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Dynamic risk assessment model to the corn production system in Mato Grosso, Brasil

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The agricultural sector suffers the influence of various risk factors. Although there is no profit without risk, it is very important to know the risks faced and devise strategies to minimize them. In this sense, this paper proposes a new approach for risk assessment, adapting the system dynamic methodology to the study of risk in agricultural systems. From this new approach, it was possible to identify new risk factors for the maize production system in Mato Grosso, Brazil. Several simulations were carried out, in order to detect the impact of each identified variable in the profitability of the system. The most important factors influencing profitability were those that directly affect the revenues of the system, such as the exchange rate, sale price, and yield.

Keywords: Maize, System Dynamics Modeling, Simulation

JEL codes: C18 - Methodological Issues: General, Q12 - Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets, Q14 - Agricultural Finance.

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1. Introduction

The state of Mato Grosso is currently the leading agricultural producer in the country. Some structural aspects such as topography, climate, the spatial configuration of the properties that, in general, have large areas, in addition to cultural aspects intrinsic to the inhabitants of this region, favors the large-scale production, mainly commodities such as soy, corn, cotton.

Another key aspect to explain the success of the agricultural sector in the state is the possibility of a second crop. This practice is still in consolidation in the main agricultural region of the state, the north-middle region, where the municipalities of Sorriso, Lucas do Rio Verde and Sinop are located, which appear frequently in the list of the largest agricultural producing counties in the country.

Initially called "*safrinha*" (which literally translates to "little crop"), this second crop, which happens in this region, roughly, between the months of January and July, began as an alternative for not letting the land unprotected in the dry season, thus avoiding problems related to physical, chemical and biological aspects of soil, which would imply lower yield of the subsequent crop. Thus, producers in this region, characterized by soybean production, began to incorporate a second crop, producing corn or cotton. The second season also promotes the dilution of fixed costs, the intensification of production factors and risk reduction through diversification.

Currently Mato Grosso leads the ranking of states that produce soybeans, corn, cotton, sunflower and has the largest Brazilian cattle herd. However, this result in maize was only achieved due to the enormous growth in the corn production in the second crop. The state production will respond, alone, for 23% of all corn production in Brazil for the 2013/2014 crop season, according to forecasts from the Brazilian National Supply Company (Conab 2014).

Corn production in the state showed a considerable growth in recent years, with an expected output of about 18 million tons, an increase of 122% over the volume produced in the 2009/2010 season.

Therefore, this paper aims to contribute to greater understanding of this process of consolidation of the second crop in mid northern region of Mato Grosso, seeking evidence to understand the risks associated with this production system. For such, a model was constructed to identify the main risk factors of the system and to estimate its impact on the profitability of the second crop corn production in the state.

For such, this work will be divided into five sections, including this introduction. Section two summarizes the literature on the subject. In section three the relevance of this production system to its region as well as the risk model developed will be presented. Section four discusses the results and some of its implications in relation to the Brazilian agricultural sector. The final section will be dedicated to the closing remarks.

2. Literature review

The agricultural sector faces a high level of uncertainty when compared to other productive activities. Besides the most common risk factors that are also noticeable in other sectors of the economy (such as macroeconomic risk, market and operational), the agricultural activity also suffers from climate impacts, pests and seasonality. In this sense, it is important to understand the risk for each production system in order to have a well-established risk management strategy, with a clear understanding of the risks that will be faced and the strategies to minimize them.

The high level of globalization nowadays has influenced the pricing dynamics of agricultural commodities, which undergoes greater influence of international prices traded on the stock exchanges. In this sense, many of the studies on risk in the agriculture sector focus on analyzing market risks arising from fluctuations in prices traded on stock exchanges.

Goodwin and Schnepf (2000) analyzed the determinants of corn and wheat price variability to the United States. Their results showed that the largest effects are originated by crop-growing conditions (data above average tend to reduce price volatility). There were also seasonal effects in volatility, being the summer period of greater volatility. Other risk factors found by the authors were the use relative to stocks[1] and factors related to the structure of the future market such as an increase in day trading or trading volume.

Santos et al. (2007) evaluated the relationship between corn prices in the domestic and foreign market from 1996 to 2006. They found a causal relationship between the corn price on the international market and the price received by domestic producers. Using the Granger Test the authors found one-way relationship between the external price and the price at producer level, suggesting that external prices cause, in the Granger way, the domestic prices. Another result found through a co-integration test indicates that the series would be co-integrated and, therefore, they have long-term relationship.

