

2
3 **ANALYSIS OF REGRESSION AND**
4 **CORRELATION ON PRODUCTION OF**
5 **SUGARCANE IN THE STATES**
6 **OF PARANÁ, SÃO PAULO AND**
7 **MINAS GERAIS, BRAZIL**

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10
11 **ABSTRACT**
12

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.

13
14 *Keywords:* Saccharum officinarum L; *Brazilian Sugarcane Production; Cane Industry; Brazilian*
15 *commodities.*

16
17 **1. INTRODUCTION**
18

19 Sugarcane (*Saccharum* spp.) is one of the commodities of greater growth in Brazil. Their cultivated
20 area is increasing sharply due to its use in the production of ethanol [1], allied to the concerns with
21 global warming and the possible scarcity of fossil energy resources, increasing the demand for
22 renewable energies [2].

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

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

32 On the other hand, the state of Paraná shows production around 23164.9 tons intended to produce
33 sugar and 45000.5 tons intended to produce ethanol in the harvest of 2016/17, the total area of
34 624.6 thousand hectares [7], thus also representative in this sector.

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

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

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

48

49 2. MATERIAL AND METHODS

50

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

58

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

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

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

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

74

$$Y_i = \beta_0 + \beta_1 X_i + e_i$$

75

76 Where: Y_i is the response/dependent variable representing the production in tones and X_i = area
77 harvested in hectares (is the value observed for the dependent variable Y at the i -th level of the
78 independent variable X). B_0 represents the value for Y when the variables are null. The terms β_i are
79 called regression coefficients, X_i is the i -th level of the independent variable X and the residue (e_i)
80 is the deviation of the observed value from the estimate of the corresponding model [11].

81

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

83

84

$$Y_i = \beta_0 + \beta_1.X_i + \beta_2.X_i^2 + e_i$$

85

86 Where: Y_i is the value observed for the dependent variable in the i -th level of independent variable
87 X . β_0 represents the constant of regression. Being that β_1 represents the regression coefficient and
88 the i -th level of independent variable X . Since β_2 is the regression coefficient and X_i^2 is the i -th level
89 of independent variable X , squared and the residue (e_i) is the standard deviation of the observed
90 value of the estimate of the corresponding template.

91 3. RESULTS AND DISCUSSION

92

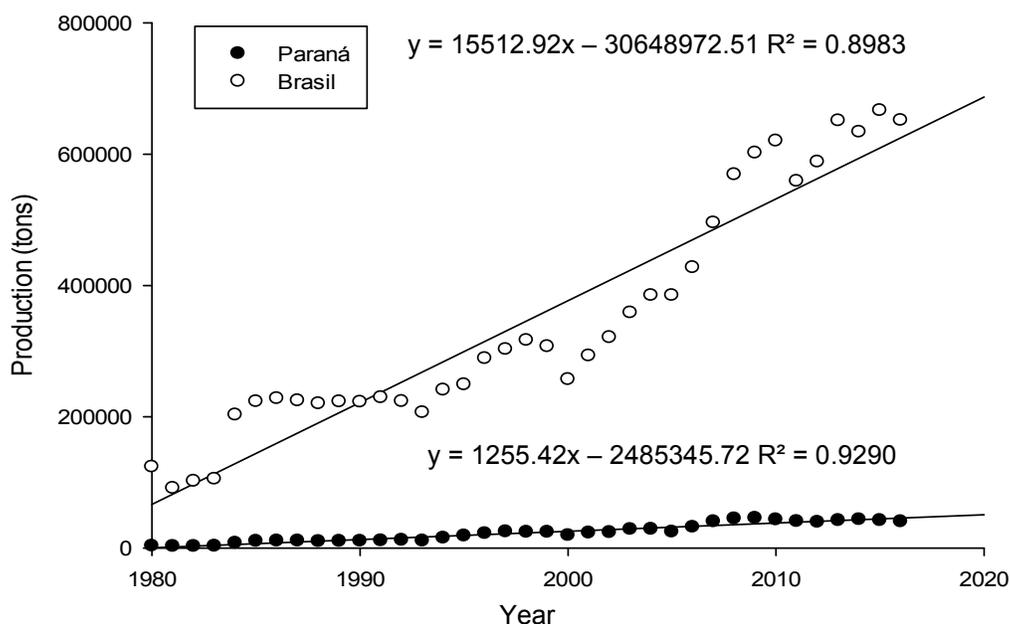
93 The analysis of variance performed for sugarcane production data in the states of Paraná, São
94 Paulo and Minas Gerais, between 1980 and 2016, were significant at 1% probability ($P = .01$) by F
95 test. The National agricultural product grew more than four times between the years 1975 to 2016
96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

