Original Research Article

ANALYSIS OF REGRESSION AND CORRELATION ON PRODUCTION OF SUGARCANE IN THE STATES OF PARANÁ, SÃO PAULO AND MINAS GERAIS, BRAZIL

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ABSTRACT

Brazil is one of the world's largest producers of sugarcane. Studies considering the production of a culture in informatic function of time allow to verify the behavior of it in a certain homologated. The aims of this work were to analyze the production of the states of Paraná, São Paulo and Minas Gerais, as well as the national production of sugarcane crops, based on statistical tools of regression analysis, and correlation. Sugar cane production data were collected from the Sugarcane Industry Union (UNICA). The work was done in the State University of Western Paraná, Post-Graduation in Agronomy, between July 2018 and December 2018. The data used were obtained from various institutions and, made available by the Sugarcane Industry Union (UNICA), constituting a historical series of 1980/81 to 2016/17. The regression models that best fit the states of Paraná and São Paulo were the linear model, with correlation equal to 0.9711 and 0.9934 respectively, while for Minas Gerais was the quadratic, with 0.9708 of correlation with the national production. The results obtained showed a greater similarity of the behavior of the production of São Paulo with the national, evidencing its importance in participating in the sugarcane agroindustry sector. Based on the regression and correlation analyses obtained, it was found that the state of Paraná and São Paulo obtained a behavior of sugarcane production like that of the national. In the sugarcane production of the state of Minas Gerais, the growth was observed only from the year 2000. Thus, it is concluded that the productions from the states of São Paulo and Paraná contributed more significantly to the national production of sugarcane in relation to the production of the state of Minas Gerais.

Keywords: Saccharum officinarum L; Brazilian Sugarcane Production; Cane Industry; Brazilian commodities.

1. INTRODUCTION

Sugarcane (*Saccharum* spp.) is one of the commodities of greater growth in Brazil. Their cultivated area is increasing sharply due to its use in the production of ethanol [1], allied to the concerns with

global warming and the possible scarcity of fossil energy resources, increasing the demand for renewable energies [2].

The sugarcane growing regions in Brazil are the center-south and north-northeast, allowing two harvests per year, which together correspond to the area planted approximately 10 million hectares in the year of 2016 [3]. This big production enabe the production of sugar and alcohol for internal and external markets during the whole year, thus representing a major contribution to the economic development of the country [4].

Brazil is the world's largest producer of the sugarcane crop, with production of 736.8 million tons in the 2016/17 harvest, being that the state of São Paulo was responsible for the production of 400.8 million tons [5]. This condition leads the milling of sugarcane in Brazil, with 55% of the entire national milling, the equivalent to 368,322.65 tons of culture [6].

On the other hand, the state of Paraná shows production around 23164.9 tons intended to produce sugar and 45000.5 tons intended to produce ethanol in the harvest of 2016/17, the total area of 624.6 thousand hectares [7], thus also representative in this sector.

The state of Minas Gerais, in turn, considered new in ethanol production, already featured within the sector. Sugarcane has been occupying areas previously used by livestock and crops such as soya, maize and rice, and the region of the Triângulo Mineiro pointing as the main pole of ethanol and sugar production within the state [8].

Several events contributed to the expansion of the area and the cultivation of sugarcane in Brazil, since 1975 to present, many transformations occurred, highlighting the creation of the Brazilian Agricultural Research Company, as well as changes in Public policies for the sector. This has brought enormous transformations that resulted in significant increases in production, positioning Brazil among the most competitive countries in the sugar-alcohol scenario [9].

Considering all the changes in the sugarcane crop production pattern, this study aimed to relate the total amount of sugarcane produced in the states of Paraná, São Paulo and Minas Gerais with the production of Brazil, by means of a series Historical, comprising the period 1980 to 2016, using regression analysis as well as the correlation between the productions.

2. MATERIAL AND METHODS

The sugarcane production data from the states of Paraná, São Paulo, Minas Gerais and the national production were compiled from the information provided by the Sugarcane Industry Union (Unica), comprising the period from 1980 to 2016, constituting a series of 36 years. Initially, the Pearson correlation coefficient was determined, which measures the existence and degree of relationship intensity between the state's production data and the national one. Thus, using the Microsoft Excel spreadsheet, the analysis of variance was performed, and the graphs were generated.