Caldarelli and Bacchi (2012) also evaluated the influence factors in the corn price in Brazil. As a result the authors found that external corn prices have relative importance in the formation of domestic grain price. It was also found a strong interaction between the corn and soybean markets, with a complementary relationship in the supply and a substitutability relationship in the demand.

On the same topic, Margarido and Barros (2000) analyzed the price transmission of international agricultural commodities from external to local agri-markets in Brazil. The results showed that the external variables has the most influence on the behavior of agricultural prices in Brazil compared to domestic variables.

Muhlen and Costa (2013) sought to analyze the behavior of soybean producers as to price risk and to the use of agricultural derivatives in Marazion, a town in Mato Grosso do Sul, Brazil. Through a survey, the authors found that the use of price protection tools is still not significant, being the

[1] World Agricultural Supply and Demand Estimates forecasts of annual total use (domestic use plus exports) relative to ending total stocks.

producers with larger property, more schooling and who are more capitalized the ones who use these tools the most. The reason given for non-use was mostly lack of knowledge and lack of trusted professionals able to guide producers.

Other research studies seek to identify the risks associated with climatic factors, such as drought (Da Mota et al. 1992; Wu, Hubbard and Wilhite 2004), climate change (Torriani et al. 2007; da Silva, Campos and Silva 2012; Torriani et al. 2007) and sowing dates (Nied et al. 2005). Silva et al. (2012) conducted a study on the impacts of climate change (based on the reports of the IPCC - Intergovernmental Panel on Climate Change) on agricultural climatic risk zoning of maize grown in Brazil´s Northeast region. The authors found that the increase of air temperature has a direct impact on arable land, reducing the period of the crop and yield dramatically. Another result found showed that maize cultivation from mid-May proved to be unfeasible from an economic standpoint.

Torriani et al. (2007) used IPCC scenarios to assess the impact of climate change on maize yield in Switzerland. In a first study, the authors found that changes in precipitation significantly affected the yield distribution. A second study showed that the sowing anticipation reduced the negative impact of climate change on the yield stability, but it was not enough to ensure the present yield levels.

In some regions of Brazil, corn is grown in the second crop, or safrinha, usually in succession to another culture (eg.: soybeans). In addition to providing a new source of income, this strategy also brings new risks because it is necessary that both crops grow in the same rainy season. Nied et al. (2005) studied the effects of different sowing dates for maize cultivation in Rio Grande do Sul, Brazil, seeking to estimate the risk of water deficit. The authors found higher probability of water deficit in October, November and in the first half of December.

Although the literature is rich in these subjects, there are still some issues that need further study: the evaluation of other risk factors such as input prices, fuel, exchange rates and its impact on the production system. However, there is no methodology in the current literature specific to these factors applied to agribusiness. In this sense, this paper proposes a new approach to risk assessment based on dynamic systems.

The dynamic systems modeling is an approach that seeks to understand the functioning of complex systems over time. Created in the 1960`s by Professor Jay Forrester (Forrester 1961) of the Massachusetts Institute of Technology to analyze cases in engineering, currently this approach has been widely used in many areas, particularly in environmental, economic, social and biological (Filho, Figueiredo and Neto 2009) models. Its application to project management is still, according Lyneis and Ford (2007), one of the most recognized uses of dynamic systems modeling.

The concept of dynamic systems is related to the concept of Systems Thinking (ST). However, they are different paradigms. Systems Thinking establishes the view that organizations can be seen as an integrated and complex system in the sense that a change in a given time will chain an impact on other variables, either on the same time or at different times, as these variables are interconnected. The System Dynamics Modelling is a methodology that applies the concept of ST in the development of formal models in order to describe, understand and simulate the relationship between the variables and identify their behavior over time.

Due to its complex feature (by involving different areas of knowledge) and dynamic (by having several activities that are performed in different periods), the agricultural sector arises as a field full of situations in which the methodology of dynamical systems can be applied.

The simulation of production systems is a major issue for agricultural success. This process is widely used in farm management as it assists owners and extension technicians in the process of decision-making. Furthermore, it is also important for research as it helps the identification of priority areas for scientific research. In addition, the simulation models can be used as a learning tool, accelerating learning and students' experience(Cunha et al. 2010).

One of the first studies of dynamical systems applied to agribusiness was developed in the 1970s by Meadows (1970). In their study, the author developed a dynamic system model to analyze the commodity production cycles for rearing pigs, chickens and cattle (Tedeschi, Nicholson and Rich 2011).

