

Costs management in maize and soybean production

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Abstract

Purpose – This research aims to identify and analyze the relationship between the elements that make up maize and soybean production costs and the revenue earned from the respective productive activities.

Design/methodology/approach – We used production cost data from Conab and the market price of maize and soybean obtained from FAO in our analyses. These data were analyzed from 1997 to 2016. The study is based on the Neoclassical Theory of Firm and its subdivision: Cost Theory.

Findings – The data showed that the variables related to the production costs of maize and soybean are associated with the gross revenue ha⁻¹. Therefore, it is possible to predict them from the regression equations. Based in these findings, farmers will have a tool that may be used in making of the best decision when they purchase agricultural inputs.

Originality/value – The main contribution of this paper relates to the possibility to predict maize and soybean revenue from the cost variables that are part of the production cost of these commodities. In this context, an interpretation of production costs, analyzing the variables involved in the cost of the crops, and with a consequent evaluation of the information on the gross revenue ha⁻¹, enables information to be obtained for decision-making regarding the agricultural activities.

Keywords – Accounting; planning; agricultural management; agribusiness.

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I Introduction

The modernization of agribusiness has made Brazil the largest producer of food located in the tropical region. While in the 1940s Brazil was a net importer of food, with its agricultural production mainly focused on coffee (Melo, 1982), nowadays the country is one of the largest producers and exporters of agricultural products in the world. Grains such as soybean and maize have experienced rapid growth in production and productivity due to geographical expansion in the Brazilian Center-West region and the adoption and diffusion of technological innovations (Borlachenco & Gonçalves, 2017; Souza, Buainain, Silveira, & Vinholis, 2001). In this context, research and extension systems have played an important role in agricultural development and have been fundamental in achieving innovation potential (Figueiredo, 2016). In developing countries, innovation has made it possible to solve several challenges faced by agriculture (e.g., the adaptation of cultivars to climatic variations and the management of natural resources). Therefore, the prosperity of rural establishments has generally been associated with the modernization of agriculture and the economic benefits originating from it.

Some technologies including seeds, fertilizers, defensives, machinery, and agricultural implements have been essential for increasing of productivity of soybean and maize (Herrendorf & Schoellman, 2015; Silveira, Borges, & Buainain, 2005). However, the adoption of this set of technologies has resulted in an increase in production costs over the last few years and consequently in the need for efficient and effective farm management. Typically, farmers make decisions by analyzing only a few sets of factors. This also occurs in soybean and maize production systems, which essentially depend on the supply of inputs. In addition, the formation of agricultural commodities prices is not carried out by farmers; they are only “price takers” (Alves, 1998). Given their “atomization”, the soybean and maize markets operate with characteristics close to

perfect competition. Thus, controlling costs and increasing crop productivity are important factors that will determine the profitability of a farm.

Given this backdrop, in the last few years several studies on production costs and their estimates have been conducted. Originating from the industrial sector, different methodologies have also been applied in other sectors, including agriculture. The agricultural inputs used in this sector, as well as their agricultural results are more complex nowadays than in the past. Controlling production costs is vital due to the narrow margin of profitability of the crops (Oliveira, Santana, & Homma, 2012). Therefore, any item of production costs has the potential to contribute in a significant way to final cost. By observing the items included in the production costs of an activity and the income earned from it, a farmer can choose the best alternative when acquiring the agricultural inputs or decide on certain services. The importance of cost analysis in agricultural activities is in line with the utility of information for decision making to identify the profitability of the activities (Barros et al., 2006; Carareto, Jayme, Tavares, & Vale, 2006; Martin, Serra, Antunes, Oliveira, & Okawa, 1994). Regarding public policies, there is a need to use calculations and estimates of agricultural costs. Production costs, for instance, serve as a basis for agricultural policies, especially to make decisions about price support levels.

Although it is important to collect production cost information, accounting methods for agricultural activities have received little attention from accountants and regulators in some countries. On the other hand, there are countries that have developed sophisticated tools for agricultural accounting. For instance, the United States Department of Agriculture (USDA) has been estimating annual production costs and returns for major agricultural commodities since 1975. In Canada, the Farm Level Data Project (FLDP) provides data to monitor financial and economic conditions on farms. An essential component of this is the Whole Farm

Database (WFDB), which integrates all available agricultural data.

In the European Union, since 1965 the Farm Accountancy Data Network (FADN) has been developing general procedures and detailed guidelines for agricultural accounting. The FADN collects farm data to determine costs and yields by conducting a commercial analysis of farms. These efforts have produced a structured set of data collection rules and procedures designed to produce aggregate reporting. In Brazil, the *Companhia Nacional de Abastecimento* (Conab) (the National Supply Company, in English) provides the production costs for the main crops and they are used as the basis for the formulation of agricultural policies (e.g., Minimum Price Policy).

Information on production costs can support farmers in making efficient and effective decisions (Barros et al., 2006; Carareto et al., 2006; Martin et al., 1994). Farm management has become an alternative for the identification of major bottlenecks in production systems, enabling the generation of information capable of supporting interventions to increase their efficiency. Given this, production systems increasingly require a high degree of technical, economic, and administrative knowledge to ensure better results (Artuzo, Jandrey, Casarin, & Machado, 2015).

In the light of the above, the purpose of this study is to identify and analyze the relationship between elements that compose the production cost of soybean and maize and the revenue earned from the respective productive activities. These commodities were chosen due to their importance in Brazilian agribusiness and this study makes it possible to identify which variables compose the production cost directly related to the income obtained by the crops.

The analysis of production costs may help to manage farmers' activities, making it possible to analyze the components that involve the production, costs, and benefits generated by them (Marion & Segatti, 2006). In this context,

by aggregating market information, it is possible to identify the risks and opportunities that the activities present in the long term. For this, a plan that uses market information and the production process is necessary to contribute to farm decision making. This paper contributes to the agricultural sector, government, and especially to farmers, by outlining the relationships between the income earned from agricultural activities and their costs, providing guidelines for predicting them.

2 Importance and productive aspects of maize and soybean

Agribusiness accounts for approximately 25% of Brazilian Gross Domestic Product (GDP) (Galvão, 2017). Therefore, the role played by the agribusiness sector influences Brazilian economic behavior and may be the result of programs focused on increasing productivity, the adoption and diffusion of agricultural technologies, efficiency in marketing products, and the stimulation of public policies. In this context, the dynamics of soybean and maize have made these crops the main commodities of Brazilian agribusiness.

