Quaestum

https://doi.org/10.22167/2675-441X-20200536
Quaestum 2020; 1: e26750536
ISSN: 2675-441X

Article

Growth and instability of the 1992/93 - 2016/17 soybean crops in the main producing states of Brazil

Crescimento e instabilidade da cultura da soja nos principais estados produtores brasileiros durante as safras 1992/93 – 2016/17

Osvaldo Chacarolli Júnior[1]*, Priscila Fortes[2]

Received: aug. 17, 2018
Accepted: mar. 25, 2019

[1]*Caixa Econômica Federal.. SBS, Qd 4 – Lotes 3/4; 70092-900 - Brasília, DF, Brazil <osvaldo.chacarolli@caixa.gov.br>

[2]Faculdade Pecege. Rua Alexandre Herculano, 120 – Vila Monteiro; 13418-445 - Piracicaba, SP, Brazil

Abstract: The expansion of world demand for food and energy has resulted in increased agricultural yields and production. Soybean production, specifically, is among the economic activities that have shown significant growth at national and global levels in recent decades. In this context, policymakers and other agents involved in the soybean production chain must pay careful attention to the instability with which yield and production increases occur over time. Therefore, the objective of this study was to evaluate this instability and growth in soybean planted area, production, and yield in the main producing states of Brazil over the 1992/93 to 2016/17 crops. We measured instability by applying the Cuddy-Della Valle index and growth rates calculated using a log-linear regression with post decomposition analysis. We observed that all variables, in all states, presented a tendency of growth—particularly that of planted area, which was the main production-defining element. We additionally found low levels of instability for planted area, production, and yield in most analyzed regions.

Keywords: Decomposition analysis; Planted area; Cuddy-Della Valle index; Yield; Growth rate.

Resumo: O aumento da produtividade e da produção das atividades agropecuárias tem sido a resposta dada à expansão da demanda mundial por alimentos e energia. Por conseguinte, a produção de soja esteve entre as atividades econômicas que apresentaram crescimento expressivo no âmbito nacional e mundial nas últimas décadas. Neste contexto, torna-se importante para formuladores de políticas públicas e demais agentes envolvidos na cadeia produtiva do grão atentar para a instabilidade com que os aumentos de produção e produtividade ocorrem ao longo do tempo. A partir destas inferências, o objetivo deste trabalho foi avaliar a instabilidade e a taxa de crescimento da área plantada, produção e produtividade de soja nos principais estados produtores ao longo das safras 1992/93 à 2016/17. A instabilidade foi determinada através da aplicação do índice Cuddy-Della Valle e a taxa de crescimento calculada a partir de regressão do tipo log-linear, com posterior análise de decomposição. Observou-se que todas as variáveis, em todos os estados, apresentaram tendência de crescimento. Tal fato ocorreu com destaque para mudanças de área plantada, sendo este o principal elemento definidor da produção. Foram auferidos baixos índices de instabilidade de área plantada, produção e produtividade na maioria das regiões analisadas.

Palavras-chave: Análise de decomposição; Área plantada; Índice Cuddy-Della Valle; Produtividade; Taxa de crescimento.

Introduction

Increases in agricultural yields and production have resulted from the expansion in world demand for food and energy. This expansion, a result of increasing populations in developing countries, of longer life spans, of intense urbanization, of expanding middle classes, and of changing consumer behaviors, has manifested itself in an estimated 35% increase in food production by 2030 (EMBRAPA, 2018a).

Consequently, soybean production is among the economic activities that have demonstrated significant growth over the last few decades. Among the global factors that have allowed for this expansion, we highlight the following: the structuring of a large international market for products of the soybean complex, the strengthening of the crop as an important source of vegetable protein—particularly in meeting the demand for animal feed—and the strong development and supply of technology (Dall'Agnol et al., 2010). Specifically, since 2000, soybeans have held fourth place as the most consumed and produced grain or oilseed globally, behind corn, wheat, and rice, and the crop has the highest annual production of any oilseed produced in the world (Hirakuri and Lazzaroto, 2014). Global production of the 2017/18 crop was 336.7 million tonnes, planted on 124.5 million hectares (EMBRAPA, 2018b).

Currently, Brazil is the second-largest world producer of soybeans. During the 2017/18 crop year, soybean production in the country was 116.9 million tonnes and planted area was 35.1 million hectares (EMBRAPA, 2018b). The soybean complex therefore has a great socioeconomic importance in the country, as the industry involves many agents and organizations related to different socioeconomic sectors, including: research institutions, input suppliers, equipment manufacturers, rural producers and cooperatives, oil producers, feed companies, and biodiesel plants, among others (Hirakuri and Lazzaroto, 2014). Furthermore, soybeans are expected to continue to be the most profitable export of the country through 2025 (OECD-FAO, 2015).