Another dynamical systems modeling study applied to agribusiness was made by Conrad (2004). The aim of this study was to understand the impact and the propagation of adverse large-scale shocks to the production of meat, milk and corn. Preliminary model analysis demonstrated its promise in helping government agencies formulate improved policies for responding to major disruptive events in agriculture.

Parsons et al. (2011) developed a model applied to an integrated production system, especially a system of crop-livestock integration. Its objective was to evaluate the production system of sheep on the Yucatan peninsula in Mexico. Model evaluation indicated that the integrated model adequately represented the complex interactions that occur between farmers, crops, and livestock.

However, few studies are found using the dynamic system approach in the Brazilian agribusiness sector. The sector has a high share in GDP and, as it is very sensitive to climate adversities, and to market fluctuations, it requires studies with this approach to understand the behavior of its variables over time, assisting the producer in its decision-making.

3. Methodology

3.1. Characterization of the study area

The cultivation of second crop maize in the state of Mato Grosso is relatively recent and its practice was possible from some technological advances such as soybeans and corn seeds with shorter production cycle, allowing the cultivation of these two crops in the same rainy season. According to the Brazilian Institute of Geography and Statistics – IBGE (2014), in 2003, the state produced nineteen percent of domestic production of the grain and just nine years later, this share increased ten percent, reaching a volume of approximately fifteen million tons.

[Figure 1]

In 2003, maize production was concentrated in the central region of the state, with the municipality of Lucas do Rio Verde leading the production. Figure 1 shows that over the years the production has grown in the northeast direction. Another important factor is the growth pattern, which always grew in the surroundings of the main producing regions.

Since this is the most important agricultural producer center of the state, the mid Northern region accounts for about 44% of the production of the second crop corn in Mato Grosso (IMEA 2014), which represented 10% of national production in the 2013/2014 season. Due to its importance, this region was chosen as the focus of this work.

3.2. Characterization of modal farm

The first step of the economic evaluation of the production cost was the characterization of the farm where the analysis was performed. It was chosen to work with the concept of modal farm. The modal farm is defined as a productive unit that has features that approximate the local reality profile to the regional (CONAB 2010).

The Mato Grosso Institute of Agricultural Economics (IMEA) in partnership with Conab performed the panel used in this work. The modal farm set in the panel has a cultivable area of 1,500 hectares, which is used twice a year, in the first crop (early rains) for soy cultivation (1500 ha) and in the second crop – safrinha - (end of rains) for growing maize (900 ha). In this situation, the limiting factor for corn production area is the raining period and technology, referring to the yield of farm machinery.

The labor characterized in the panel has both fixed and temporary workers. In the first category, the farm has four employees, one machine operator, two tractor drivers and a cook. The temporary labor includes a machine operator and two tractor drivers with a three-month contract. However, it is noteworthy that these workers serve the entire farm, ie, all cultures produced there. The annual expenditure on wages and payroll taxes was R$ 178,605.00. This cost was split between the two crops for their use of land.

The farm infrastructure has a house, a lodging, a cafeteria, a shed, a tank and two warehouses, one for products and another for packaging. The average value of these buildings was approximately R$ 416,500.00.

The machinery used in the modal farm corresponds to a small tractor, one medium, two large, one self-propelled sprayer and one harvester of forty feet. The farm also uses a distributor of lime and fertilizer, an agricultural trailer, a planter of twenty lines, a water tank of 20,000 liters, a straw wagon, a shell kit and a corn platform eighteen lines. The estimated value of those items was R$ 4,497,400.00, of which R$ 3,863,000.00 for machinery and R$ 416,500.00 for implements.

3.3. The Production Systems modeling in the second crop

Due to its flexibility, multidisciplinary and its intuitive development environment, the approach of dynamical systems can and should be applied to agricultural systems. Its use gives important information about the risks associated with the agricultural production and the decision-making process.

The modeling was performed in 10.0 Stella software, which is a modeling tool for building dynamic systems that use an iconographic interface to facilitate the construction of these systems.

The software allows a better understanding of how complex the systems really work from a practical and dynamic view.

In order to estimate the relationship of each variable and its dynamics, it was necessary to monitor all activities that occur in the production process before the production cost estimation. Each activity had its estimated cost according to a specific methodology, which presented an innovative character by the adoption of a new approach for evaluating cost and risk.

The cost of each activity in the production process depends on three factors: labor, machineries and inputs. The pricing of these production factors follows the methodology defined by Conab (2010). However, to capture all of the relationships between variables in the system by this new approach, the modeling process was built to use a minimal level of aggregation as possible. Figure 2 shows, as an example, the pricing of a tractor with its dependent variables and their relationships.