Nowadays, maize and soybean production systems require a higher level of technical and economic knowledge to ensure the best results. For this, it is necessary to have adequate planning in farms, which requires market information and resource management, among other elements that can support farmers' decision making. Agricultural activities can be grouped into sectors. This research's focus is rural production. Batalha (2001) argues that this segment encompasses several activities (e.g., preparation and management of soils, cultivation of crops, irrigation, and harvests). In addition, this segment has relationships with sectors "before" and "after" the gate. "Before" the gate are enterprises that market agricultural inputs (e.g., fertilizers, defensives, correctives, seeds, machinery, equipment, and services), and "after" the gate refers to activities performed after agricultural products leave the farm (e.g., transportation, storage, industrialization, packing, and distribution) (Batalha, 2001).

This study only focuses on “inside” the gate (i.e. on the farm), because in this segment the farmers’ decide “what, where, how, when, and why” to produce. “What” refers to the agricultural activity. “Where” is the location of the agricultural activity. “How” refers to the type of agricultural system (e.g., conventional, organic, or agroecological). “When” refers to the best season and/or year to produce. Finally, “why” is the main motivation to produce (e.g., income generation). Management of these factors may result in income maximization. Therefore, analyzing production costs, as well as their relationship with market price, provides an understanding of the components that involve agricultural production, costs/benefits, and risks and opportunities.

2.1 Soybean production

Soybean is one of the most important crops to the Brazilian and world economies. This can be attributed to the development and structure of the international market, the consolidation of soybean as a source of vegetable protein, and the generation of new technologies that have enabled the expansion of production in several regions of the world (Hirakuri & Lazzarotto, 2014).

In Brazil, soybean has been consolidated as one of the main agricultural products, strengthening the country’s position as one of the main players in world agricultural trade. Exports from the soybean agroindustrial complex reached approximately US\$ 25 billion in 2016, which represented approximately 35% of national agribusiness exports (Brazil, 2016).

Brazilian soybean production has expanded in the last few years, increasing from 26,160 thousand tons in 1997 to 95,434.60 thousand tons in 2016 (an increase of 264.81%) (Companhia Nacional de Abastecimento [Conab], 2017a). In the same period, cultivated area increased from 11,381.3 thousand ha (hectares) to 33,251.9 thousand ha (an increase of 192.16%) (Conab, 2017a) (Figure 1).

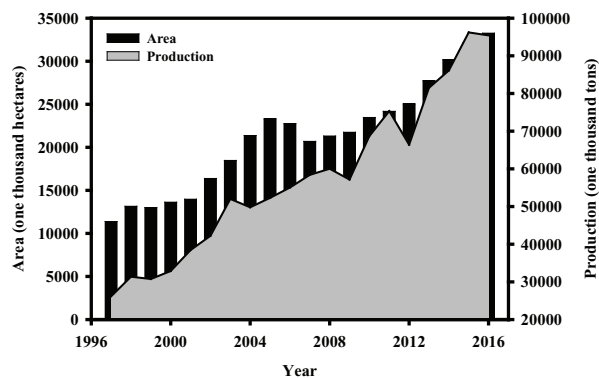


Figure 1. Area cultivated and production of soybean in Brazil from 1997 to 2016.

Note: Source: Adapted from “Summer Cultures - Historical Series”, from *Companhia Nacional de Abastecimento*, 2017a. Retrieved from <http://www.conab.gov.br/conteudos.php?a=1555&t=2>

The increase in soybean production is related not only to the increase in cultivated area, but also to the increase in productivity. In 1997, soybean productivity was 2,298.5 kg ha⁻¹ and in 2016 it was of 2,870 kg ha⁻¹ (Conab, 2017a). This increase can be attributed to several factors, such as: the use of seeds with high productive potential, the application of large amounts of fertilizers for the full development of the crop, the ideal time for sowing, efficiency in management, and efficiency in pest and disease control (Inácio, Urquiaga, Chalk, Mata, & Souza, 2015; Paré, Lafond, & Pageau, 2015; Roberts & Johnston, 2015). However, even with the possibility of implementing production technologies, there are variations regarding productivity between different Brazilian states. Most of the production is concentrated in the South and Center-West regions, which in 2016 accounted for 82.70% of soybean production. Mato Grosso, Paraná, and Rio Grande do Sul states are the largest producers and they are historically among the states with the highest productivity (Conab, 2017a).

Analyzing the global context, soybean cultivation is mainly concentrated in three countries: the USA, Brazil, and Argentina. Together, these countries account for 71.2% and 81.3% of soybean area and soybean world

production, respectively (Food and Agriculture Organization of the United Nations [Faostat], 2017a). Given the increase in productivity that Brazil has achieved in the last decades, it has become the second largest producer of soybeans, behind only of USA.

Due to its expressive participation in Brazilian exports, soybean is an important commodity for the economy of Brazil. Therefore, it is necessary to analyze soybean production costs. Among the elements that impact these costs are technology level (seeds, fertilizers, defensives, and agricultural machinery) and other factors.

2.2 Maize production

The maize productive chain is also an important economic segment of Brazilian agribusiness. Maize production accounts for 37% of total grain produced in the country (Conab, 2017a). Maize production increased from 35,715.6 thousand tons to 66,530.6 thousand tons between 1997 and 2016 (an increase of 86.28%) (Conab, 2017a). With regard to cultivated area, in the same period there was an increase of 15.39%, from 13,798.800 ha to 15,922.500 ha (Figure 2).

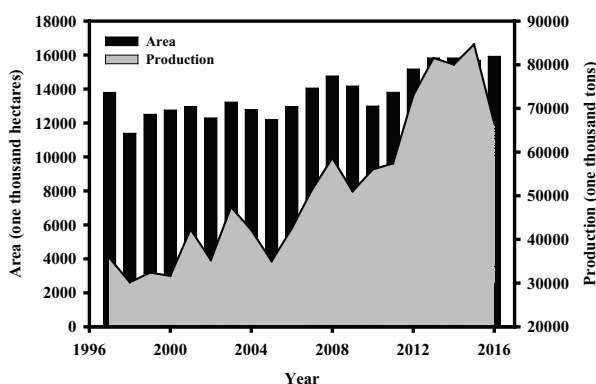


Figure 2. Area cultivated and production of maize in Brazil from 1997 to 2016.