Given this scenario, policymakers and agents involved in the soybean supply chain must be aware of the historical instability of soybean production and yields. Instability is inherent to agriculture, as production is dependent on environmental factors and subject to substantial variation from one year to the next (Vaidyanathan, 1992). In addition, high instability has an adverse effect on production by: increasing production risk, affecting producer revenue, impacting consumers—particularly those with low incomes, and reducing macroeconomic stability (Chand and Raju, 2009).

In this context, this study aims to answer the following question: what was the growth dynamic of Brazilian soybean production over the last few decades? Specifically, the objective of this study is to evaluate the growth rate and instability of soybean planted area, production, and yields in the main soybean-producing areas of Brazil from the 1992/93 to the 2016/17 crop years.

Material and Methods

This study uses historical data series of planted area, yield, and production for soybeans from 1992/93 to 2016/17, from the National Supply Company (Companhia Nacional de Abastecimento – CONAB) (CONAB, 2017). The data are by state (Unidade Federativa-Safra), in units of thousand hectares (planted area), thousand tonnes (production), and kilograms per hectare (yield). We used data from a period that coincided with the time that Brazil began to open itself to the international market in the 1990s and the implementation of the Plano Real in 1994, both of which were critical in the growth of Brazilian agriculture, particularly regarding the abandonment of the import substitution process, which encouraged competition and excluded less efficient producers (Colussi et al., 2016). We used data available for the states of Goiás, Mato Grosso, Mato Grosso do Sul, Paraná, and Rio Grande do Sul, which together represented 77.3% of Brazilian soybean production in 2016/17 (Table 1).

Table 1. State shares of Brazilian soybean production for the crop year 2016/17

State	Production	Share	Cumulative Share
	thousand tonnes	---------------------------%---------------------------	
Mato Grosso	30.514	26.7	26.7
Mato Grosso do Sul	8.576	7.5	34.3
Goiás	10.819	9.5	43.8
Paraná	19.586	17.2	60.9
Rio Grande do Sul	18.714	16.4	77.3
Others	25.867	22.7	100.0

Source: CONAB (2017)

We calculated the annual composite growth rate of the variables using a simple linear regression (Equation 1), as described by Negri Neto, Coelho and Moreira (1993).

$$V_t = V_1(1+r)^t \quad (01)$$

where t is time, in values of any magnitude, V_t is the beginning value of V_1, and r is the growth rate

Applying logarithms, we can rewrite this as the following:

$$\text{Log } V_t = \text{Log } V_1 + t \text{ Log } (1+r) \quad (02)$$

Considering Equations (3) and (4)

$$\alpha = \text{Log } V_1 \quad (03)$$

$$\beta = \text{Log } (1+r) \quad (04)$$

we can rewrite Equation (1) as the following:

$$Y_i = \alpha + \beta t \quad (05)$$

In which Equations (6) and (7):

$$Y_i = \text{Log } V_t \quad (06)$$

$$r = (\text{antilog } \beta) - 1 \quad (07)$$

Any change in the production of a given crop fundamentally depends on changes in the area allocated to its harvest and its average yield (Ayalew, 2015). Therefore, we measured the contribution of area and yield in production growth using the decomposition analysis described in the works of Ayalew (2015) and Tewari, Singh and Tripathi (2017), as shown in Equation (8):

$$P = A_0(Y_n - Y_0) + Y_0(A_n - A_o) + \Delta A \Delta Y \quad (08)$$

where P is production, Y_0 is the yield in the base year, Y_n is the yield in the current year, A_0 is planted area in the base year, An is planted area in the current year, ΔA is the change in planted area, and ΔY is the change in yield. In this equation, we calculated the yield effect, area effect, and effect resulting from both, in a first, second, and third step, respectively.

Instability in the agricultural sector refers to a measure of change in different areas, and can be calculated for planted area, production, or yield (Sihmar, 2014). According to Sudhakar, Singh and Bhatt (2016), the measure used to estimate instability of a long-term variable must satisfy two minimum conditions: first, it must not include deviations present in the data series that result from the presence of trend or growth, and second, the measure must be comparable between datasets. The coefficient of variation (CV) is the most commonly used and easily interpreted measure of the average variation of a data series. However, if the series exhibits any temporal trend, the CV can only be calculated following the application of a method to remove the trend (Cuddy and Valle, 2009). Its use as a measure of instability faces the limitation that in the presence of a trend, the average variation can be overestimated (Krishan and Chanchal, 2014; Sihmar, 2014).