[Figure 2]

All the activities in the production system were estimated by the production cost panel. With the advice of farmers and technical experts it was estimated the technical coefficients, labor and inputs requirements for each activity and each machinery.

The costing system used to estimate the production cost was the Activity Based Costing (ABC). This system is an instrument of accounting which aims to improve the cost visualization by analyzing the activities developed by the company and their respective relationships with the products.

As the production process in agriculture is divided into various activities and the smooth running of these is directly related to the farm profit, using a costing method that enables a greater understanding and control of each of these activities becomes essential. In the ABC method, costs are distributed according to the activities performed by the farm, and precisely through these activities is that costs are allocated to products, goods or services. Thus, the impact for each activities is obtained in the production process. Figure 3 shows an example of activity pricing for spraying.

[Figure 3]

It is important to note that although the ABC system is not a new methodology, its application to the Brazilian agribusiness is innovative and has the potential to generate important indicators that will assist the decision making process, positively affecting the success of their activity.

The main advantages presented by this costing system are: i) it allows a better estimation of the production cost by showing it in more detail; ii) it provides better performance indicators, facilitating the decision-making process; iii) it displays costs through activities; iv) it mitigates the distortions caused by arbitrary apportionment (Moraes et al. 2014).

One of the main features of the ABC system is that it is divided into two parts: Cost and Expense. The cost can be understood as the financial sacrifice on the acquisition of goods and services to be used in the production of another good or service. Expense can be understood as all financial sacrifice for acquire revenue.

[Figure 4]

The chart in Figure 4 shows the costing system structure used for these study activities. The "Cost" item has two categories: i) direct cost and ii) indirect cost. Direct costs are those that can be allocated directly in a productive activity, for example, seeds or harvesting machinery expenses. Indirect costs are those related to productive activity, but may not be directly related to a productive activity. This allocation is usually performed by some method of apportionment. Examples of indirect costs are technical assistance, maintenance and depreciation.

In the "Expenses" category, there are three items: i) administrative expenses, ii) financial expenses and iii) selling expenses. Administrative expenses are those expenditures with the administration of the property and that are not related in a direct way with the productive activity, for example, energy, alimentation, telephone, accounting and legal assistance. Financial expenses represent expenditure on loans, financing and interest rates. Finally, sales expenses are those that include all necessary expenses for selling the product, such as storage costs, transportation and processing.

3.4. Identification of risk factors

The identification of risk factors occurred after the production system modeling in Stella software, because, through this software, it was possible to identify the relationship between variables as well as the system dynamics.

It is important to note that this is a new approach and its advantage is to capture new interactions in an intuitive way, creating important information to help the farm decision-making process. To do that, it was necessary to perform a detailed study of the entire production system. To capture the relationships of all variables, it was required to build the model equations fully disaggregated. In this sense, different modules were built to group different equations and variables. These modules were interconnected via connectors, allowing better organization and understanding of its dynamics.

Sixteen different risk factors have been identified for the corn production system, which were grouped into four risk categories, namely: Exchange Rate, Markets, Agronomics and Inputs. The first category refers to macroeconomic variables such as exchange rates, which influences both the selling price and input prices. In the Market category, it was identified the corn selling price and the oil (diesel) price. In Agronomic factors, grain yield was identified, which undergoes the influence of climatic factors as much as the crop management. The last category is the Input, which has the price of twelve products that can be grouped into fertilizers, seeds, adjuvants, insecticides, herbicides and fungicides. This information is summarized in Figure 5.

[Figure 5]

Eight risk scenarios were created, plus the baseline scenario, for which it was used the average of the 2013/2014 season prices (October 2013 to September 2014). For those eight scenarios, several simulations were run, with positive and negative shocks of one, two and a half, five and ten percent of variation in relation to the baseline scenario.

At the end, 144 simulations were performed, which consisted of a combination of risk scenarios with risk factors. In each simulation it was estimated the impact of each variable on the system profitability, always in Brazilian Reais per hectare.

4. Results

The variable that had the highest impact on the production system was the exchange rate (with a marginal impact of 1.9%), due to its direct impact on the system revenues. As a result of the high level of globalization of world economies, the exchange rate appears as an important variable for agribusiness, with direct impact on the activity outcome. In general, its depreciation tends to increase revenue as the commodity price rises. However, currently most agricultural inputs in Mato Grosso are imported or are influenced by the exchange rate. Thus, the exchange rate depreciation ends up raising the production cost, which generates an uncertain effect on the final profitability.