Note: Source: Adapted from “Summer Cultures - Historical Series”, from *Companhia Nacional de Abastecimento*, 2017a. Retrieved from <http://www.conab.gov.br/conteudos.php?a=1555&t=2>

The increase in maize production is related to an increase in productivity, even considering

the increase in cultivated area. While in 1997 maize productivity was 2,588.3 kg ha⁻¹, in 2016 it was 4,178 kg ha⁻¹ (an increase of 61.43%) (Conab, 2017a). Although the average productivity in the last harvests has been between 3,500 and 5,396 kg ha⁻¹ (Conab, 2017a), these values are low compared with the average productivity in the USA (where maize productivity exceeds 9,000 kg ha⁻¹). In addition, maize productivity varies between the different Brazilian states, which may be explained by the technological level of production (Coelho, Cruz & Pereira, 2013). Maize production is also concentrated in the Center-West and South Brazilian regions: in 2016, Mato Grosso, Paraná, and Goiás were, respectively, the largest producers. Historically, these states are among those with the highest yields (Conab, 2017a). In the world scenario, maize cultivation is mainly concentrated in three countries: USA, China, and Brazil. These countries account for 54.49% of maize area and 66.39% of world production of this commodity (Faostat, 2017a).

Compared with US production, it is possible to highlight the potential production of Brazilian maize, because if Brazilian production was similar to US production, considering the area, it could reach 154.62 million tons. For this, it is necessary to invest in the productive process (Heumesser, Fuss, Szolgayová, Strauss, & Schmid, 2012), mainly in an increase in efficiency related to pest and disease control, potential and rational use of agricultural fertilizers, the adoption of precision agricultural machinery and equipment, and other supports for the productive system (Kaneko, Hernandez, Shimada & Ferreira, 2012; Rotili, Afféri, Peluzio, Carvalho, & Santos 2015). The adoption of innovations (product or process innovations) will generate costs, increasing the cost of production of this commodity and making it necessary to evaluate the relationship between production costs and income per ha, to better predict the necessity and viability of adoption and the best way of acquiring inputs.

3 Theoretical-conceptual foundations of the study

This paper is based in the Neoclassical Theory of Firm and its subdivision: Cost Theory. The Theory of Firm was synthesized by Alfred Marshall. It presents models that capture the logic of firm and market behavior, subdivided into three parts: (a) Production Theory, which covers the concepts of production and productivity; (b) Cost Theory, which addresses concepts such as economic cost, total cost, marginal cost, and average cost; and, (c) Income Theory, which aims to focus on the minimization of production costs, with the aim of maximizing profits, and covers concepts such as Total Revenue, Average Revenue, and Marginal Revenue, analyzing the determination of the equilibrium (price and amount) (Pindyck & Rubinfeld, 2002).

Firm refers to the place where several technological transformations occur to generate a good or service. The Theory of Firm explains the behavior of the firm when it develops its productive activity (Vasconcellos & Pinho, 2002). The firm buys inputs (factors of production) and processes and sells them (output) in the market. This process involves profit maximization (Bateman, Edwards & Levay, 1979) and encompasses general industrial activities, including industrial and agricultural, professional, technical, and service activities (Carvalho, 1998; Pinho & Vasconcellos, 2006).

Farms may consider the same line of thought provided above. In farms there is the purchase of agricultural inputs (fertilizers, seeds, and defensives), the processing of them (phase of implementation of the crop until its harvest), and the sale of the product (commercialization). In this context, some researchers argue that agribusiness firms are usually explained by neoclassical economic principles of the Theory of Firm (Sporleder, 1992; Barry, 1999).

Profitability from production is related to its technical and economic efficiency. In this context, technical efficiency involves physical aspects of production (e.g. productivity) and

economic efficiency involves the monetary aspects of production. Based on this, a productive process is sought that obtains the maximum profit or the lowest cost (Münch, Berg, Mirschel, Wieland, & Nendel, 2014), and it is thus essential to analyze the costs of production.

The information generated by the analysis of production costs has relevance at the managerial level, for rural producer decision-making, and at the government level, for rural credit and minimum price policies (Martin, 1994). As the price of maize and soybeans are determined by the market, there is a search to minimize costs. For Pindyck and Rubinfeld (2002), one way of minimizing costs is to choose the best combination of inputs. Under this approach, production is a technical issue, but it brings in several economic aspects that require analysis.

3.1 Agricultural production costs

Based on the costs of agricultural production, it is possible to evaluate the profitability and efficiency of the production system adopted by rural producers (Richetti, 2016). In agricultural production systems, all spending related directly or indirectly to the crop (or product) are characterized as costs (Andrade, Pimenta, Munhão, & Moraes, 2012). Labor, soil preparation, the purchase of seeds, fertilizers, defensives, and fuels are examples of costs of agricultural production (Andrade et al., 2012; Duarte, Pereira, Tavares, & Reis, 2011) incurred from the period prior to planting until post harvest. At the national level, the methodology of Conab (2010) groups production costs into: variable costs, fixed costs, operating costs, and total cost.

Variable costs refer to expenditure on crop costs (e.g., machinery and implements, administrative expenses, seeds, fertilizers, and labor costs) and post-harvest costs (e.g., technical assistance and rural extension, agricultural insurance, external transport, and storage). Fixed costs include depreciation of improvements, installations, machinery and implements,

depletion of cultivation, labor and labor charges, and fixed capital insurance. Finally, operating costs consider variable and fixed costs and the expected return on fixed capital and on land. By adding these amounts, the total cost of production is obtained.

Analyzing and understanding production costs is important at farm and government levels. On the farm, the farmer is the decision maker and seeks, through the processes and productive resources, to select the best input allocation (Menegatti, Lahóz & Barros, 2007) to obtain results that maximize his or her utility. Besides farm management, production costs also serve as support for credit policies and minimum prices (Martin et al., 1994).

4 Methodological Research Procedures

4.1 Description of the study

This study was carried out in Brazil, using soybean and maize data. The data used were: a) the national average productivity, b) cost of

production, and c) market price. Productivity and production costs were obtained by *Companhia Nacional de Abastecimento* (Conab). In addition, the values referring to the market price were obtained from data available from the Food and Agriculture Organization of the United Nations (FAO), Statistics Division (Faostat). The analysis was carried out from 1997 to 2016.