To examine the extent of instability in production, planted area, and yield, we chose to use the Cuddy-Della Valle index, which has been preferred by researchers due to its superiority in relation to other methods (Sudhaka, Singh and Bhatt, 2016). This index removes the trend of a times series, allowing the identification of the direction of instability (Sihmar, 2014). The index proposed by Cuddy and Valle (2009) is essentially a CV corrected by the multiplication factor $\sqrt{(1 - R^2)}$, as shown in the following equation:

$$Ix = CV \sqrt{(1 - R^2)} \quad (09)$$

where Ix is the index, CV is the variation coefficient, R^2 is coefficient of multiple determination

Ix has a lower limit equal to zero and an upper limit equal to the CV of the time series, since at the extreme, when R^2 is equal to one, the instability measure Ix is equal to zero. By this condition, the real values of the variable analyzed do not show any deviation from the estimated regression, and therefore are not unstable in relation to the explanatory model. At the other extreme, when R^2 is equal to zero, Ix is equal to CV, since, in this situation, the explanatory model for the variable does not actually explain anything and measuring instability is no longer relevant. Between these limits, the correction factor decreases Ix relative to CV, since the more adjusted the regression model, the lower the Ix, due less variation between the values of the variable compared to the calculated regression model.

To select the instability measurement, we calculated: CV, Ix_1 (which refers to a linear regression), and Ix2 (which refers to a log-linear regression). According to Cuddy and Valle (2009), the rule of value selection for a 1% significance level is: a) if both regression equations are significant, we choose Ix_1 if the R^2 of the linear regression is higher. Otherwise, we choose Ix_2; b) If one equation is significant but the other is not, we choose the Ix corresponding to the significant equation; and c) if neither equation is significant, we choose the CV. Using the selected values, we classify states into three categories of instability, based on Sihmar (2014): low (between 0 and 15%), medium (greater than 15% but less than 30%), and high (greater than 30%).

Results and Discussion

Between the crop years 1992/93 and 2016/17, all variables in all states demonstrated a growth trend (Table 2). We found that Mato Grosso was the state that showed the greatest expansion in planted area (in absolute terms), with an increase of 7.61 million hectares. Next, Paraná and Rio Grande do Sul increased their planted area by 3.25 and 2.47 million hectares, respectively, followed by Goiás and Mato Grosso do Sul, which saw increases in planted area of 2.29 and 1.46 million hectares, respectively. As a result of this expansion in area, the relative positions occupied by the states shifted during the period. In 2016/17, Mato Grosso surpassed Rio Grande do Sul as the leader in planted soybean area. Meanwhile, Goiás surpassed the state of Mato Grosso do Sul to take fourth position, while the state of Paraná assumed third position in terms of planted area.

Table 2. Change in soybean planted area, production, and yield between the crop years of 1992/93 and 2016/17

Variable		GO[1]	MS[2]	MT[3]	PR[4]	RS[5]	Average
		million hectares					
Planted Area	1992/93 Crop Year	0.98	1.07	1.71	2.00	3.10	1.77
	2016/17 Crop Year	3.28	2.52	9.32	5.25	5.57	5.19
	Change	2.29	1.46	7.61	3.25	2.47	3.42
		%					
	Change	233.2	136.5	444.1	162.5	79.7	211.2
		million tonnes					
Production	1992/93 Crop Year	1.97	2.23	4.20	4.72	6.29	3.88
	2016/17 Crop Year	10.82	8.58	30.51	19.59	18.71	17.64
	Change	8.85	6.35	26.32	14.87	12.42	13.76
		%					
	Change	449.8	284.7	626.9	315.0	197.4	374.7
		kg ha^{-1}					
Yield	1992/93 Crop Year	2,000	2,090	2,450	2,360	2,030	2,186
	2016/17 Crop Year	3,300	3,400	3,273	3,731	3,360	3,413
	Change	1,300	1,310	823	1,371	1,330	1,227
		%					
	Change	65.0	62.7	33.6	58.1	65.5	57.0

Note: [1]Goiás; [2]Mato Grosso do Sul; [3]Mato Grosso; [4]Paraná; [5]Rio Grande do Sul
Source: CONAB (2017)

With respect to production, the ranking of states with the greatest gains throughout the period is similar to that for planted area. We note the significant increase in production in the state of Mato Grosso, roughly 26.32 million tonnes (626.9%) during the period. This increase made Mato Grosso the largest producer in the country, exceeding Rio Grande do Sul beginning in the 2000/01 crop year (Pinto, Faria and Campos, 2018). Meanwhile, with an increase in production of 14.87 million tonnes, Paraná became the second-largest producer, and Rio Grande do Sul the third-largest in the 2016/17 crop year. Production in Goiás also surpassed that of Mato Grosso do Sul in 2016/17, taking the place as fourth-largest soybean producer.