In this sense, the simulation results showed that the dollar impact on maize production system is much larger on revenue than the cost, where it was estimated three-quarters of the effect on revenues and the remaining on cost. In sum, it was found that an exchange rate appreciation (a movement were the Brazilian real values more than the U.S. dollar) has a much worse net effect than an exchange devaluation, where the gains from sale for a higher price more than offset the losses from the purchase of more expensive inputs.

Corn selling price was the second with greater impact, with a marginal impact of 1.21%. Corn yield also presented a positive marginal impact on the system profitability (0.82%). Due to its direct relationship with revenue system, these were the only variables that had a positive impact on the system profitability.

After that comes the Inputs. In this category, the inputs that stood out were the fertilizers and seeds due to their high participation in the production cost. Diesel came in the twelfth place, with a negative marginal variation of 0.05%. Figure 6 summarizes the simulations results for all variables.

[Figure 6]

5. Conclusions

The Brazilian agricultural sector is influenced by various risk factors. This study aimed to identify the risk factors affecting the corn production system in the second crop cycle in Mato Grosso, Brazil. From an innovative approach, with the use of dynamical systems theory applied to agriculture sector, it was possible to estimate the impact of each risk factor in the system profitability.

It was observed that the risk factors that most influence the system are those that have direct impact on system revenues, such as the exchange rate, corn selling price and the corn yield. In the cost side, the factors that had a greater impact on the system outcome were the fertilizers and seeds. By using this new approach, the evaluation of the system dynamics occurs, hence, generating information that supports the decision-making process of the producer.

This new approach has the advantage to improve the risk analysis of the Brazilian agricultural production system by letting us go beyond the traditional sensitivity analysis. As the Brazilian Agricultural System is becoming so dynamic and complex (some farms in Mato Grosso can grow up to three different crop in the same season), the System Dynamic methodology presents itself as a promising alternative.

The seek for sustainable systems is pushing the producers to promote intensification of land. A promising alternative is the integrated systems, such as Crop-Livestock-Forest integrated system. Those systems are very complex and dynamic and have a large amount of interactions. The Brazilian government has a goal to expanding the adoption of these systems in 4 million hectares until 2020. As there are a lack of economic analysis of these systems in Brazil, this new approach presented here shows as a promising alternative in the extent that allows the modeling of these complex systems from a new perspective, capturing the interactions and the complexity of these systems in a clear and precise way.