The correlation coefficient (r) for sample *n* pairs of values may present three results, which are, X and Y are positively correlated, or are negatively correlated, or that there is no correlation. It is verified that the square of the correlation coefficient is equal to the coefficient of determination of the simple linear regression.

For qualitative evaluation of Pearson correlation coefficient, the criterion established by [10] was adopted, where: if $0.00 < r < 0.30$, there is weak linear correlation; If $0.30 \leq r < 0.60$, there is moderate linear correlation; If $0.60 \leq r < 0.90$, there is strong linear correlation; If 0.90 is $\leq r < 1.00$, there is very strong linear correlation.

Subsequently, the regression analysis was performed that best adjusted to the data. The analysis of variance was performed to verify the equality of the averages, attesting to the regression effect and that the estimates are dependent.

For the treatment of production data of the states of Paraná and São Paulo was used simple linear regression and for the production data of the state of Minas Gerais was used quadratic polynomial regression due to the better adjustment of data. Where Simple linear regression was obtained by (Equation 1):

$$Yi=\beta 0+\beta 1.Xi+ei$$

Where: Yi is the response/dependent variable representing the production in tones and Xi = area harvested in hectares (is the value observed for the dependent variable Y at the i-th level of the independent variable X). B0 represents the value for Y when the variables are null. The terms βi are called regression coefficients, Xi is the i-th level of the independent variable X and the residue (ei) is the deviation of the observed value from the estimate of the corresponding model [11].

The quadratic polynomial regression model with a variable, it's (Equation 2) [12]:

$$Yi=\beta 0+\beta 1.Xi+\beta 2.Xi^2+ei$$

Where: Yi is the value observed for the dependent variable in the i-th level of independent variable X. $\beta 0$ represents the constant of regression. Being that $\beta 1$ represents the regression coefficient and the i-th level of independent variable X. Since $\beta 2$ is the regression coefficient and Xi^2 is the i-th level of independent variable X, squared and the residue (ei) is the standard deviation of the observed value of the estimate of the corresponding template.

3. RESULTS AND DISCUSSION

The analysis of variance performed for sugarcane production data in the states of Paraná, São Paulo and Minas Gerais, between 1980 and 2016, were significant at 1% probability (P = .01) by F test. The National agricultural product grew more than four times between the years 1975 to 2016 In the period between 1975 to 2016, considering the product holdings in the value of production, it is verified that the largest increases in relative participation in the last two decades (2000 to 2016) occurred with soybean grain, orange, banana, chicken and sugarcane [9].

The production of sugarcane presented important growth mainly after the implantation of Proálcool on november 14, 1975, by Decree No. 76.593. The decree was aimed at stimulating the production of alcohol, aiming to meet the needs of internal and external market and the policy of automotive fuels, passing through a period of stagnation in the decade of 80, however, from 2001, this production began to rise rapidly [13, 14].

The incentives to produce ethanol in Brazil has assisted in strengthening the sugarcane sector, due to the use of alternatives such as the increase of excise duties on petrol, the maintenance of low taxes on ethanol, and the increase in the percentage of anhydrous ethanol from 25% to 27% in the composition of petrol [15]. From this period, there was an increase of 30.7% in the area harvested crops in Brazil, with the incorporation of almost 15 million hectares [16].

The advances in productivity resulting from a set of technological factors, which together have enabled the increase in production, among them the genetic improvement, agricultural zoning, tillage in straw, development of more efficient machinery for harvesting and empowerment of the producer in the management of costs in the production chain [16].

The national production in tons of sugarcane in the analyzed period obtained a R^2 of 0.8983, showing linear growth, from 123681 tons in 1980 to 651841 tons in 2016, reaching a greater

increase of five times (Figure 1). In the state of Paraná between the years 1980 to 2016, the production in tons of sugarcane presents a coefficient of determination (R^2) of 0.9290 and adjustment to the linear regression model. In the period of 1980 to 2016 the average production went from 3269 tons to 40417 tons.

