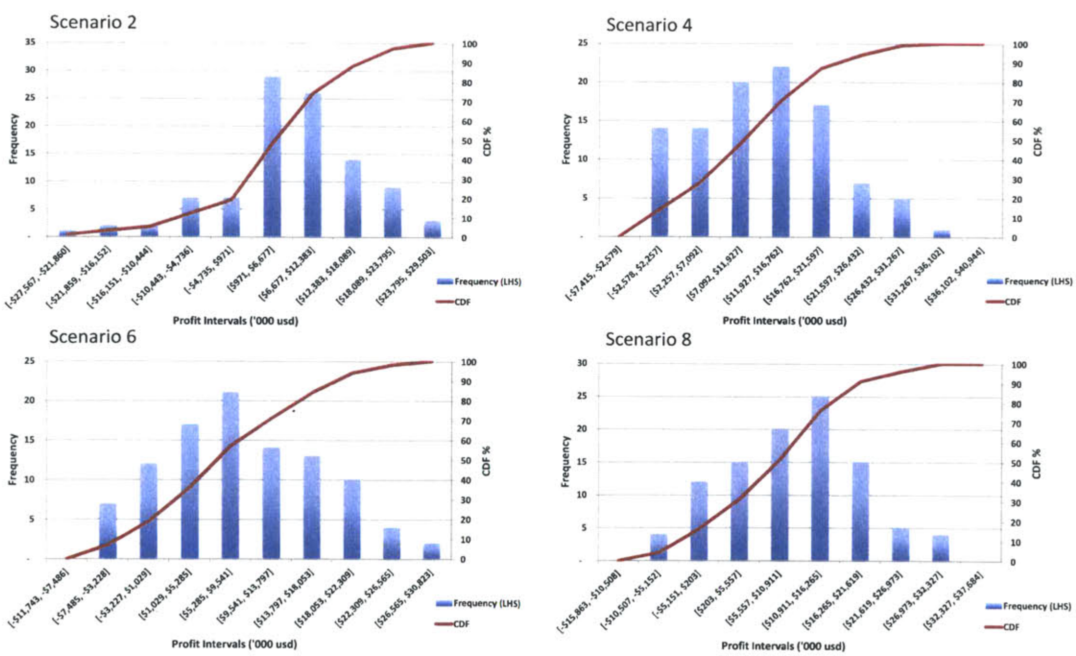


Figure 11: Histograms of Profit under High Growth Scenarios with High Storage Capacity Configuration.

Since the company's set of decisions was the same in every one of these 100 simulations, market conditions alone were responsible for all this variation. Since I used historical and empirical data to calibrate most variables, this portrait is rather accurate. Now that we know how market conditions aggregately affect the bottom line, another question needs to be asked: What variables created most disparity? The short answer is: none by itself, but many variables acting together. Through a series of sensitivity analysis, we will focus in how each component of the profit affects the final result.

Sensitivity Analysis

Yield

Yield can be estimated before the crop, but can't be known in advance. It depends on a wide variety of factors such as weather, level of mechanization of the farmer, days of harvest and planting. The impact of yield variability in the profit and profit variability was captured by a simple simulation exercise. For the same mean value of $ExpYd_i$, we ran 100 simulations, using each rule, with three different standard deviation values:10%, 15% and 20%. The results are shown in the tables below.

Table 8: Sensitivity of profit to yield variation, Rule 1

Statistic	Standard Deviation = 0.1	Standard Deviation = 0.15	Standard Deviation = 0.2
Min	4,573,302	2,529,420	-2,235,340
Max	10,676,895	10,976,779	9,968,948
Average	8,280,929	6,864,635	6,546,094
Percentile 75	7,402,088	6,047,211	5,544,661
Percentile 25	9,235,607	7,738,010	8,309,119
Std. Deviation	1,393,107	1,548,297	2,461,226
Std. Deviation %	16.80%	22.60%	37.60%

Table 9: Sensitivity of profit (usd) to yield variation, Rule 2

Statistic	Standard Deviation = 0.1	Standard Deviation = 0.15	Standard Deviation = 0.2
Min	6,199,661	73,185	1,487,795
Max	13,212,485	11,594,655	13,892,313
Average	10,650,002	6,445,897	8,930,038
Percentile 75	9,814,666	5,081,761	7,143,187
Percentile 25	11,861,417	8,181,636	10,839,254
Std. Deviation	1,645,958	2,394,615	2,725,887
Std. Deviation %	15.46%	37.15%	30.52%

Increasing the Yield's standard deviation from 10% to 15% caused the average profit to fall around 20%, and when the standard deviation increases from 15% to 20%, the average profit falls by less than 5%. Historic figures show that the standard deviation for Canola Yield in South America is around 13%. As we would think, profit's uncertainty, measured by the standard deviation, increases with the increase in yield uncertainty.