In addition, the variable, yield, demonstrated a growth trend that was less pronounced than that of planted area or production (Table 2). While planted area and production presented average changes of 211.2% and 374.7%, respectively, the change in yield was 57% between 1992/93 and 2016/17. In absolute terms, the states of Paraná, Rio Grande do Sul, Mato Grosso do Sul, and Goiás saw relatively similar changes in yield, near 1,300 kg ha^{-1}. Mato Grosso saw a yield increase of 823 kg ha^{-1} for the same period, the smallest increase among the states analyzed, which can be explained by the fact that the initial yield in the state was above those of the other states due to a greater application of factors of production (Helfand and Levine, 2004). In relative terms, Rio Grande do Sul and Goiás were the states with the greatest yield gains, near 65%, followed by Mato Grosso do Sul (62.7%), Paraná (58.1%), and Mato Grosso (33.6%).

We can analyze increases in planted area, production, and yield by calculating the annualized growth rate for each, which can be affected by several factors: the existence of economic plans and packages, agricultural policy interventions, and biological and climatic influences, among others (Negri Neto, Coelho and Moreira, 1993). With respect to planted area, we find that Mato Grosso was the state demonstrating the highest annual composite growth rate (7.59%), two percentage points ahead of Goiás (5.59%). Mato Grosso do Sul and Paraná had equivalent growth rates (both 4.23%), and Rio Grande do Sul presented the lowest growth rate in planted area of all the states, at 2.64% (Table 3).

Table 3. Annual composite growth rate (%) of soybean planted area, production, and yield, between the crop years 1992/93 and 2016/17

State	Annual composite growth rate		
	Planted Area	Production	Yield
	%		
Mato Grosso	5.59**	7.22**	1.55**
Mato Grosso do Sul	4.23**	5.70**	1.42**
Goiás	7.59**	8.61**	0.95**
Paraná	4.23**	5.34**	1.06**
Rio Grande do Sul	2.64**	4.84**	2.14**

Note: ** significant at 1%, * significant at 5%.

State rankings in terms of changes in production were the same as those for planted area over the period, with Mato Grosso showing the greatest change in production (8.61%), followed by Goiás and the others. In this case, Goiás presented a smaller change in percentage terms (1.39%) compared to growth in planted area for the state. The change in production for Mato Grosso do Sul (5.70%) was similar to that of Paraná, at 5.34%. Rio Grande do Sul demonstrated the smallest annual growth rate in production for the period, at 4.84%.

In terms of changes in yield over the period, the state rankings differed from those of changes in planted area and production. Rio Grande do Sul was the state with the highest annual growth rate (at 2.14%). Next, Goiás had a growth rate of 1.55%, followed by Mato Grosso do Sul (1.42%) and Paraná (1.06%). Meanwhile, unlike for planted area and production, Mato Grosso showed the smallest annual growth rate in terms of yield, at 0.95%.

Decomposing the growth of soybean production into the effects of yield, area, and the interaction between the two allowed us to identify differences among states with respect to the incorporation of technology in the production process (Tsunechiro and Ferreira, 1996). We found total production to be more influenced by changes in planted area, which demonstrated a decomposition share greater than 40% in all states, and exceeded 70% in the case of Mato Grosso (Figure 1).

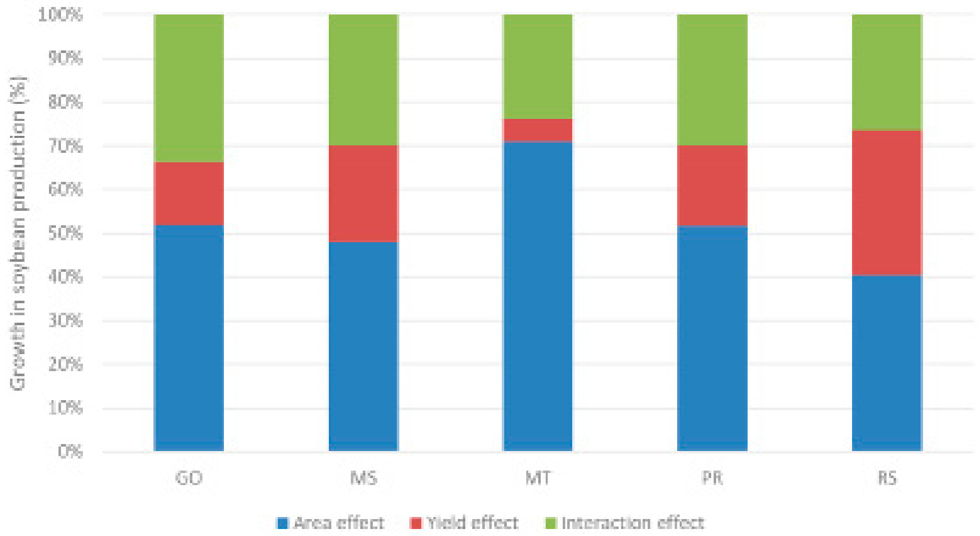

Figure 1. Decomposition of the growth in soybean production, in %, between the crop years of 1992/93 and 2016/17