Production costs were delimited according to the Conab methodology (2010). Table 1 shows the variables that make up the cost of production of maize and soybean. Only the costs related to the items that are part of the cost of the crops were chosen, thus excluding any other costs or expenses. The criterion is based on the possible variables of farmer management in the development stage of the commodity production. The “airplane operation” and “machine rent” variables were not used in this research, because during the years of analysis there were no expenses for either variable. The values for the “temporary labor” and “fixed labor” variables were added together, generating a single “labor” variable.

Table 1

Variables that make up the production costs of maize and soybean

I – Cost of the crop expenses	II - Post-harvest costs
a) Airplane operation	a) Production insurance
b) Machinery operation	b) Technical assistance
c) Machinery/Services rent	c) Transport
d) Temporary labor	d) Storage
e) Fixed labor	III – Financial expenses
f) Seeds	a) Interest
g) Fertilizers	V – Other fixed costs
h) Defensives	a) Periodic maintenance of machines / implements
IV - Depreciations	b) Social charges
a) Depreciation of improvements / installations	c) Insurance of fixed capital
c) Depreciations of agricultural implements	VI - Income from factors
d) Depreciations of machinery	a) Expected return on fixed capital
VII – Total cost	b) Land

Note. Source: Adapted from “Conab methodology for calculating cost of production”, From *Companhia Nacional de Abastecimento*, 2010. Retrieved from <http://www.conab.gov.br/CONABweb/download/safra/custosproducaometodologia.pdf>

The values of production costs and prices were deflated to correct them for real values equivalent to the month of December 2016, the final year of analysis. For the deflation of nominal prices, the General Price Index (IGP-DI), calculated by the Getúlio Vargas Foundation, was used, which reflects the price for the final consumer, such as prices within production chains and commercialization channels.

4.2 Description of the analysis

The correlation analysis was performed to analyze the strength of the association between the variables that compose the cost of the crop with the gross revenue ha^{-1} . The normality test was used to verify if the variables follow a normal distribution (parametric variables). For this, the test used was that of Kolmogorov-Smirnov (Lilliefors). This test observes the maximum absolute difference between the cumulative distribution function assumed for the data, in the normal case, and the empirical distribution function of the data.

Based on the normality test result, correlation analysis was performed. For the parametric variables, the Pearson correlation coefficient (ρ) was calculated. For the non-parametric variables, the Spearman correlation coefficient (r) was calculated. The value of the coefficients can assume values ranging from -1 to 1. When the variable assumes the value 1, it

means the correlation is positive and perfect; when it assumes the value -1, it means the correlation is negative and perfect; if one variable increases, the other decreases. Finally, when it assumes the value 0, it means the two variables do not present any correlation (Hair, Black, Babin, Anderson, & Tatham, 2009). For the variables that presented a correlation with gross revenue ha^{-1} , a regression was performed to find an equation that explains the relationship between the dependent and the independent variables. Table 2 describes the independent variable and the dependent variables.

Table 2
Dependent and independent variables

Independent variable	Dependent variables
Gross revenue ha^{-1}	Machinery operation
	Labor
	Seeds
	Fertilizers
	Defensives

Note: Values in Reais (R\$)

To analyze the behavior of soybean and maize production costs, the price per 60 kg bag multiplied by productivity (sc ha^{-1}) was used, resulting in the gross revenue ha^{-1} (Table 3). In addition, the price paid is reflected by the market, and there is interaction between the maize and soybean markets in the formation of the price of both commodities (Caldarelli & Bacchi, 2012).

Table 3
Sale price (R\$) of 60 kg sc of maize and soybean, from 1997 to 2016

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Maize	29.16	32.21	33.99	35.82	25.81	36.81	35.92	31.91	30.48	25.71
Soybean	62.51	50.73	52.58	50.73	56.68	70.82	71.06	69.69	48.37	41.14
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Maize	31.15	32.89	26.15	23.26	30.8	30.78	27.85	26.45	28.3	27.35
Soybean	47.31	59.76	60.64	49.27	51.18	67.35	64.12	60.98	63.48	64.20

Note. Source: "Prices", Food and Agriculture Organization of the United Nations, 2017b. Retrieved from http://faostat3.fao.org/browse/P/*/E/

5 Results and discussion

Production costs for maize and soybean are represented in Figure 3, with the respective gross revenue ha^{-1} , covering the period from 1997 to 2016 and divided into the variables: “machine operation”, “labor”, “seeds”, “fertilizers”, and “defensives”. Between 1997 and 2016, gross revenue ha^{-1} from maize grew by 41.65% (between 1997 and 2014 the increase was 84.72%). During

this period, twice the crop presented greater oscillations in total variable costs: a) between the 2007 and 2008 harvests, and b) between the 2012 and 2013 harvests, of 26.32% and 24.66%, respectively. Regarding soybean, the increase in gross revenue was 11.11% (22.69% between 1997 and 2014). In the period, total variable costs fluctuated mainly between 2007 and 2008, increasing by 31.95%.