Crush Margin

The crush margin, $Crush_i$:

$$PriceMeal_i^t * \%MealContent_i + PriceOil_i^t * \%OilContent_i - PriceGrain_i^t$$

Defines how much the company makes by transforming one ton of grain in oil and meal. It is a raw measure because it does not take into consideration the operational costs related to that. Summary statistics for the crush margin of the three crops are shown in table X.

Table 10: Summary Statistics for Crush Margins

Crop	Average	Min	Max	Percentile 75	Percentile 25	% Std. Dev.
Canola	333.46	25.33	708.27	250.91	407.93	38%
HO Sunflower	321.35	41.87	652.63	238.72	399.87	38%
Sunflower	278.95	30.44	601.80	197.98	349.67	40%

Because prices are a function of the size of the crop and the projected size of crop are negatively correlated to the difference between the expected and the actual crop,($Crop_i$ −

$ExpCrop_i) \propto 1/Price_i$, a high crush margin will usually mean a low quantity crop. Whether the company is better off in a low supply or high supply scenario is not clear and will depend on the value of $ElastSupply_i$.

The chart below shows the crush margins and amount of grain received, illustrating the inverse relationship between size of crops and the crush margin. As we can see, the peak margins occurred in years where the total amount of rains received, which is a proxy for the size of the crop, was rather small.

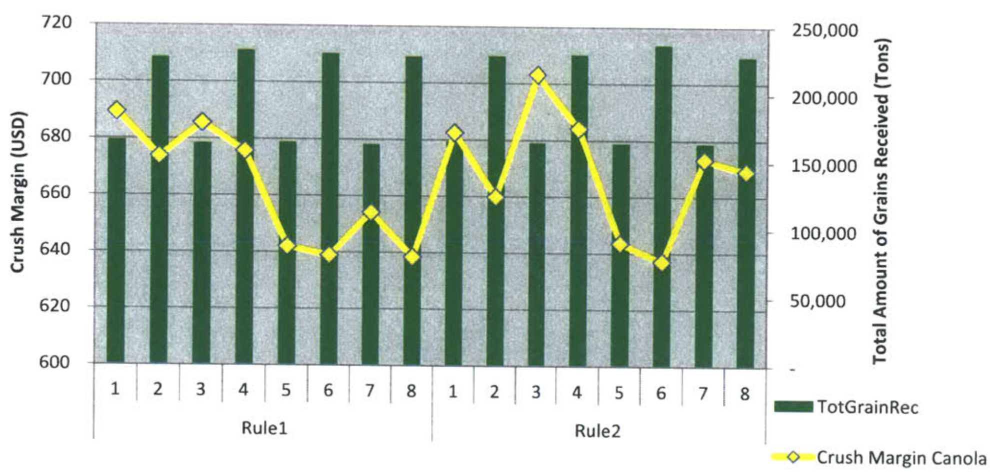


Figure 12: Crush Margin (USD) and Total Grain Received (Tons)

Storage and Crushing Capacity

One of the main strategic decisions that the company faces is the storage and crushing capacity. In this paper, we do not attempt to discuss the pros and cons of ownership versus outsourcing and the indirect effects of an asset-heavy balance sheet. These are decisions that involve non quantifiable aspects. What we are going to do is to show the potential profits of different configurations of business in different scenarios. In order to show how the business can be affected by different storage capacity configurations, the charts below show the expense incurred in third party storage for oil and meal, in each scenario, under each rule and with low and high capacity storage configurations[19].