Tables and Figures

Figure 1

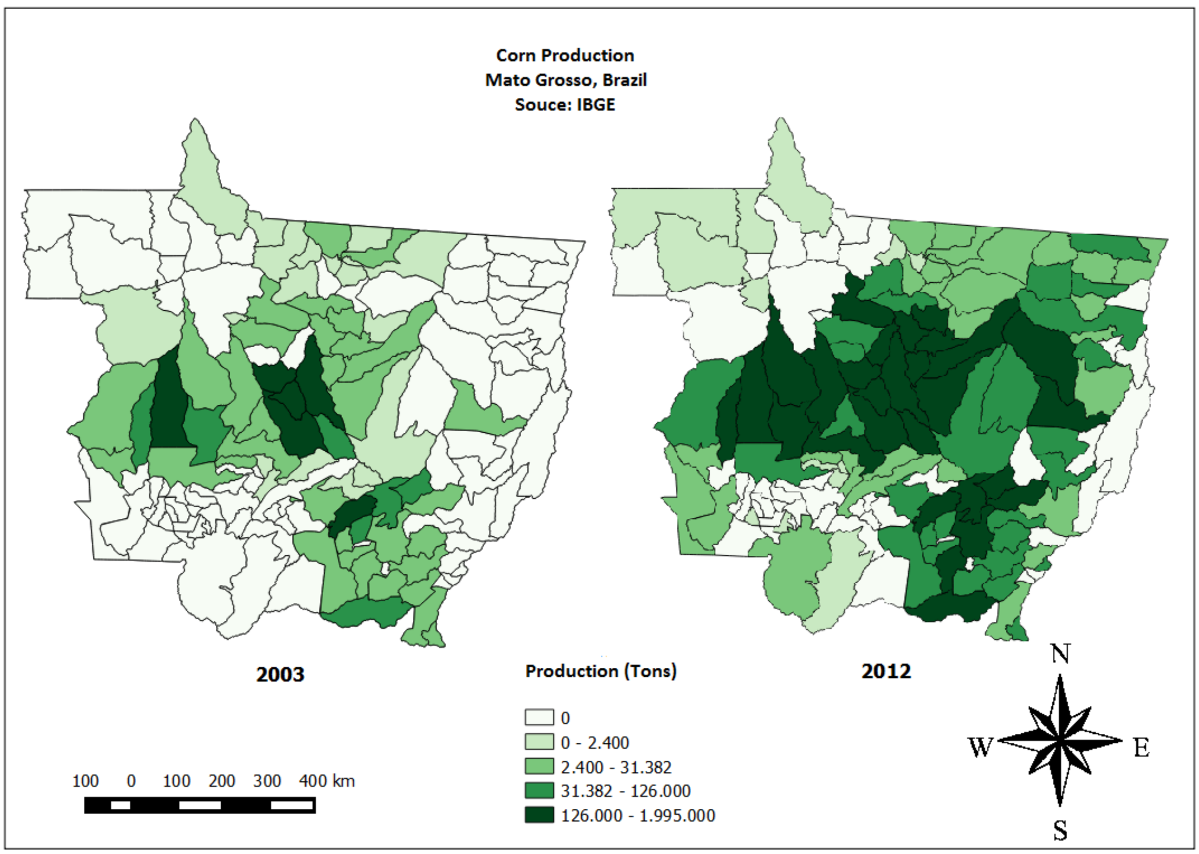

Figure 2

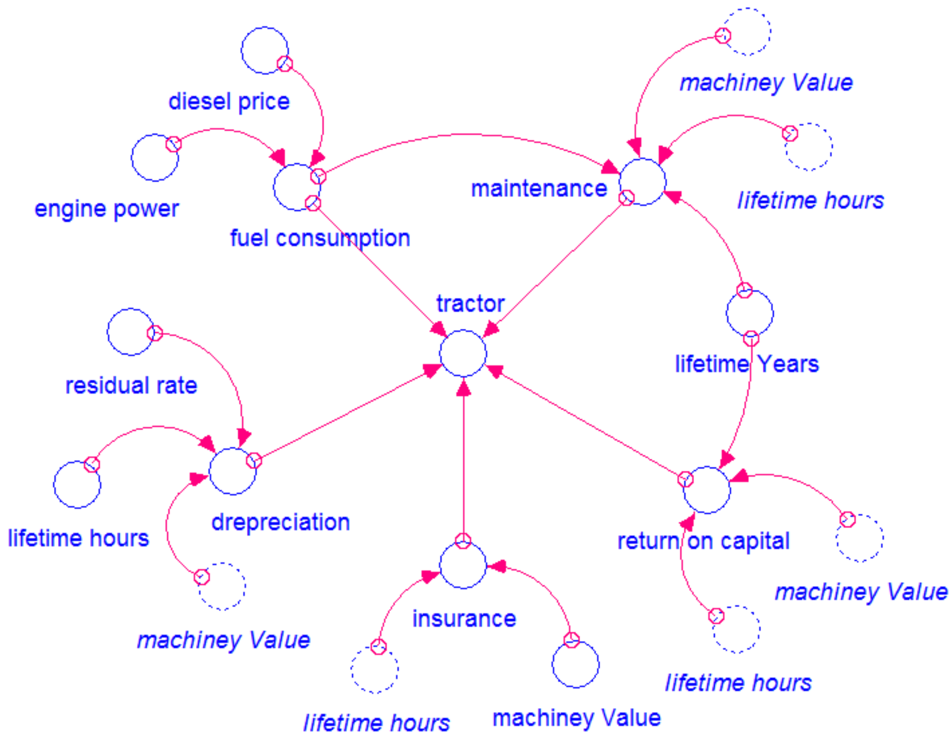
diesel price
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Figure 3