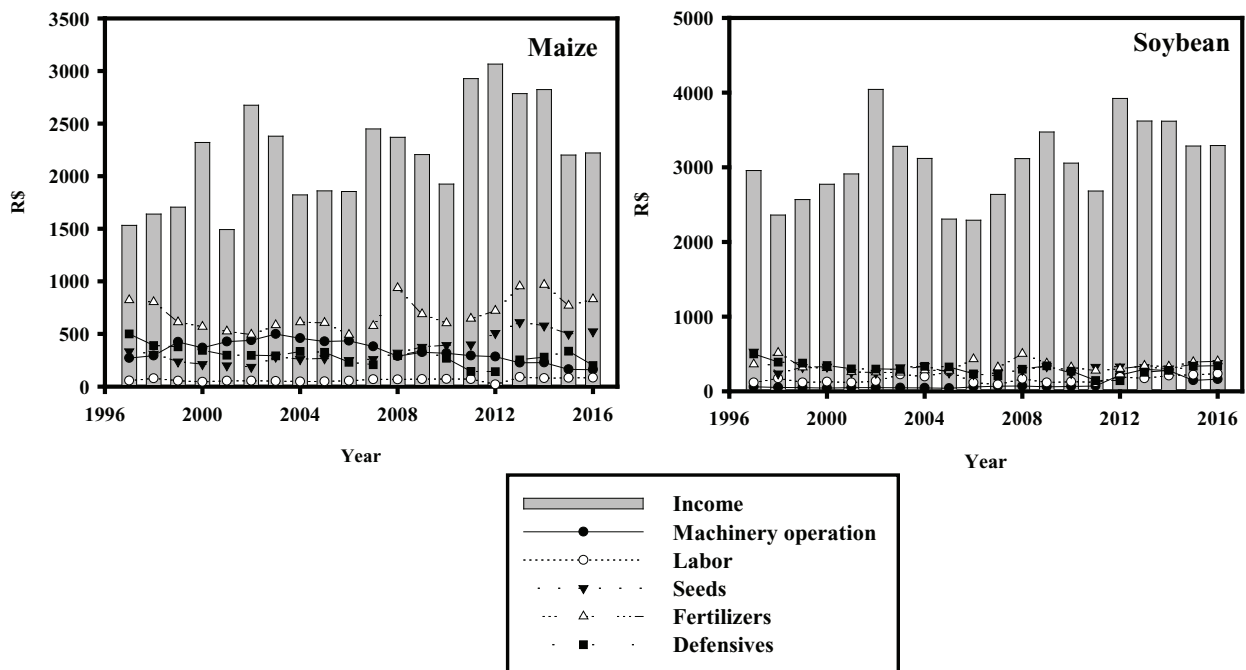


Figure 3. Income (R\$ ha^{-1}) and cost of production of maize and soybean for the variables: operation with machines, labor, seeds, fertilizers, and defensives, from 1997 to 2016.

Note. Source: Adapted from “Prices”, from Food and Agriculture Organization of the United Nations, 2017b. Retrieved from http://faostat3.fao.org/browse/P/*/E/; Adapted from “Summer Cultures - Historical Series”, from *Companhia Nacional de Abastecimento*, 2017b. Retrieved from <http://www.CONAB.gov.br/conteudos.php?a=1555&t=2>

The data set for each variable was tested using the Kolmogorov-Smirnov test (with a 5% error level) to analyze the normality of the data. The variables considered parametric for maize are: a) “labor”, b) “fertilizers”, c) “total cost”, and d) “national production”. Regarding soybean crop,

the variables considered parametric are: a) “seeds”, b) “fertilizers”, c) “defensives”, d) “total cost”, e) “national production”, and f) market price. The normality of the data is due to the low dispersion (oscillation) of historical values between the years from 1997 to 2016 (Table 4).

Table 4

Test of normality of maize and soybean crop for the variables: costs, total variable costs, national production, and market price.

		Normal	
		Yes	No
Maize	Machinery operation		X
	Labor	X	
	Seeds		X
	Fertilizers	X	
	Defensives		X
	Total variable costs	X	
	National production	X	
Soja	Market price		X
	Machinery operation		X
	Labor fixe		X
	Seeds	X	
	Fertilizers	X	
	Defensives	X	
	Total variable costs	X	
National production	X		
Market price	X		

Note: Kolmogorov-Smirnov test with an error level of $p < 0.05$. Yes = parametric data; No = non-parametric data.

Source: Adapted from “Historical Series of Planted Area, Productivity and Production”, from *Companhia Nacional de Abastecimento*, 2017b. Retrieved from <http://www.CONAB.gov.br/conteudos.php?t=2&a=1252&filtrar=1&f=1&p=115&e=0&d=0&m=0&s=0&ac=0&tps=0&lvs=0&l=0&ed=0&i=>

The production cost variables are associated with “gross revenue ha^{-1} ” and “total cost” (Table 5). For maize, there is strong correlation between total cost and a) “labor”, b) “seeds”, c) “fertilizers”, and d) “defensives”. Gross revenue ha^{-1} presented a moderate association with a) “defensives”, b) “machinery operation”, and c) “total costs”. Soybean cultivation had a similar strength of association as the maize crop - only the “defensive” variable had a strong correlation with gross income ha^{-1} . For maize, the “seeds” variable presented the highest coefficient of correlation for “total cost” and “gross revenue ha^{-1} ”, in the amount of 0.973 and 0.858, respectively (with a 1% significance level). Regarding soybean, the “seeds” variable presented the highest coefficient of correlation with “total cost”, to the value of 0.897. In relation to “gross revenue ha^{-1} ”, the “labor” variable obtained the highest coefficient,

with a value of 0.860 (both with a 1% level of significance).

Based on the correlations, it is possible to assert that the production costs of maize and soybean accompany the gross revenue ha^{-1} , for both total cost and its variables (machine operation, labor, seeds, fertilizers, and defensives). Thus, there is a trend in which an increase in the market price of the commodities will increase the price of the agricultural inputs. With regard to this, farmers aiming to increase the price of commodities have the possibility of managing strategies for acquiring inputs (e.g., purchasing in advance).

With the adoption of agricultural technologies, farmers have the possibility of increasing the cost of one variable by reducing the cost of another variable (besides increasing productivity). With this, it is possible to analyze

which will become economically viable. For example, the agricultural management system depends on the treatment of the soil for the farm. Using variable rate fertilizer (AP) makes efficient use of agricultural fertilizers possible (Artuzo, Foguesatto, & Silva, 2017; Artuzo, Soares, & Weiss, 2017). Applying fertilizers in the quantity necessary for the plant enables maximum efficiency in its development and in its productive potential (Duan, et al., 2014; Zhang, 2015). The productive increase is occasionally

and indirectly caused by the “operation of agricultural machinery”. In this example, there is an increase in the cost of “farm machine operation”, a reduction in the cost of “fertilizers”, and an increase in production per area (due to the application and precise amount of fertilizers). The increase in productivity will affect gross revenue ha^{-1} . In this context, the farms can decide on the best combination of decisions in the search for profitable agricultural activity.

Table 5

Maize and soybean correlation matrix between variables: machinery operation (MO), labor, seeds, fertilizers, defensives, total costs (TC), and revenue.