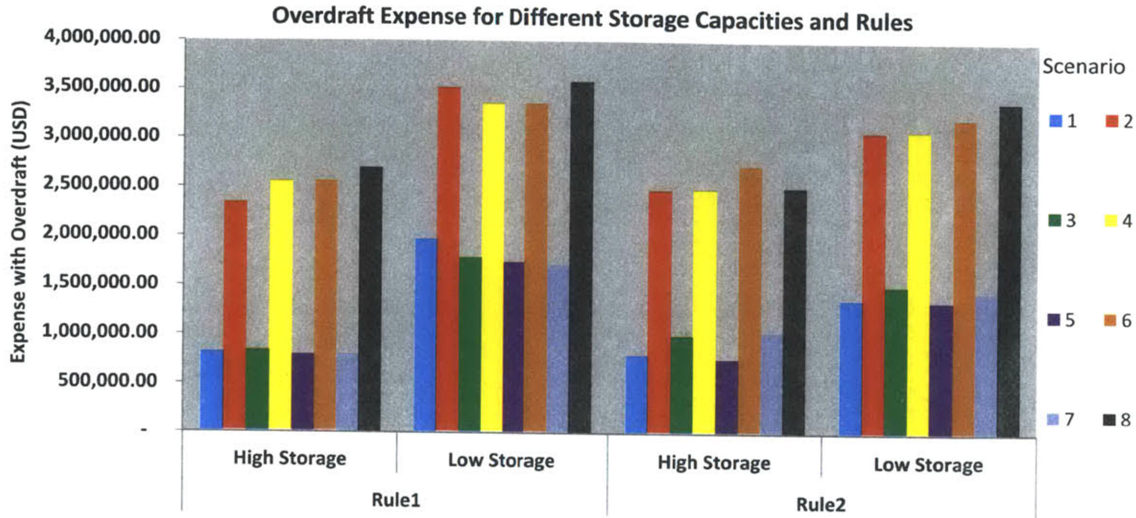


Figure 13: Overdraft expenses based on 2011 prices of third party storage, for low and high storage capacities, company data.

The crushing capacity is also an important driver of costs in the system. Because there is a difference in the price of storing oil, meal and grains and also because of the uncertainty demand patterns, the crushing capacity will be a relevant decision for Celena. The chart below shows how three pre-defined levels of crushing capacity – 200, 300 and 400 metric tons per day generate different overdraft costs.

[19] High capacity scenario considers a static capacity of 16,560 Tons of grain, 6,500 Tons of oil and 10,000 Tons of meal. Low Capacity considers 10,560 Tons of Grains, 2,500 Tons of Oil and 6,000 Tons of Meal.

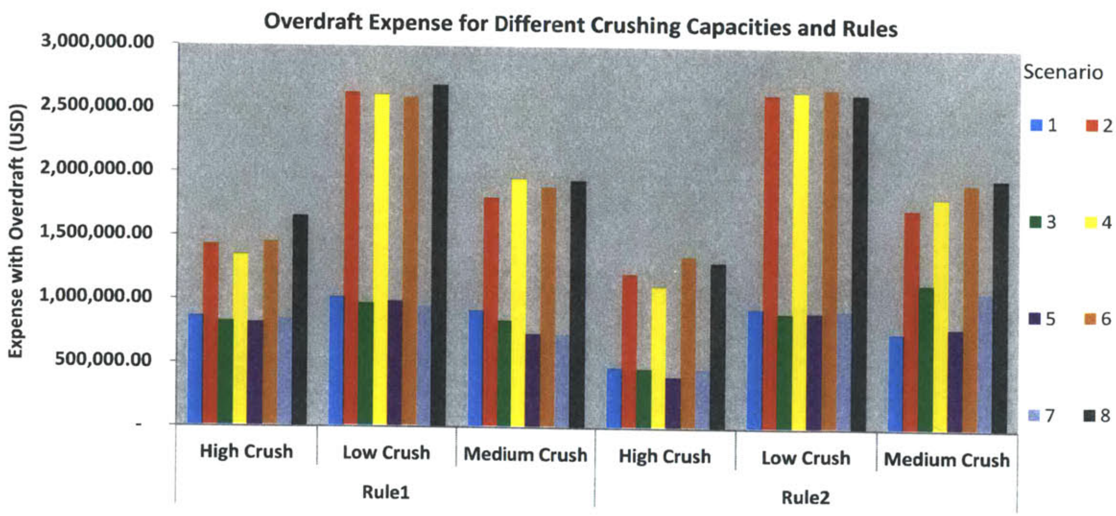


Figure 14: Overdraft expenses based on 2011 prices of third party storage, for low, medium and high crushing capacities, company data.

The crushing capacity can also affect the service level of Celena. Being a just in time provider of oils for some of the leading food companies in Brazil and in the world, it is very important that Celena has oil in stock when orders are put. Below we can see the value of unfulfilled sales[20] due to lack of inventory available, for different crushing capacities and rules one and two[21].

Table 11: Lost sales sensitivity to crushing capacity for Rules 1 and 2, based on growth scenario 2.