According to Brandão et al. (2006), throughout the 1990s, the expansion in soybean production occurred from the prevalence in increases in yield in relation to a relatively constant planted area. This differs from the expansion in production in recent years, driven predominately by increases in planted area due to the conversion of degraded pasture into soybean fields, in conjunction with the greater ease of producer acquisition of agricultural machinery and implements through the Program for the Modernization of the Tractor and Agricultural Machinery (MODERFROTA). In addition to the conversion of pasture into soybean fields, another recent phenomenon that contributed to the expansion in production was the conversion of fields formerly dedicated to growing first-crop corn, whose area decreased over the period for all states analyzed (Figure 2).

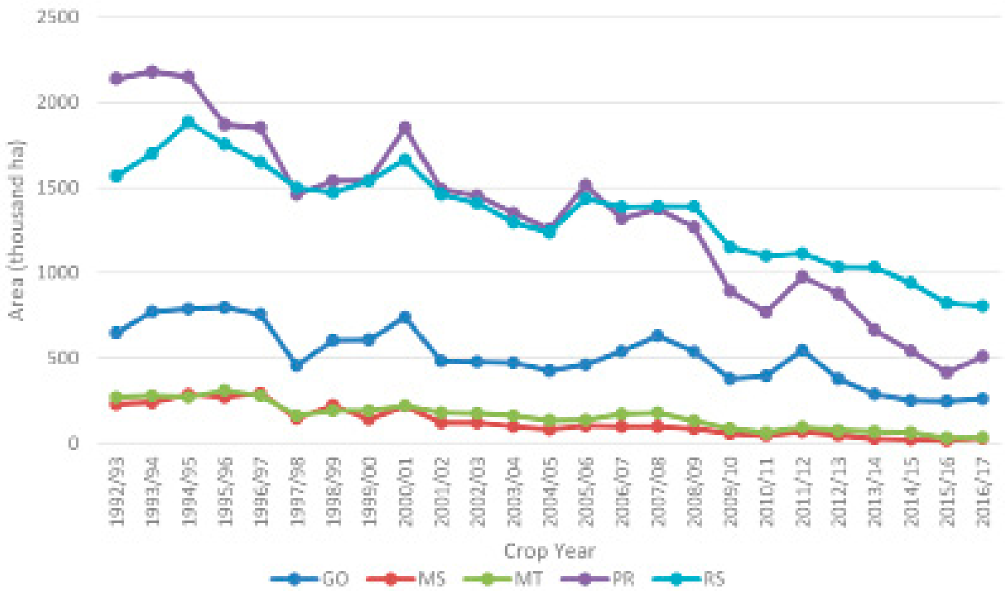

Figure 2. Area dedicated to planting first-crop corn, in thousand ha, 1992/93 to 2016/17
Source: CONAB (2017)

The fall in first-crop corn area was offset by the increase in area dedicated to second-crop corn (Figure 3), a pattern of substitution similarly identified by Landau, Guimarães and Penna et al. (2011). This concentration of second-crop corn can be explained by two factors: first, by the possibility of growing soybeans as a first crop, whose profitability is greater compared to first-crop corn, and second, by the larger marketing window for second-crop corn, whose harvest is concentrated between June and August, just prior to the beginning of the U.S. harvest, which generally begins in September (CONAB, 2018).

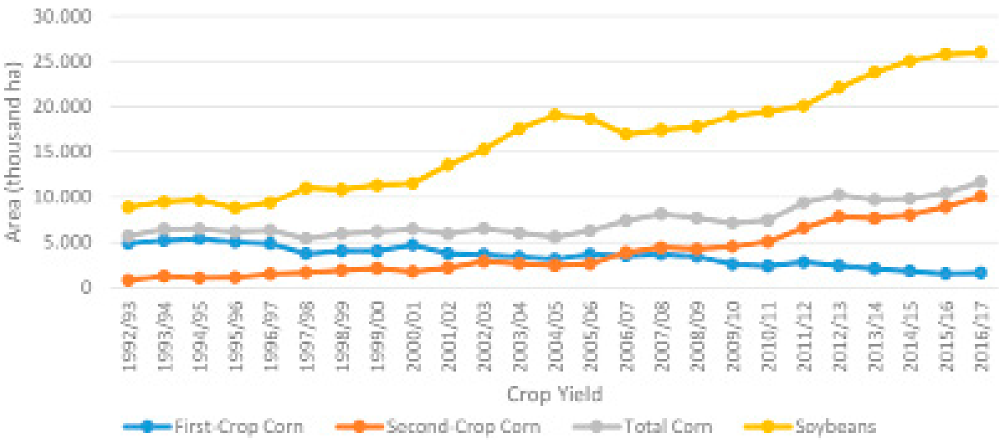

Figure 3. Area dedicated to planting corn and soybeans in the states under analysis, 1992/93 to 2016/17 crop years
Source: CONAB (2017)