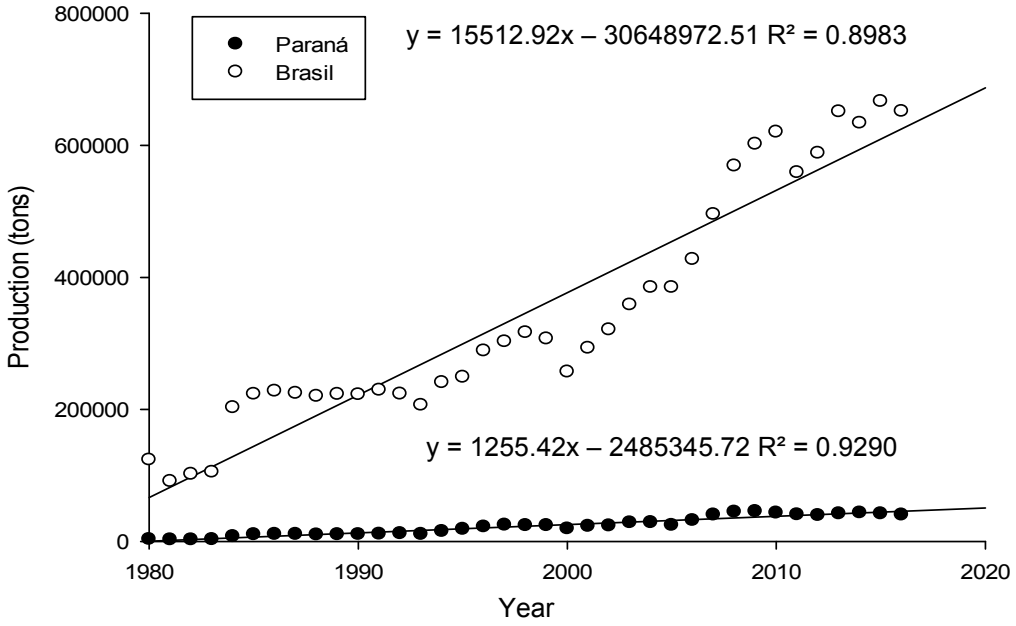

Figure 1 – Brazilian sugarcane production and in the state of Paraná between the periods from 1980 to 2016.

Data from [17] also point out that the state of Paraná produced about 47.3 million tons in the period between 2011 and 2015, which represents 6.4% of the national production, making the state 4th largest producer of sugarcane in the national ranking.

The correlation of national production with the state production and sugarcane was high (r = 0.9711) showing high similarity of behavior between the two straight from the figure 1. This growth has been justified mainly by increases in productivity associated, among other factors, to the management of crops and the management and conservation of soil since it's considered practically exhausted the possibility of expansion of the agricultural frontier area in the state of Paraná [15].

Soil conservation is an extremely important factor for agricultural productivity, since the Paraná presents fertile soils, popularly known for its "purple land", a type of soil that is very fertile and suitable for the farming of the shedding of volcanic lava in the Mesozoic era, rich in minerals, especially iron, consequence of the decomposition of sandstone-basaltic rocks [18]. In view of this, the state of Paraná presents a soil with desirable characteristics for agriculture, such as its good fertility, the high production of sugarcane in this state is justified in this way, because the investment made in production, to increase the productivity of the cultivable areas there was a return over the years, contributing very significantly to the domestic sugarcane production.

For the state of São Paulo, it was observed that the linear regression was significant, presenting R^2 of 0.9184. The production in tons of sugarcane from the state has similar behavior to national, obtaining a correlation coefficient (r) equal to 0.9934, which qualifies a very strong linear correlation between the two productions (Figure 2).