	Crushing Capacity, tons per day			
Rule	**200**	**300**	**400**	**500**
Rule 1	23,195,169	16,349,002	16,260,745	16,260,745
Rule 2	16,945,259	8,802,096	8,735,565	8,735,565

The amount of storage available for grain, oil and meal interfere the total value that the company needs to pay third parties for storage. The relation between how much is crushed

[20] Unfulfilled sales here are any sales that are not fulfilled the day demand existed. In regular conditions, orders would be backlogged and part of them would be fulfilled later.
[21] We used scenario 1. The model can easily be adapted to portray other scenarios or custom values.

and the storage capacity also matters. If the company crushes all its grains as fast as possible, it needs higher capacities of oil and meal storage. If, on the other hand, Celena tries to have a balanced inventory of oil, meal and grain, it can manipulate the amount crushed to achieve it. The tables below show how the outside storage expense bill varies according to different sets of configuration of storage and crushing capacity limits.

Table 12: Profit sensitivity to different crushing, oil storage (top) and grain storage (bottom) capacities.

	Rule 1, Profit (USD/Year), @ different crushing			
Oil Storage Capacity (Tons)	200	300	400	500
-	4,949,577	4,522,057	4,302,923	4,259,560
2,000	5,061,322	4,640,401	4,422,434	4,379,136
4,000	5,148,629	4,746,623	4,531,585	4,488,830
6,000	5,183,395	4,842,175	4,633,734	4,593,234
8,000	5,183,395	4,917,070	4,728,623	4,692,305
10,000	5,183,395	4,918,967	4,769,104	4,749,938

	Rule 2, Profit (USD/Year), @ different crushing			
Oil Storage Capacity (Tons)	200	300	400	500
-	4,656,910	4,855,090	4,792,235	4,698,411
2,000	4,709,925	4,970,449	4,911,557	4,818,661
4,000	4,709,925	5,060,925	5,017,541	4,928,549
6,000	4,709,925	5,124,513	5,112,075	5,030,788
8,000	4,709,925	5,144,717	5,185,205	5,115,474
10,000	4,709,925	5,144,717	5,230,229	5,177,716

	Rule 1, Profit (USD/Year), @ different crushing			
Grain Storage Capacity (Tons)	200	300	400	500
-	4,607,005	4,272,093	4,116,300	4,104,965
10,000	4,964,744	4,623,101	4,443,442	4,420,932
15,000	5,130,194	4,760,083	4,554,859	4,517,015
20,000	5,274,160	4,859,929	4,636,603	4,587,600
25,000	5,382,387	4,919,095	4,676,526	4,617,716
30,000	5,460,370	4,936,307	4,676,526	4,617,716

	Rule 2, Profit (USD/Year), @ different crushing			
Grain Storage Capacity (Tons)	200	300	400	500
-	4,129,756	4,681,820	4,790,951	4,778,615
10,000	4,491,178	4,967,187	4,986,548	4,928,892
15,000	4,658,542	5,068,677	5,050,331	4,970,331
20,000	4,822,041	5,150,231	5,096,568	4,998,463
25,000	4,971,606	5,212,665	5,127,493	5,002,914
30,000	5,089,394	5,255,113	5,134,449	5,002,914

This data tables provide the theoretical marginal value of storage. For example, if Celena contracted someone to crush 300 tons per day, and currently have a grain storage capacity of 10,000 tons, should it build extra capacity or not? Evidently, the answer would depend on the cost to build and operate its own capacity and the cost of outsourcing this activity for the amount that will be required. In the example, a capacity of 20,000 tons of grain storage would provide expected savings of USD 641,747 – 317,963 = USD 323,784 a year. It is the manager's decision whether this is worth the capital cost incurred in building storage. The marginal value of crushing capacity is not relevant, because the way we defined rules 1 and 2, capacity is always fulfilled as long as there is inventory. Obviously, if we can crush

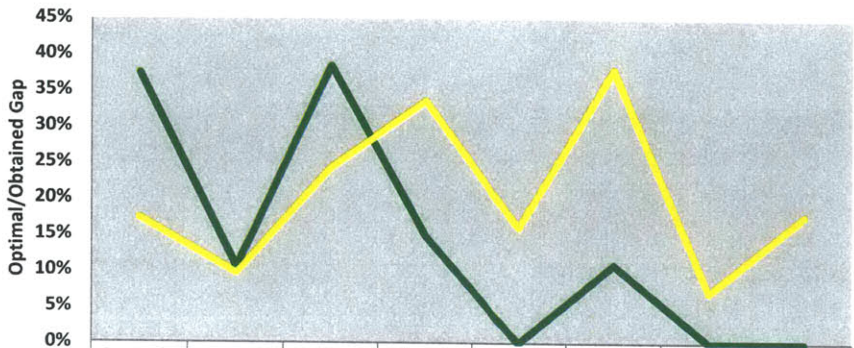
400 tons in a day, we can only use 200 tons of this capacity. This flexibility is not built in the model.