With respect to the effect of yield, we highlight the states of Mato Grosso and Rio Grande do Sul. In Mato Grosso, the yield effect was roughly 5%, the least of all states. This may indicate that the adoption of technology in growing the crop was less pronounced here. This perception is shared by Duarte, Cruz and Garcia (2007), who found lower geometric growth rates for soybeans compared to corn in the state, and argued that this situation may result from soybeans already being an established crop grown on large areas, with high yields and production. In Rio Grande do Sul, the yield effect was roughly 33%, higher than in the other states. This may imply that the use of technology was greater here compared to other states. In this same vein, Gonçalves and Sibaldelli (2018), when analyzing the economic viability of soybean production in the south of the state—a region traditionally characterized by natural pasture and extensive livestock production—found that the level of technology employed in the area had increased over the last few decades, leading to an increase in yield. The changes in yield and the annual growth rates found in Tables 2 and 3 corroborate their findings.

The instability for planted area, production, and yield was low in most states (Table 4). We note that Rio Grande do Sul was the only state whose behavior distinguished it from the rest, as the state presented average instability rates for production and yield. These results followed our expectations, as rural properties in the South and Central-West practiced intensive input use and employed high levels of technology in their production, and additionally benefitted from adequate rainfall, better soils, and more developed infrastructure compared to other states (OECD-FAO, 2015).

Table 4. Instability (%) of soybean planted area, production, and yield, from the 1992/93 to 2016/17 crop years

State	Variable	CV	Ix_1	Ix_2	Category
Goiás	Planted area	36.90	10.75*	12.45	Low
	Production	44.17	8.81*	13.13	Low
	Yield	13.05	7.60*	7.78	Low
Mato Grosso do Sul	Planted area	31.31	12.28*	12.65	Low
	Production	41.97	14.08	10.69*	Low
	Yield	15.48	11.57*	11.90	Low
Mato Grosso	Planted area	48.18	10.17*	11.02	Low
	Production	52.14	9.18*	11.48	Low
	Yield	8.49	5.38*	5.41	Low
Paraná	Planted area	28.53	4.81*	6.38	Low
	Production	37.99	12.17	10.33*	Low
	Yield	12.98	10.25*	10.42	Low
Rio Grande do Sul	Planted area	20.89	8.04	7.36*	Low
	Production	46.74	28.10*	30.39	Average
	Yield	28.12	22.74*	24.79	Average

Note: *Selected values
Source: Study results

Paraná and Rio Grande do Sul were the states with the lowest instability of planted area, at 4.81% and 7.36%, respectively. Mato Grosso do Sul was the state with the highest instability in planted area, at 12.28%. We assume that these results reflect the quantity of degraded pasture available for conversion. According to Dias-Filho (2014), pasture with a maximum average stocking rate of 0.4 UA ha^{-1} can be considered as degraded, and the South has 14.8% of its area in this condition. In comparison, the Central-West has 47.4% of such areas, or 3.2 times as much as the South.

The instability of production in Rio Grande do Sul (28.10%) was the highest among all the states in our study, and 2.6 times greater than that of Mato Grosso do Sul (10.69%). Meanwhile, Paraná, Mato Grosso, and Goiás demonstrated production instability values all near 10%. With respect to instability in yield, the states of Rio Grande do Sul and Mato Grosso do Sul followed the same ranking as instability of production, at 22.74 and 11.57%, respectively. Goiás and Mato Grosso were found to be the least stable in terms of yield, with instability rates of 7.60 and 5.38%, respectively.

When we analyze the instability of production and yield, and the relationship between the latter and the use of technology, we find that in the case of Rio Grande do Sul, the average instability rates result from frequent oscillations in yield (Figure 4). This can be explained by the significant differences in rainfall from one year to the next, as a function of El Niño and La Niña (Gusso, 2013). Meanwhile, we found that producer adoption of technology via the intensive use of chemical inputs and machinery contributed to maintaining crop yields despite fluctuations in environmental conditions (Smith, Menalled and Robertson, 2007).