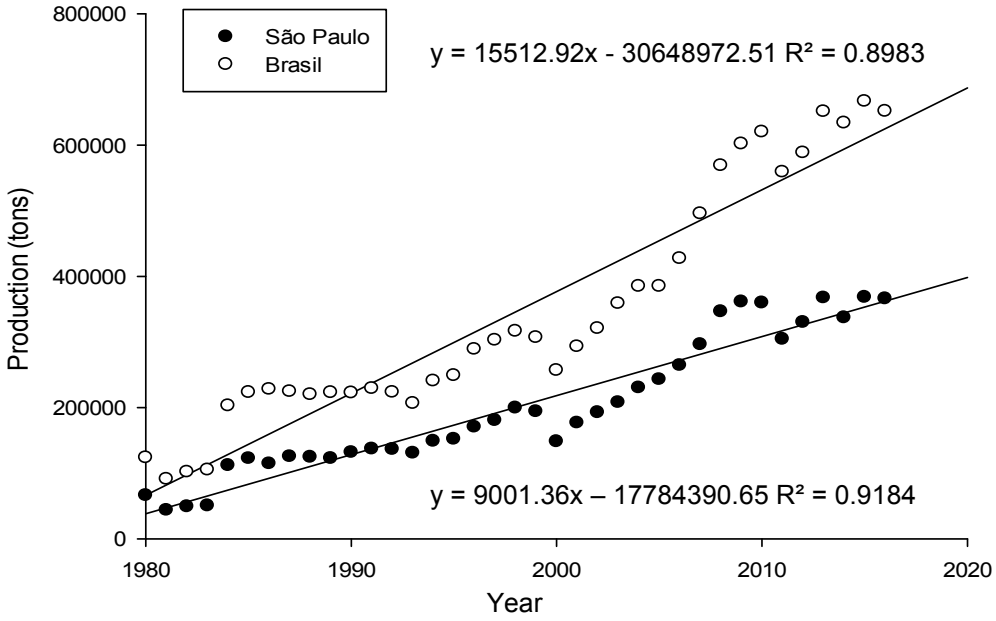

Figure 2 - National sugarcane production and in the state of São Paulo, between the periods from 1980 to 2016.

The state has been the most important representative of the national ethanol industry [19], and in the year 2011 São Paulo represented approximately 54% of national production of sugarcane, 55% ethanol and 59% of sugar [20]. There was an increase in the cultivated area of sugarcane in the southeastern region, with 96.38% of the total area, representing 357183 hectares concentrated mainly in São Paulo, with an increase of 246011 hectare [21].

In 1980 the average production of the state of São Paulo was equal to 65967 tons and in the year 2016 it reached 365990 tons, representing an increase of more than five times in production. From 2003 there was greater demand for areas to stimulate the production of biofuels, expanding ethanol producing plants. At this time, states such as São Paulo, Minas Gerais and Goiás, regions where traditionally stand out for grain production, began to gain prominence in the production of sugar cane [20]. From then on, the state of São Paulo started to lead the milling of sugarcane in Brazil, with 55% of all national grinding, being the second place, the state of Goiás with 11% [3].

São Paulo is a traditional state in the production of sugarcane, in figure 2 is evident the growth of the production of the state in linearity with the national production. Because it is a producer state, São Paulo found no difficulty in maintaining its large production, expanding its cultivable areas and, consequently, maintaining itself as the most sugarcane producing state in Brazil.

Sugarcane is a culture that adapts very well in tropical climate regions with temperatures between 19 and 32 ºC with well distributed rainfall. The state of São Paulo presents climatic conditions similar to these, for this reason it becomes excellent for the production of sugarcane, allowing the vigorous growth of the plant during spring and summer, and offering adequate conditions for the Maturation and harvest, during autumn and winter [22], justifying the reason for this state to be the leader in sugarcane production, contributing strongly to the production at national level.

In the figure 3, the increase in the sugarcane production in the state of Minas Gerais was 90.66% between the years analyzed, showing a correlation coefficient (r) of 0.970 with the national production, with quadratic polynomial behavior, presenting R^2 of 0.9526, with more expressive growth from the beginning of the year 2000.