Comparing Rules and Scenarios

In order to compare results yielded by different scenarios, and the two crushing rules, we gathered the following information for every scenario and rule combination: maximum value, minimum value, average value, standard deviation, and 25th and 75th percentiles. The values were computed for the following variables: grain buying value; total crush expense; overdraft expense with grain, oil and meal; each crop's revenue with oil and meal sales; inventory of each crop in grain, oil and meal; volume crushed of Canola, HO Sunflower and Sunflower; quantity received of grains per crop; quantity sold of oil and meal per crop; total revenues and expenses and profits; overdraft quantity and cost for grain, oil and meal; overdraft days for grain, oil and meal, lost sales of oil and meal; crush margin for each crop; prices for each crop in grains, oil and meal and finally the end of period inventory. The results were loaded to a database and customized as pivot tables and charts.

An overall comparison between the optimal values, obtained by running the model presented in the methodology section, rule 1 and rule 2 profits is presented in table 13 below.

Table 13: Percentage loss from optimal crushing for each scenario and rule.



	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Rule 1	37%	10%	38%	15%	0%	11%	0%	0%
Rule 2	17%	10%	24%	33%	16%	38%	7%	18%

Figure 15: Gap between profits obtained in optimal conditions and rules 1 and 2

High versus Low Growth

We compared the profits obtained using both crushing rules in the figure below. In red are the growth scenarios, in blue the no growth scenarios. To illustrate the difference between having a high storage capacity and low storage capacity, we show figures 15 and 16. In figure 15, we compute the profits for the eight scenarios, on a crushing capacity of 300 tons per day and our low storage capacity, as defined in table 6. Figure 16 depicts the same variable, but this time considering that the company has a high capacity of storage network.

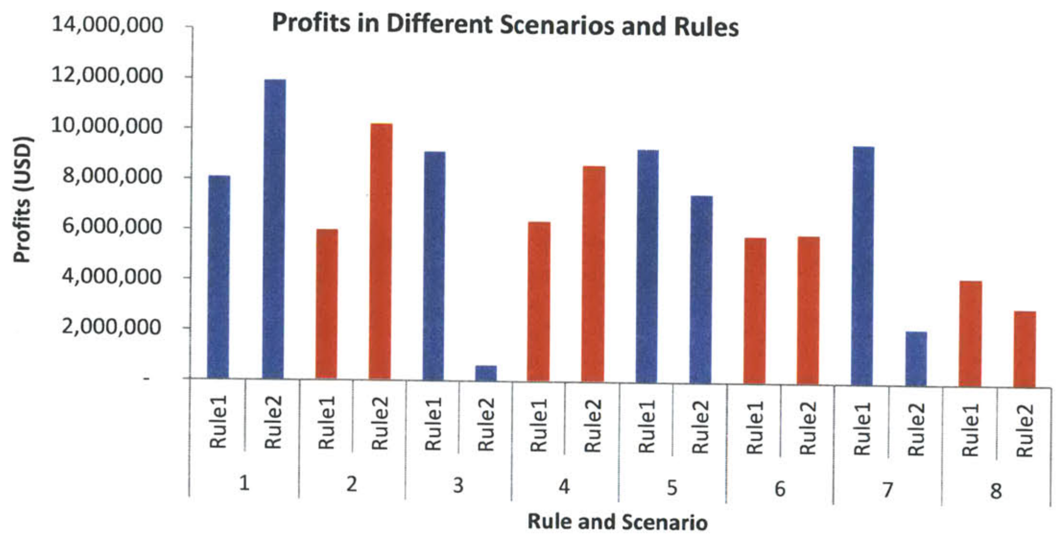


Figure 16: Average profit (usd) in various scenarios and rules, low storage and medium crushing capacities

The figure is insightful. When we have balanced supply, rule two is a clear outperformer over rule one. In low volume scenarios, crushing less does not necessarily impact the cost structure of the company, because the storage capacity in place may still be enough to keep all inventory in-house. When we switch to oversupply, scenarios five to eight, rule 1 becomes a clear outperformer. When there is a lot of grain coming in, crushing and selling them quickly is a necessity to avoid high inventory keeping costs.

Evidently, crushing the most available quantity of grains every week allows for higher utilization rate of the crushing and more final products. As explained, in a low supply scenario, this is not significant, because costs with storage are much lower and even with less crushing, the company is able to crush the whole or the majority amount of grains received.