Maize							
	MO	Labor	Seeds	Fertilizers	Defensives	TC	Revenue
MO	1						
Labor	0.682**	1					
Seeds	0.367	0.787**	1				
Fertilizers	0.382	0.746**	0.966**	1			
Defensives	0.287	0.835**	0.729**	0.775**	1		
TC	0.548**	0.752**	0.973**	0.985**	0.831**	1	
Revenue	0.609**	0.647**	0.858**	0.804**	0.546**	0.857**	1
Soybean							
	MO	Labor	Seeds	Fertilizers	Defensives	TC	Revenue
MO	1						
Labor	0.306	1					
Seeds	0.568*	0.786**	1				
Fertilizers	0.487*	0.650**	0.762**	1			
Defensives	0.699**	0.614**	0.672**	0.728	1		
TC	0.668**	0.826**	0.897**	0.856**	0.875**	1	
Revenue	0.522*	0.860**	0.804**	0.803**	0.742**	0.888**	1

Note: * Correlation is significant at 5% error level. ** Correlation is significant at the 1% error level. For the normal variables the Pearson's correlation was calculated and for the non-normal variables the Spearman correlation was calculated. The variables “airplane operation” and “machine/service rent” had cost values of “0” during the period from 1997 to 2016. Source: Adapted from “Historical Series of Planted Area, Productivity and Production”, from *Companhia Nacional de Abastecimento*, 2017b. Retrieved from <http://www.CONAB.gov.br/conteudos.php?t=2&a=1252&filtrar=1&f=1&p=115&e=0&d=0&m=0&s=0&ac=0&tps=0&lvs=0&l=0&ed=0&i=>; “Prices”, from Food and Agriculture Organization of the United Nations, 2017b. Retrieved from http://faostat3.fao.org/browse/P/*/E/

Practically all correlated variables have a high determination value (Figure 4). From the regression, it was possible to determine a mathematical equation for each variable, so the

predicted effect of “gross revenue ha^{-1} ” can be used to predict the production cost variables, i.e., what would be the cost of production variables for each unit increment in gross revenue ha^{-1} .

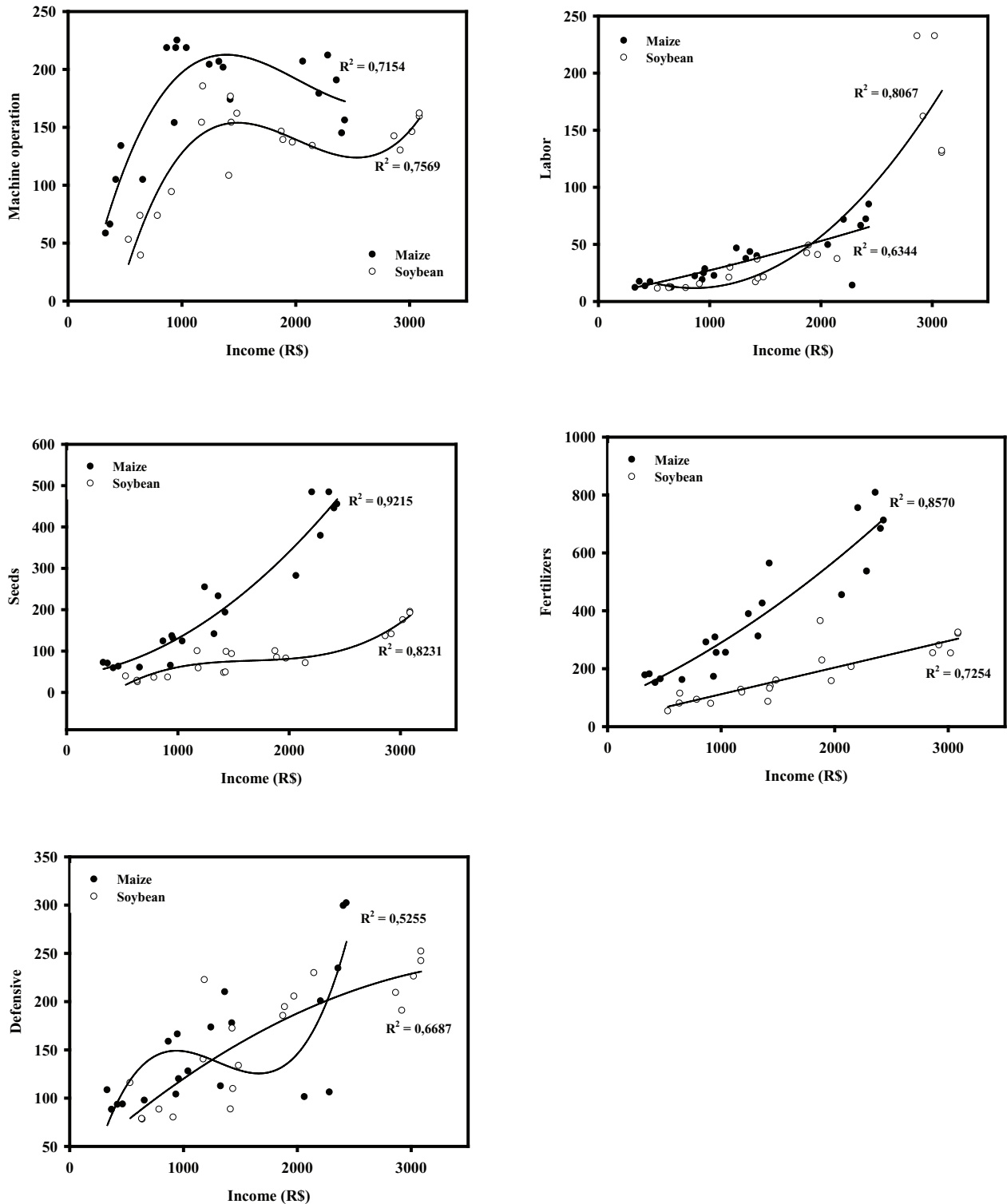


Figure 4. Dispersion diagram of the variables “machine operation”, “labor”, “seeds”, “fertilizers” and “defensives” for the maize and soybean crop.