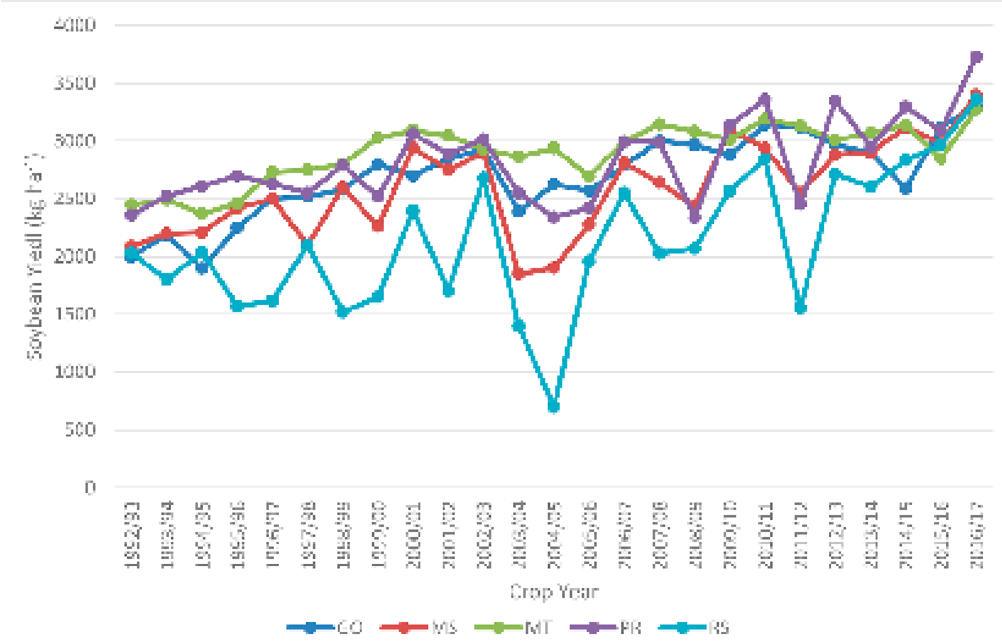

Figure 4. Average soybean yield for the states analyzed, 1992/93 to 2016/17
Source: Prepared by the author, using CONAB (2017)

Our finding of growth rates for planted area, production, and productivity with low levels of instability may be related to the fact that soybeans have long been associated with scientific advances and the availability of technology for production (Freitas, 2011). Likewise, Freitas and Mendonça (2016) argued that the fact that changes in soybean area did not result in a decrease in yield for the crop was associated with the degree of technology and standardization in growing the crop.

The mechanization and growing of highly productive crops adapted to diverse regions, the development of technology packages related to various management practices—of soil, of fertilizer and lime application, and of pests and diseases—and the identification of solutions to the primary factors responsible for harvest losses all promoted this advance in soybean production. Furthermore, we must remember that the expansion of soybean production had state support through the provision of abundant credit to purchase machinery and inputs and through minimum price policy, land policies, and other facilitating measures (Cunha and Espíndola, 2015).

Conclusions

The results of this study show that soybean planted area, production, and yield demonstrated a growth trend in the main producing regions for the period under analysis. This occurred particularly due to changes in planted area, the defining element of production. The relative importance of the main producing states shifted over the period: Mato Grosso became the largest domestic producer, with an annual growth rate of production of 8.61%.

We found low indices of instability in planted area, production, and yield for most of the regions analyzed, with the exception of Rio Grande do Sul, whose instability in production and yield were found to be classified as average.

To enrich our discussion, further work could include segmenting the period of analysis and identifying the determinants of growth and instability. Such work could involve determining how growth and instability rates fluctuate according to agricultural policy interventions and biological and climatic influences.

How to cite: Castro, C.V.V.M.; Camargo Junior, J.B. 2020. Benefits and challenges that the Continuous Improvement area faces in a manufacturing unit. Quaestum 1: e26750528

Author Contributions: Conceptualization: Castro C.V.V.M.; Camargo Jr, J.B. Data acquisition: Castro C.V.V.M. Data analysis: Castro C.V.V.M. Design of methodology: Castro C.V.V.M.; Camargo Jr, J.B. Writing and editing: Castro C.V.V.M.; Camargo Jr, J.B.