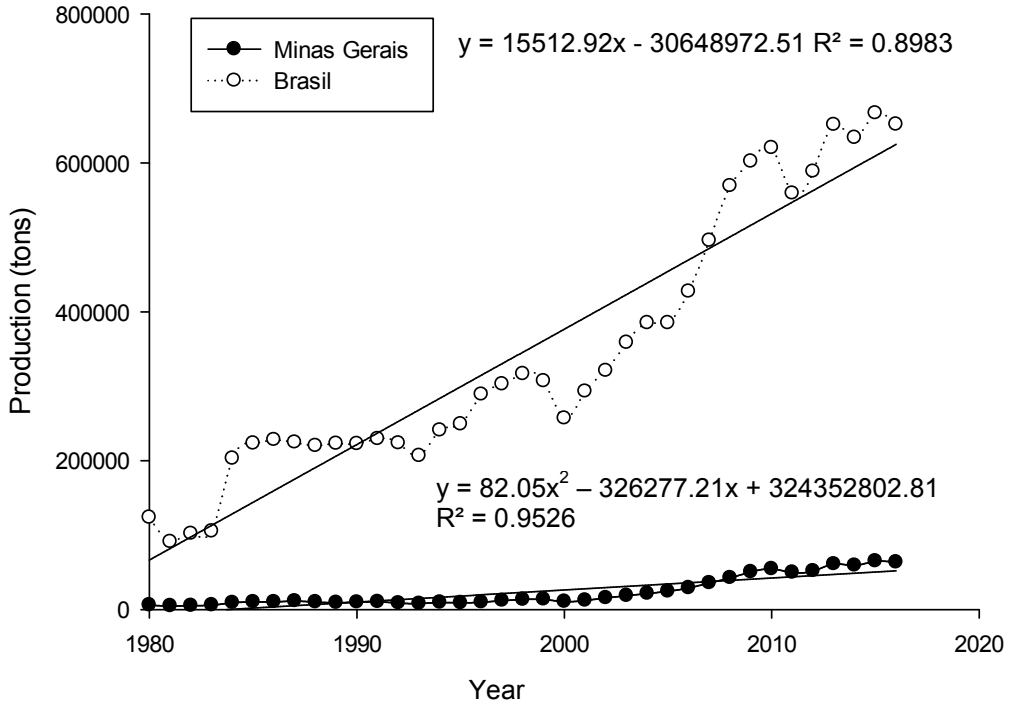

Figure 3 - National and sugarcane production and in the state of Minas Gerais, between the periods from 1980 to 2016.

The sugarcane was one of the cultures that more expanded in the state between the years of 1990 and 2008, there is an incorporation of approximately 961 thousand hectares of cultivable areas, corroborating with the increase of production, especially from the year of 2000. Such expansion was, according to the authors, in replacement of cultures that have lost areas, such as the maize, coffee, beans and rice [13]. Similarly, in the analyze the period of 2007 and 2008, also observed an increase of the cultivated areas, which attributed this growth to the replacement of crops of maize, rice and cassava [23].

Sugarcane has important participation in the Brazilian economy since the colonial period, and nowadays the production of culture expands, especially about the production of renewable energy. Due to this perspective, Brazilian Agroenergy policies have influenced the redistribution of sugarcane production, the state of Minas Gerais being one of the states with potential and tendency of production expansion [24]. Therefore, the political incentive has also contributed to states that traditionally did not have sugarcane as the focus of cultivation to increase their productions and consequently substitute crops previously cultivated in greater amount, by sugarcane.

Sugarcane, as stated throughout this work, is a culture of extreme importance in the Brazilian economy, which shows growth in production between the years 1980 and 2016. This expansion of production of this culture is also linked to studies conducted in research centers in plant breeding in the country, which select hybrids resistant to pests and diseases, which result in high yields [25]. Therefore, it's evident that for the success of the production of a culture within the national scope, it depends on the investment in expanding the cultivable areas, the conditions of climate and soil to be favorable to the success of production and also investment in research of plant breeding in order to create more resistant and productive crops, this being the combination that has worked for Brazil to be a major producer of sugarcane of world recognition.

4. CONCLUSION

Based on the regression and correlation analyses obtained, it was found that the state of Paraná and São Paulo obtained a behavior of sugarcane production like the national, due to its soil and climate characteristics, which are favorable for the culture success. The production of the state of Minas Gerais showed evident growth only from the year 2000, which was mainly due to the substitution of other crops, such as coffee and maize. Thus, it is concluded that the productions from the states of São Paulo and Paraná contributed more significantly to the national production of sugarcane in relation to the production of the state of Minas Gerais.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. NKC, DHSG and DB realized the data collection, statistical analysis and formulated this work. KPSC, PCA and TCM helping in the writing and the statistical analysis this work and EKMJ coordinated the elaboration this work. All authors read and approved the final manuscript.

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