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

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

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

113 The national production in tons of sugarcane in the analyzed period obtained a R^2 of 0.8983,
114 showing linear growth, from 123681 tons in 1980 to 651841 tons in 2016, reaching a greater
115 increase of five times (Figure 1). In the state of Paraná between the years 1980 to 2016, the
116 production in tons of sugarcane presents a coefficient of determination (R^2) of 0.9290 and
117 adjustment to the linear regression model. In the period of 1980 to 2016 the average production
118 went from 3269 tons to 40417 tons.



119
120 **Figure 1 – Brazilian sugarcane production and in the state of Paraná between the periods**
121 **from 1980 to 2016.**

122
123 The correlation of national production with the state production and sugarcane was high ($r =$
124 0.9711) showing high similarity of behavior between the two straight from the figure 1. This growth
125 has been justified mainly by increases in productivity associated, among other factors, to the
126 management of crops and the management and conservation of soil since it's considered
127 practically exhausted the possibility of expansion of the agricultural frontier area in the state of
128 Paraná [15]. Data from IBGE (2016) also point out that the state of Paraná produced about 47.3
129 million tons in the period between 2011 and 2015, which represents 6.4% of the national
130 production, making the state 4th largest producer of sugarcane in the national ranking [17].

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

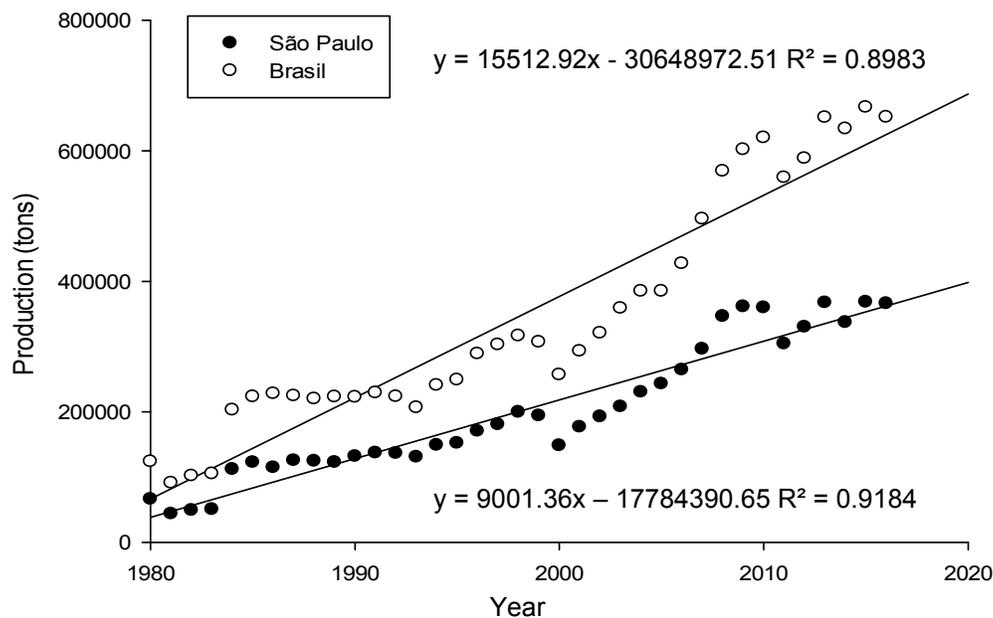
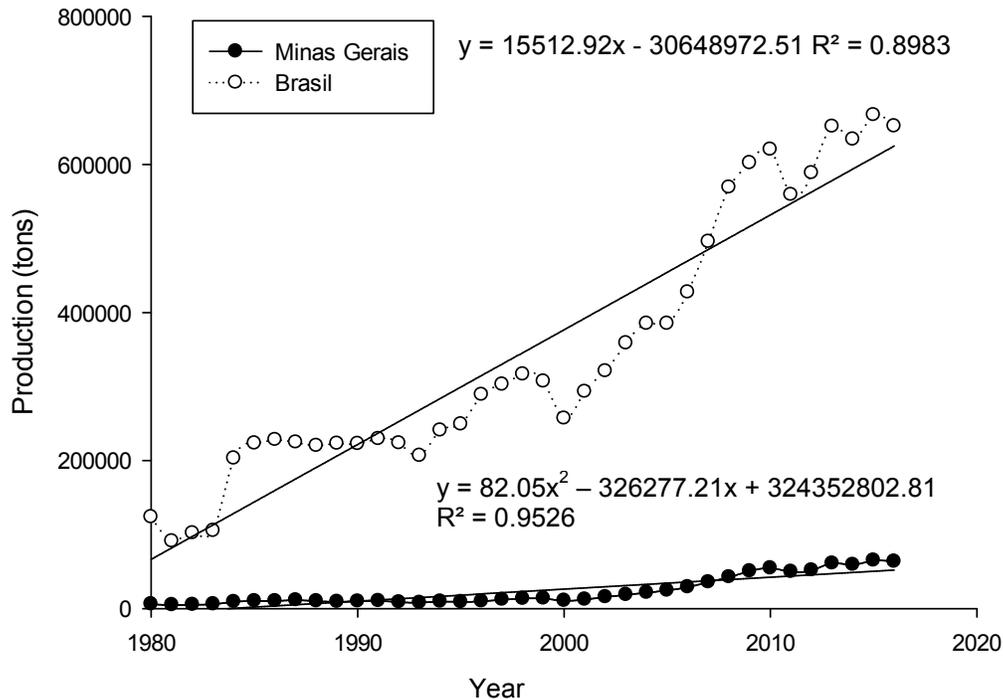