Referências

Ayalew, B. 2015. Trends, growth and instability of finger millet production in Ethiopia. Research Journal of Agriculture and Environmental Management 4(2): 78-81.
Brandão, A.S.P.; Rezende, G.C.; Costa Marques, R.W. 2006. Crescimento agrícola no período 1999/2004: a explosão da soja e da pecuária bovina e seu impacto sobre o meio ambiente. Economia Aplicada, 10(2): 249-266.
Chand, R.; Raju, S.S. 2009. Instability in Indian agriculture during different phases of technology and policy. Indian Journal of Agricultural Economics, 64(2): 187-207.
Colussi, J.; Weiss, C.R.; Souza, A.R.L.; Oliveira, L. 2016. O agronegócio da soja: uma análise da rentabilidade do cultivo da soja no Brasil. Revista Espacios, 37(16): 23-33.
Companhia Nacional de Abastecimento [CONAB]. 2017. Séries históricas de área plantada, produtividade e produção. Avaliable in: <www.conab.gov.br>. Access in: nov. 21, 2017.
Companhia Nacional de Abastecimento [CONAB]. 2018. Acompanhamento da safra brasileira: grãos, quinto levantamento, fevereiro 2018. Avaliable in: <http://http://www.conab.gov.br/conteudos.php?a=1253&t=2>. Access in: fev. 07, 2018.
Cuddy, J.D.A.; della Valle, P.A.; 2009. Measuring the instability of time series data. Oxford Bulletin of Economics and Statistics, 40(1): 79-85.
Cunha, R.C.; Espíndola, C.J. 2015. A dinâmica geoeconômica recente da cadeia produtiva da soja no Brasil e no mundo. GeoTextos, 11(1): 217-238.
Dall'Agnol, A.; Lazarotto, J.J.; HirakurI, M.H. 2010. Desenvolvimento, mercado e rentabilidade da soja brasileira. Circular técnica 74. Embrapa Soja. Londrina, PR, Brazil.
Dias-Filho, M.B. 2014. Diagnóstico das pastagens no Brasil. 1ed. Embrapa Amazônia Oriental, Belém, PA, Brazil. Available in: <https://www.infoteca.cnptia.embrapa.br/handle/doc/986147>. Access in: nov. 18, 2017.
Duarte, J.O.; Cruz, J.C.; Garcia, J.C. 2007. A evolução da produção de milho no Mato Grosso: a importância da safrinha. Embrapa Milho e Sorgo, Sete Lagoas, MG, Brazil. Available in: <https://www.infoteca.cnptia.embrapa.br/bitstream/doc/486134/1/Com150.pdf>. Access in: mar. 18, 2019.
Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA]. 2018a. Visão 2030: o futuro da agricultura brasileira. Embrapa, Brasília, DF, Brazil. Available in: <https://www.embrapa.br/visao/o-futuro-da-agricultura-brasileira>. Access in: fev. 12, 2019.
Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA]. 2018b. Soja em números - safra 2017/2018. Available in: <https://www.embrapa.br/soja/cultivos/soja1/dados-economicos>. Access in: mar. 14, 2019.
Freitas, M.C.M. 2011. A cultura da soja no Brasil: o crescimento da produção brasileira e o surgimento de uma nova fronteira agrícola. Enciclopédia Biosfera, 7(12): 1-12.
Freitas, R.E.; Mendonça, M.A.A.D. 2016. Expansão Agrícola no Brasil e a Participação da Soja: 20 anos. Revista de Economia e Sociologia Rural, 54(3): 497-516.
Gonçalves, S.L.; Sibaldelli, R.N.R. 2018. Riscos climáticos e viabilidade econômica da produção de soja no sul do Rio Grande do Sul. Embrapa, Londrina, PR, Brazil. Available in: <https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1094511/1/COMUNICADOTECNICO94.pdf>. Access in: mar. 15, 2019.
Gusso, A. 2013. Integração de imagens NOAA/AVHRR: rede de cooperação para monitoramento nacional da safra de soja. Revista Ceres, 60(2): 194-204.
Helfand, S.M.; Levine, E.S. 2004. Farm size and the determinants of productive efficiency in the Brazilian Center-West. Agricultural Economics, 31(2-3): 241-249.

Hirakuri, M.H.; Lazzarotto, J.J. 2014. O agronegócio da soja nos contextos mundial e brasileiro. Embrapa, Londrina, PR, Brazil. Available in: <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/990000/o-agronegocio-da-soja-nos-contextos-mundial-e-brasileiro>. Access in: out. 20, 2017.

Krishan, B.; Chanchal, A. 2014. Agricultural growth and instability in western himalayan region: an analysis of Himachal Pradesh, India. Journal of Agriculture and Life Sciences, 1(1): 21-27.

Landau, E.C.; Guimarães, L.S.; Penna, LB. 2011. Variação da produção estadual de milho no Brasil entre 2000 e 2009. 1ed. Embrapa Milho e Sorgo, Sete Lagoas, MG, Brazil. Available in: < https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/920747/1/bol39.pdf>. Access in: mar. 18, 2019.

Negri Neto, A.; Coelho, P.J.; Moreira, I.R.O. 1993. Análise gráfica e taxa de crescimento. Informações Econômicas, 23(10): 99-108.

Organisation for Economic Co-operation and Development - Food and Agriculture Organization of the United Nations [OECD-FAO]. 2015. Agricultural Outlook 2015-2024. OECD Publishing, Paris, France.