Note. Source: Adapted from “Historical Series of Planted Area, Productivity and Production”, from *Companhia Nacional de Abastecimento*, 2017b. Retrieved from <http://www.CONAB.gov.br/conteudos.php?t=2&a=1252&filtrar=1&f=1&p=115&e=0&d=0&m=0&s=0&ac=0&tps=0&lvs=0&l=0&ed=0&i=>; Adapted from “Prices”, from Food and Agriculture Organization of the United Nations, 2017b. Retrieved from http://faostat3.fao.org/browse/P/*/E/

It is possible to infer for the “fertilizer” variable in the soybean crop that, by presenting a linear correlation, each unit of gross revenue ha⁻¹ arithmetically increased the unit of cost by 0.0919. For the other variables, because they do not present linearity, profit maximization can be predicted by their respective equations, from determining revenue and cost (Table 6 and 7). The regression method in the analysis of variance determined whether the model satisfactorily

explains the relationship between production cost variables and gross revenue ha⁻¹. For this, the test F was used to determine the possible equations and the coefficient of determination (R²) to demonstrate the degree of explanation of each equation. The F test, in the analysis of variance, tested only the coefficient associated with the “gross revenue ha⁻¹” variable in its largest exponent, testing the effect of degree *p*.

Table 6

Regression of the variables in relation to the income from the maize

	Coefficient	sig coefficient	Equation	Sig equation*
MO	y0= -66.1124	0.0287	$f = -66,1124 + 0,4856x - 0,0003x^2 + 4,3895 * 10^{-8} * x^3$	<0.0001
	a= 0.4856	0.0090		
	b= -0.0003	0.0360		
	c= 4.3895*10 ⁻⁸	0.0040		
L	y0= 5.3642	0.3112	$f = 5,3642 + 0,0200x + 1,9013 * 10^{-6} * x^2$	<0.0001
	a= 0.0200	0.1945		
	b= 1.9013*10 ⁻⁶	0.0080		
S	y0=39.7837	0.3490	$f = 39,7837 + 0,0315x + 5,9309 * 10^{-5} * x^2$	<0.0001
	a= 0.0315	0.6571		
	b= 5.9309*10 ⁻⁵	0.0241		
F	y0= 83.5662	0.3016	$f = 83,5662 + 0,1688x + 3,7744 * 10^{-5} * x^2$	<0.0001
	a= 0.1688	0.2192		
	b= 3.7744*10 ⁻⁵	0.4181		
D	y0= -71.3853	0.4251	$f = -71,3853 + 0,5792x - 0,0005x^2 + 1,2388 * 10^{-7} * x^3$	0.0017
	a= 0.5792	0.0474		
	b= -0.0005	0.0570		
	c= 1.2388*10 ⁻⁷	0.0509		

Note: MO = Machine operation; L = Labor; S = Seeds; F = Fertilizers; and D = Defensives.

* F Test with significance level of $p < 0.05$. Analysis of Residuals in Table 1 in Appendix.

Table 7

Regression of the variables in relation to soybean crop income

	Coefficient	sig coefficient	Equation	Sig equation*
OM	y0 = -203,4189	0,0021	$f = -203,4189 + 0,5962x - 0,0003x^2 + 5,2577 * 10^{-8} * x^3$	<0,0001
	a = 0,5962	0,0002		
	b = -0,0003	0,0008		
	c = 5,2577*10 ⁻⁸	0,0019		
MO	y0 =37,4202	0,0112	$f = 37,4202 - 0,0598x + 3,4785 * 10^{-5} * x^2$	<0,0001
	a = -0,0598	0,0445		
	b = 3,4785*10 ⁻⁵	0,0080		
S	y0 = -113,8373	0,0195	$f = -113,8373 + 0,3418x - 0,0002x^2 + 3,9662 * 10^{-8} * x^3$	<0,0001
	a = 0,3418	0,0042		
	b = -0,0002	0,0334		
	c = 3,9662*10 ⁻⁸	0,0251		
F	y0 = 20,0609	0,0281	$f = 20,0609 + 0,0919x$	<0,0001
	a = 0,0919	<0,0001		
D	y0 = 25,5726	0,0466	$f = 25,5726 + 0,1079x - 1,3375 * 10^{-5} * x^2$	<0,0001
	a = 0,1079	0,0412		
	b = -1,3375*10 ⁻⁵	0,0295		

Note: MO = Machine operation; L = Labor; S = Seeds; F = Fertilizers; and D = Defensives.

* F Test with significance level of $p < 0.05$. Analysis of Residuals in Table 2 in Appendix.

The coefficients of determination for the maize production cost variables are: (a) “machine operation”: 71.54%, (b) “labor”: 63.44%, (c) “seeds”: 92.15 %, (d) “fertilizers”: 85.70%, and e) “defensives”: 52.55%. For the soybean crop, the coefficients of determination are: a) “machine operation”: 75.69%, b) “labor”: 80.67%, c) “seeds”: 82.31%, (d) “fertilizers”: 72.54%, and e) “defensives”: 66.87%. The historical cost values for these variables were proportional to the gross revenue ha⁻¹, and it is possible to better predict them with the regression equation.

The “defensives” variable for maize and soybean yielded a moderate coefficient of determination. This is explained by the discrepancy between the historical cost values, caused by the annual variation in applying defensives, performed according to the incidence of pests, diseases, and in the control of invasive plants, as described by Satish, Chander, Reji, and Singh (2007) and Henriques et al., (2014).

From the analysis of the cost of production with the income from the agricultural activity, farmers can extract information that will help them in decision making during the productive cycle of the crops. Based on the equations, it is possible to predict and/or estimate the cost of each variable pertaining to the cost of the crop and simulate technologies (technical coefficients) and prices, making it possible to substitute production processes and make cost reductions.

6 Final considerations

Farmers cannot always monitor all the processes of their agricultural activities, thus not giving the necessary importance to the managerial analysis of their farms. The technological transformation in agriculture, especially in soybean and maize production, requires an efficient management of rural activity, based on management tools. It is therefore necessary

to improve management in the rural sector. Surveying and interpreting production costs by analyzing the variables involved in the cost of the crop, with a consequent evaluation of information on gross revenue ha^{-1} , enables information to be obtained for decision-making in agricultural activities.

The elements that compose the costs of production, such as (i) machine operation, (ii) labor, (iii) seeds, (iv) fertilizers, and (v) defensives, are associated with gross revenue ha^{-1} from maize and soybean. Investment in the production process, such as in seeds with high production potential and acquiring modern agricultural machinery, increases the cost of production but also helps the full development of agricultural crops, maximizing their productivity and affecting the revenue earned from the agricultural activity. A lack of investment in the production process will lead to a reduction in gross revenue ha^{-1} . In this case, a specific analysis, considering the peculiarities of each production unit, will assist the producer in deciding whether to make an investment - considering that the cost of the investment should be lower than the economic return generated by it.