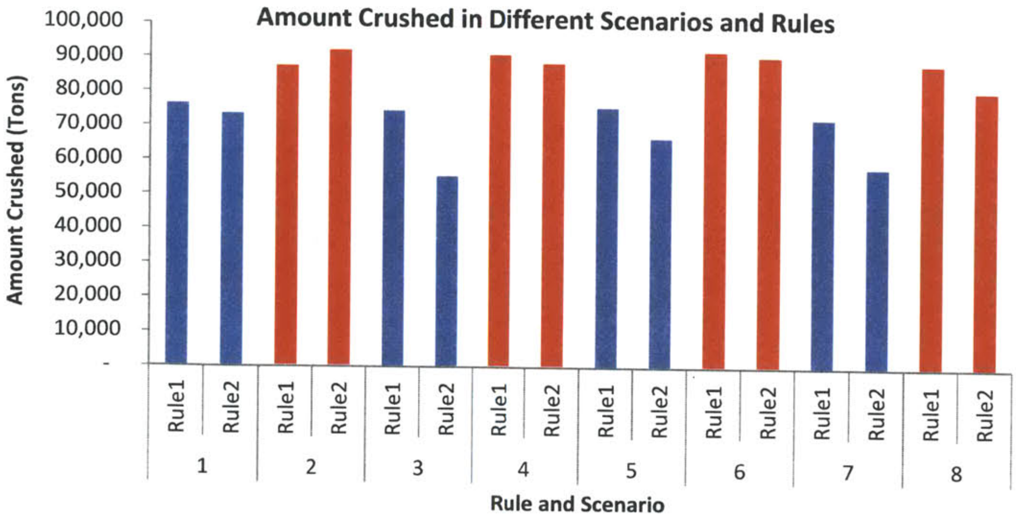


Figure 17: Average amount of grains crushed (Tons) in various scenarios and rules.

Conclusion

While there is considerable uncertainty even in one year's horizon, a simulation model can be a helpful tool for the company to plan for the coming cycles. By knowing the expected marginal values of building storage capacity, the company can quote tanks and warehouses to compare the costs with the potential benefits. Our results indicate that the company has higher incentives to invest in grain than in oil or meal storage[22]. Also importantly, the company can use the statistical data and plan for different risk-appetite strategies, such as: maximum gain at 75% probability, minimum loss with 10% probability and so on. All these scenarios can be developed simply by changing the inputs of the program.

Although $Crushing_i^t$ in this paper was set to be the maximum value between *CrushCap* and $Inventory^j_{i,t}$, it can be changed to the best amount that does not exceed the maximum value between these two variables. In this case, the same marginal value analysis that was done for the storage capacity can be done to the crushing capacity. This should be analyzed in further research.

Interestingly, the study shows how business activity and profits do not necessarily go together, thus pointing to the importance of careful planning of the storage and crushing network. Comparing scenarios in terms of demand growth don't show a clear advantage for high demand. In fact, comparison of scenarios that only differ in terms of demand growth showed that in 50% of the cases, demand growth did not account for higher profits. This may be function of the crushing rules that the author acknowledge not to be ideal, and should be further studied.

---

[22] Table 11

If demand was not a decisive factor of profitability, the decision on how to crush is important. In low supply scenarios, making sure that the most oil is in stock is preferred to getting rid of grain inventory. In high supply scenarios, getting rid of grain becomes a major issue and significant cost differences were observed for various crushing and storage configurations, as presented in figures 12 and 13.

Overall, this paper provides a new methodology for Celena to invest intelligently in future projects of storage and grain processing. New variables and rules will need to be added, and recalibration, especially of market data will be required at every cycle. Still, the model can be adjusted and run in a very timely manner.