Figure 2 - National sugarcane production and in the state of São Paulo, between the periods from 1980 to 2016.

The state has been the most important representative of the national ethanol industry [18], and in the year 2011 São Paulo represented approximately 54% of national production of sugarcane, 55% ethanol and 59% of sugar [19]. 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 [20].

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 sugarcane [20].

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.



154
155 **Figure 3 - National and sugarcane production and in the state of Minas Gerais, between the**
156 **periods from 1980 to 2016.**
157

158 The sugarcane was one of the cultures that more expanded in the state between the years of 1990
159 and 2008, there is an incorporation of approximately 961 thousand hectares of cultivable areas,
160 corroborating with the increase of production, especially from the year of 2000. Such expansion
161 was, according to the authors, in replacement of cultures that have lost areas, such as the maize,
162 coffee, beans and rice [13]. Similarly, in the analyze the period of 2007 and 2008, also observed an
163 increase of the cultivated areas, which attributed this growth to the replacement of crops of maize,
164 rice and cassava [21].

165 **4. CONCLUSION**
166

167 Based on the regression and correlation analyses obtained, it was found that the state of Paraná
168 and São Paulo obtained a behavior of sugarcane production like that of the national. In the
169 sugarcane production of the state of Minas Gerais, the growth was observed only from the year
170 2000, which was mainly due to substitution of other crops, such as coffee and maize.

171 Due to this, it is possible to prove the representativeness of the states of São Paulo and Paraná in
172 sugarcane production, since these states present linear growth since the years 1980,
173 accompanying the national production. Thus, it is concluded that the productions from the states of
174 São Paulo and Paraná contributed more significantly to the national production of sugarcane in
175 relation to the production of the state of Minas Gerais, which began to contribute in a way important
176 from the years 2000.
177

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184 185 **COMPETING INTERESTS**

186
187 Authors have declared that no competing interests exist.

188 189 **AUTHORS' CONTRIBUTIONS**

190
191 This work was carried out in collaboration between all authors. NKC, DHSG and DB realized the
192 data collection, statistical analysis and formulated this work. KPSC, PCA and TCM helping in the
193 writing and the statistical analysis this work and EKMJ coordinated the elaboration this work. All
194 authors read and approved the final manuscript.

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