In identifying the behavior of costs, in relation to the gross revenue ha^{-1} , it is possible to establish a parameter to predict possible revenues or costs from forecasts and/or market scenarios. The equations for the maize crop explain: 71.54%, 63.44%, 92.15%, 85.70%, and 52.55% of the cases observed, respectively, for the variables “machine operation”, “labor,” “seeds,” “fertilizers,” and “defenses.” Similarly, for the soybean crop, for the same variables the equations explain: 75.69%, 80.67%, 82.31%, 72.54%, and 66.87% of the observed cases.

The high cost of producing soybeans and maize - due to using agricultural technologies - coupled with fluctuations in the market price of the products may lead to loss of profitability or even loss of activities. Knowledge of the behavior of crop cost variables is effective for controlling agricultural activities. With such knowledge it is

possible to create strategic plans for the acquisition of inputs.

Efficiency in using the factors of production makes it possible to maximize gross revenue ha^{-1} . The equations constitute a tool that enables rural producers to predict their revenues from cost information, starting from the premise that in the rural area the difficulty in managing and controlling the costs of the productive process is an obstacle in farm management.

The results found reflect the modal reality of Brazilian agricultural units, since they are based on an analysis of the production costs from Conab, which are determined using a modal panel. The data reveal the possibility of analyzing other agricultural commodities, in order to verify if they have the same behavior as maize and soybean. In addition, an analysis of the behavior of costs in relation to variations between gross revenue ha^{-1} and net revenue ha^{-1} would be appropriate, given a standard level of adoption of technologies in the production process.

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Appendix

Table 1

Analysis of variance of the variables “machine operation”, “labor”, “seed”, “fertilizers” and “defensive” for maize

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	4	609444.2401	152361.06		
Residual	16	12313.4274	769.5892		
Total	20	621757.6675	31087.8834		
MO					
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	3	39058.7951	13019.5984	16.9176	<0.0001
Residual	16	12313.4274	769.5892		
Total	19	51372.2225	2703.8012		

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	3	38157.5233	12719.1744		
Residual	17	689.5251	40.5603		
Total	20	38847.0484	1942.3524		
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	2	9266.8824	4633.4412	114.2359	<0.0001
Residual	17	689.5251	40.5603		
Total	19	9956.4074	524.0214		

L

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	3	1331865.244	443955.0812		
Residual	17	32194.0216	1893.766		
Total	20	1364059.265	68202.9633		
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	2	427690.1887	213845.0943	112.9205	<0.0001
Residual	17	32194.0216	1893.766		
Total	19	459884.2103	24204.4321		

S

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	3	3802943.01	1267647.67		
Residual	17	114324.4429	6724.9672		
Total	20	3917267.453	195863.3726		
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	2	796003.7998	398001.8999	59.1827	<0.0001
Residual	17	114324.4429	6724.9672		
Total	19	910328.2427	47912.0128		

F

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	4	522617.151	130654.2877		
Residual	16	33582.4248	2098.9016		
Total	20	556199.5758	27809.9788		
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	3	50401.5317	16800.5106	8.0044	0.0018
Residual	16	33582.4248	2098.9016		
Total	19	83983.9565	4420.2082		

D

Note: MO = Machine operation; L = Labor; S = Seeds; F = Fertilizers; and D = Defensives.

* F Test with level of significance of $p < 0.01$

Table 2

Analysis of variance of the variables “machine operation”, “labor”, “seed”, “fertilizers” and “defensive” for soybean

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	4	355940.7963	88985.1991		
Residual	16	6620.5175	413.7823		
Total	20	362561.3138	18128.0657		
MO					
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	3	25721.4958	8573.8319	20.7206	<0.0001
Residual	16	6620.5175	413.7823		
Total	19	32342.0133	1702.2112		
Variance analysis					
	DF	Sum of squares	Middle square		
Regression	2	153964.5327	76982.2663		
Residual	18	26567.4982	1475.9721		
Total	20	180532.0309	9026.6015		
MO					
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	1	73711.4852	73711.4852	49.941	<0.0001
Residual	18	26567.4982	1475.9721		
Total	19	100278.9835	5277.8412		
Variance analysis					
	DF	Sum of squares	Middle square		
Regression	4	214204.677	53551.1692		
Residual	16	8468.0861	529.2554		
Total	20	222672.7631	11133.6382		
S					
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	3	48375.3109	16125.1036	30.4675	<0.0001
Residual	16	8468.0861	529.2554		
Total	19	56843.397	2991.7577		

Variance analysis					
	DF	Sum of squares	Middle square		
Regression	2	762277.1266	381138.5633		
Residual	18	43594.3614	2421.909		
Total	20	805871.488	40293.5744		
F					
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	1	123996.4061	123996.4061	51.1978	<0.0001
Residual	18	43594.3614	2421.909		
Total	19	167590.7675	8820.5667		
Variance analysis					
	DF	Sum of squares	Middle square		
Regression	3	575508.3431	191836.1144		
Residual	17	21119.5607	1242.3271		
Total	20	596627.9038	29831.3952		
D					
Corrected by average observations					
	DF	Sum of squares	Middle square	F	P*
Regression	2	50135.7476	25067.8738	20.1782	<0.0001
Residual	17	21119.5607	1242.3271		
Total	19	71255.3083	3750.2794		

Note: MO = Machine operation; L = Labor; S = Seeds; F = Fertilizers; and D = Defensives.

* F Test with level of significance of $p < 0.01$


Supporting Agencies:

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Contribution	Felipe Dalzotto Artuzo	Cristian Rogério Foguesatto	Ângela Rozane Leal de Souza	Leonardo Xavier da Silva
1. Definition of research problem	√			√
2. Development of hypotheses or research questions (empirical studies)	√		√	
3. Development of theoretical propositions (theoretical Work)	√			√
4. Theoretical foundation/ Literature review	√	√	√	√
5. Definition of methodological procedures	√		√	
6. Data collection	√	√		
7. Statistical analysis	√			
8. Analysis and interpretation of data	√	√	√	√
9. Critical revision of the manuscript	√	√		√
10. Manuscript Writing	√	√		
11. Translation (English)		√		