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Appendix

Appendix 1 - Infrastructure Developments

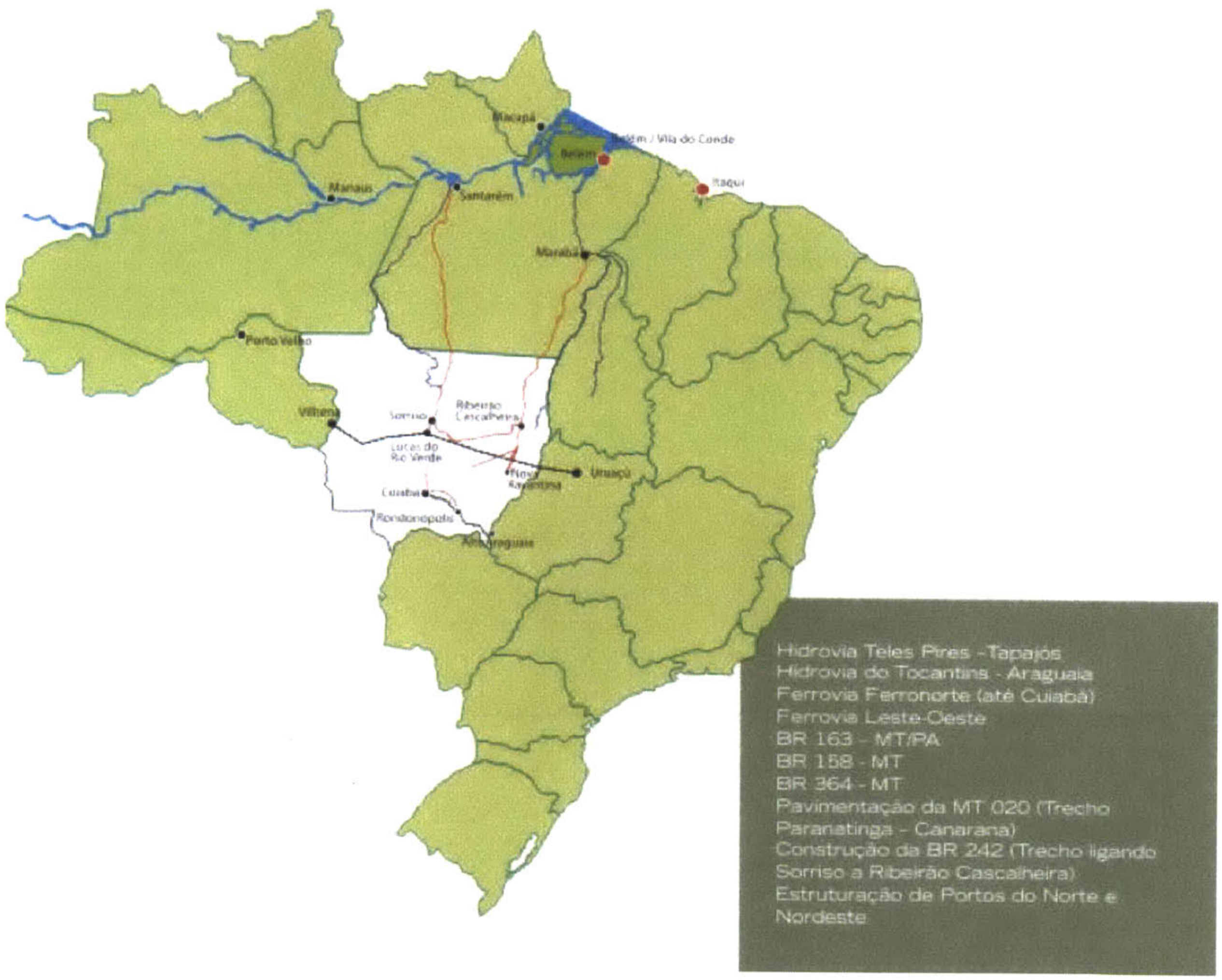

Figure 18: Infrastructure developments requested by the state of Mato Grosso. Source: Movimento Pro-Logistica

Figure 19: Brazilian highways per level of service projection for 2015: Source PNLT