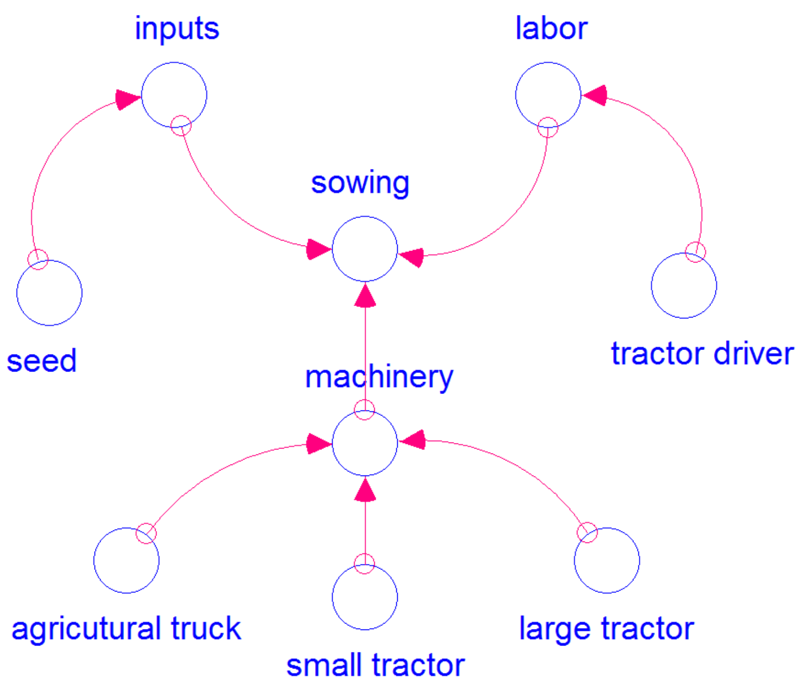


Figure 4

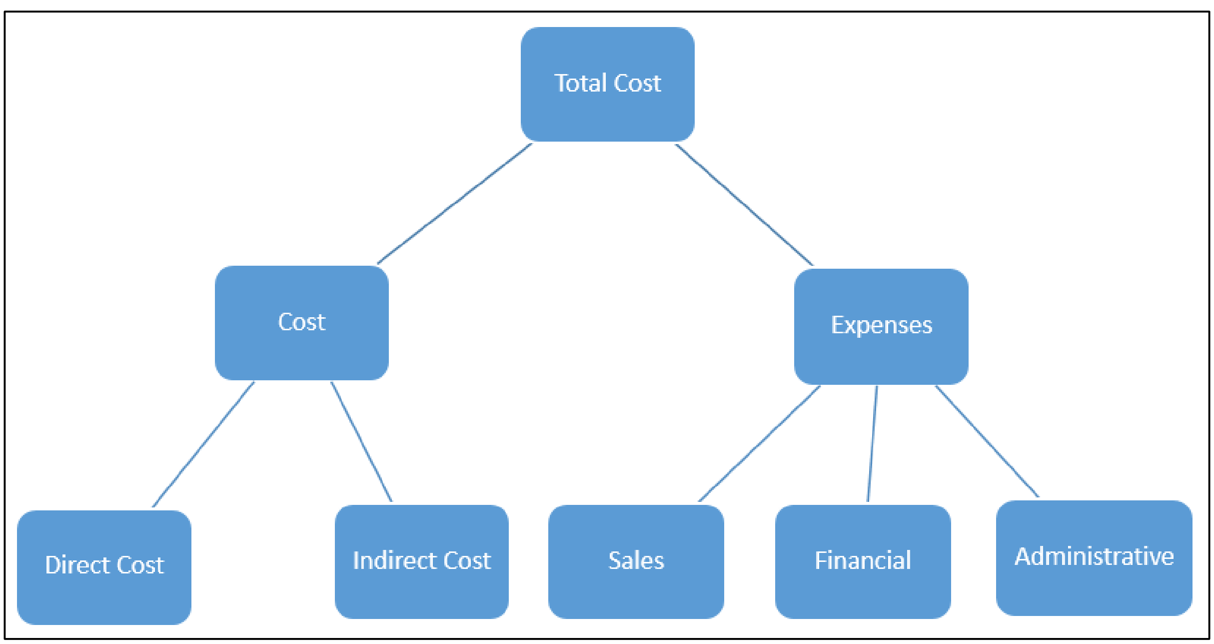


Figure 5

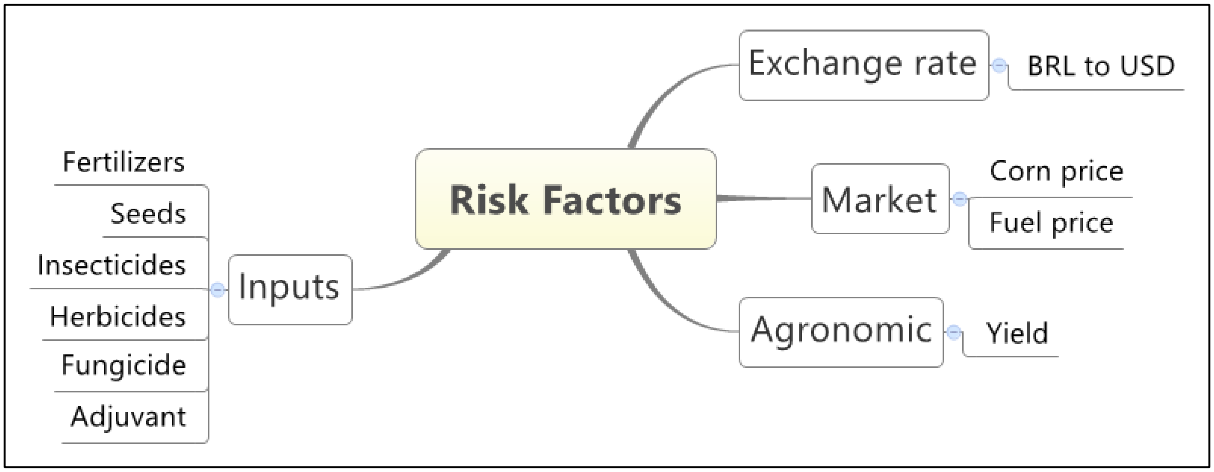
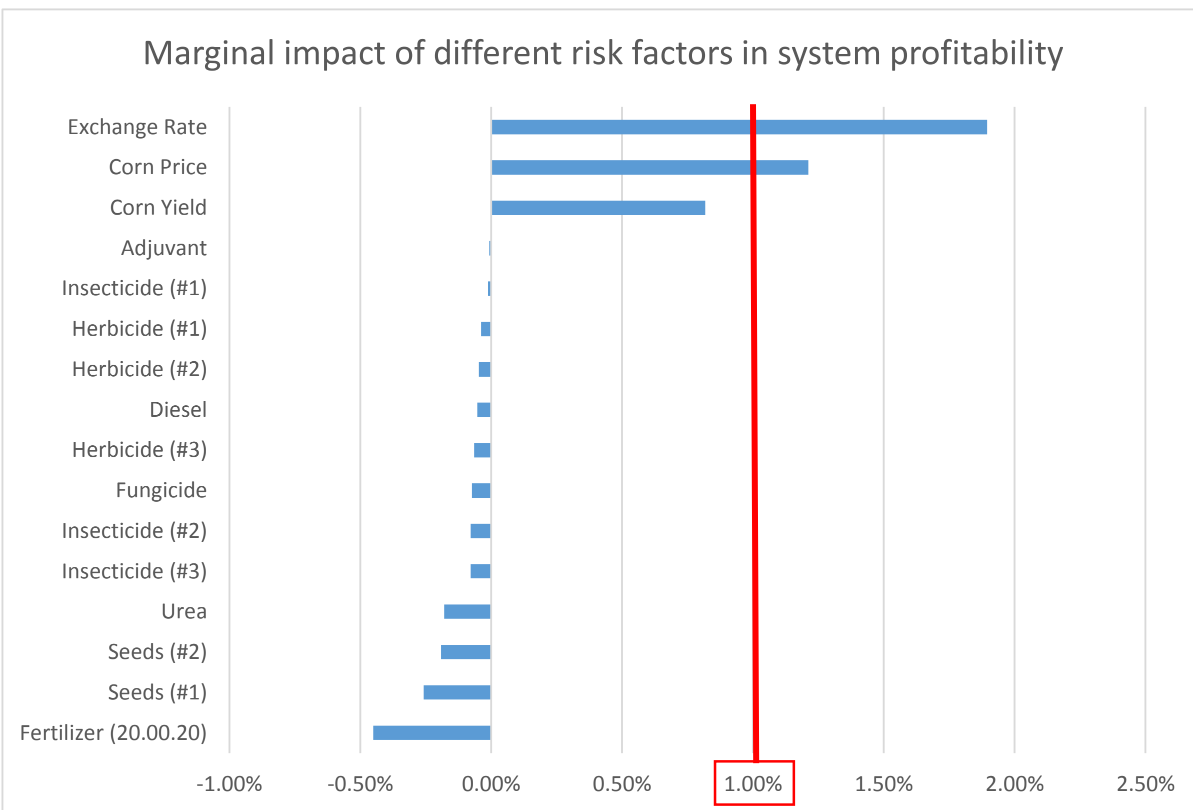

Risk Factors
Exchange rate
BRL to USD
Market
Corn price
Fuel price
Agronomic
Yield
Inputs
Fertilizers
Seeds
Insecticides
Herbicides
Fungicide
Adjuvant

Figure 6


Marginal impact of different risk factors in system profitability
Exchange Rate
Corn Price
Corn Yield
Adjuvant
Insecticide (#1)
Herbicide (#1)
Herbicide (#2)
Diesel
Herbicide (#3)
Fungicide
Insecticide (#2)
Insecticide (#3)
Urea
Seeds (#2)
Seeds (#1)
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-0.50%
0.00%
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1.00%
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2.00%
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