Appendix 2 – Variables

Variable	Description	Source
$EstDemand_i$	Estimated Oil Demand of crop i	Company
$EstYield_i$	Estimated Yield of crop i	Company, based on public data and agronomists
$SafetyMult_i$	Variable that represents the willingness of the company to create oversupply (if >1)	Company
$ElastSupply_i$	Price Elasticity of Supply of Grain i	Papers, company
$SeedOrder_i$	Amount of seeds sold by them company, measured in hecatares to be planted	Endogenous
$\%EstOilContent_i$	Oil content in grain of crop i, measured in weight	Embrapa
$\%EstMealContent_i$	Meal content in grain of crop I, measured in weight	Embrapa
$ActYd_i$	Actual Observed yield. Follows a normal distribution. $ActYd_i \sim Normal\left(EstYd_i, \frac{EstYd_i}{10}\right)$	Observed, Company
$Crop_i$	Crop Size of i	Endogenous
$OilPrice_i$	Price of Oil i	Endogenous
$CrushMargin_i$	Crush Margin, or difference between revenue from oil and meal and the cost of grain to produce the amount sold	Endogenous
$BaseOilPrice_i$	Base oil Price over which oil price will be calculated	Company
$BaseGrainPrice_i$	Base grain price	Company
$BaseMealPrice_i$	Base oil Price over which Actual will be calculated	Company
$CrushCost_i$	Crush Margin. Depends on prices of Oil, Bas prices of grain and meal	Endogenous
$Received_{i,t}$	Amount of grain I received in day t, follows a normal distribution. $Received_i^t \sim Normal\left(Crop_i * \frac{TableIndex}{30.5}, 20\%\right)$	Endogenous
$OilDemand_{i,t}$	Demand for Oil I in time t $OilDemand_i^t \sim Normal\left(\frac{Crop_i * \%OilContent_i}{365}, \frac{Crop_i * \%OilContent_i}{365 * 5}\right)$	Endogenous
$MealDemand_{i,t}$	Demand for Oil I in time t $MealDemand_i^t \sim Normal\left(\frac{Crop_i * \%MealContent_i}{365}, \frac{Crop_i * \%MealContent_i}{365 * 5}\right)$	Endogeneous
$Inventory^j_{i,t}$	Inventory of crop I, in form j, at time t	Endogenous
$Sales^j_{i,t}$	Sales of crop i, in form j, at time t. It is the minimum between demand and inventory position	Endogenous
$Crush_{i,t}$	Crush is the amount crushed of grain I in time t. It is contingent on the weekly decision of what to crush, inventory and capacity.	Endogenous
$Overdraft^j_{i,t}$	Quantity of crop i, in form j, at time t, that needed to be stored with a third party.	Endogenous
$OverdraftCost^j_{i.t}$	Expense with overdraft for crop i, form j in time t.	Endogenous and Exogenous
$StorageCapacity^j$	Storage capacity for all crops, per form.	Company
$CrushCapacity$	Capacity that can be crushed in any given day.	Company

Appendix 3 – Summary of Program Loop

```
Do While countsim < 102
Do While countweek < 53 'every week, crop to be crushed is decided
If CanolaOil <= HOSunOil And CanolaOil <= SunOil
        CanolaCrush.Value = 1
        HOSunCrush.Value = 0
        SunCrush.Value = 0

         Else
           If HOSunOil < CanolaOil And HOSunOil <= SunOil Then
            CanolaCrush.Value = 0
            HOSunCrush.Value = 1
            SunCrush.Value = 0

Else
        CanolaCrush.Value = 0
        HOSunCrush.Value = 0
        SunCrush.Value = 1
        End If
    End If

    countweek = countweek + 1
    countday = countday + 7
    Loop
Loop
End Sub
```

Appendix 4 – Simulation Model Interface

Initiation

		Canola	HO Sun	Sun
	Inputs			
Step 1.a	Expected Oil Demand	26,435	10,057	3,221
Step 1.b	Exp Demand, Grains Equiv	69,566	26,465	8,476
Step 2	Expected Yield, Tons/ha	1.3	1.2	1.2
Step 3	Safety Parameter	1	1	1
	Yield Std Dev	0.1	0.1	0.1
	Outputs			
	Actual Yield	1.281	1.116	1.066
	Crop Size	68,571	24,603	7,530
	Parameters			
	Oil-Grain Ratio	38%	38%	38%
	Meal-Grain Ratio	60%	60%	58%
	Crop Growth Rate	12%	15%	10%
	Years of Growth	5		
	Crushing Capacity Tons/day	300		

History Based Data
Nature Based Data
Company Decision
Output

	Canola	HO Sun	Sun	Total
Overdraft Cost (usd/ton*day)				
Grain	0.12	0.15	0.15	
Oil	0.2	0.2	0.2	
Meal	0.15	0.15	0.15	
Crush Cost (usd/ton)	40	55	55	
Capacity				
Grain	6560	10000	0	16,560
Oil	1500	1500	1500	4,500
Meal	2000	2000	2000	6,000

	Canola	**HO Sun**	**Sun**
Price / Supply elasticity Grain->	0	0	0
Price / Supply elasticity Oil->	-0.5	-0.5	-0.5
Price / Supply elasticity Meal->	0	0	0
Initial Grain Base Price	500	500	500
Initial Oil Base Price	1,700	1,700	1,600
Initial Meal Base Price	300	300	300
Oil Price Std Deviation	1%	1%	1%
Initial Grain Actual Price	500.0	500.0	500.0
Initial Oil Actual Price	1,657.6	1,893.7	2,089.1
Initial Meal Actual Price	300.0	300.0	300.0
Crush Margin	310	400	468