REGULAR ARTICLE

Work accidents in agriculture: a study of Brazilian soybean production

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Abstract

Soybean cultivation has great economic and social impacts, meaning it offers many job opportunities. Studying the number of accidents in this field is essential for a better understanding of the quality of work related to it. Therefore, the purpose of this article is to verify if, in the field of soybean cultivation, there are correlations between productivity, product price, and the number of accidents, between the years of 1999 and 2018, in Brazil. For that, Pearson's method was applied, allowing for a bivariate analysis that can quantify a degree of strength between different variables. As a result, it was found that soybean production and price are linearly related to the number of work-related accidents in cultivation. Therefore, it is concluded that, if an increase in price or production occurs, it will lead to an increase in accidents, and the opposite will also happen.

Keywords

Work accident; Brazil; Soybean production; Linearity

Introduction

Soybean is an oilseed typical of temperate countries that was tropicalized and presents itself, today, as one of the most prominent crops in Brazilian territory (Domingues *et al.*, 2014). According to Bonato and Bonato (1987), the first test record of such a product was presented in the state of Bahia in 1882 and, from that point forward, Brazil was marked by some events that later characterized the expansion of soybeans in Brazil, namely: the incentive to cultivate soybeans in 1900, with the distribution of grains for planting; the cultivation attempts in the states of Rio Grande do Sul and São Paulo in the first three decades of the 20th century; and soybean generating official statistical results in these states in the 1940s.

According to Campos (2011), the southern region of Brazil led, until the 1980s, 98% of the national production of soybeans and, therefore, under the command of these states, more modern farming techniques were developed, allowing for the agricultural expansion to the Midwest to take place. The expansion of soybeans continued; the states of the North and Northeast witnessed the introduction of the product after the last decade of the 20th century. In the last two decades, Brazilian grain production has gained great international importance, with Brazil being the second largest exporter and producer of soybeans, thus reaching a value of US$ 346 billion in relation to the export of the product (Embrapa, 2021).

Agribusiness is one of the greatest sources of wealth in the country and is responsible for 35% of the employed workforce in Brazil. The Midwest region stands out as a soybean producing hub and, at the same time, is marked by the precariousness of road transport. The lack of investment in the area does not generate expansion, restoration, or conservation of the routes. The road network is used for the shortest time and viable cost for the transport of soybeans, but it is this mode of transport that also records the highest number of accidents (Correa and Ramos, 2010).

It is important to emphasize that several factors were, in the environmental and economic aspects, necessary for there to be a possible increase, not only in the cultivated area, but also in productivity. Among the reasons that led to the expansion of soybeans in Brazil, one can point out: soybeans were used in succession to wheat, a situation that allowed the use of the same area, machinery and even labour; in addition to the great adaptability of the varieties; favouring the condition of the foreign market; and the lack of option of edible vegetable oils as a substitute for the use of animal fat (Bonato and Bonato, 1987).

The expansion of soybeans in the country influenced both the environmental and economic aspects, as well as the social and labour relations. In one classification, Brazil had high levels of deaths and accidents. Considering a total of 200 countries, Brazil ranks fourth in deaths from work-related activities, and fifth in the number of accidents at work (Cesteh, 2019). In the field of occupational health, case studies have indicated a positive correlation between the expansion of

commodities and the increase in the number of work-related accidents (Oderich *et al.*, 2019).

During a worker's day of labour, it is possible that several accidents and incidents occur. Work safety is defined as a science that studies the causes, presenting as an objective the adoption of preventive measures to guarantee a safer and more peaceful work environment, for both employee and employer (Barsano and Barbosa, 2018).

Law No. 8,213, of July 24, 1991, states that a work accident is that which occurs by the exercise of labour in the service of a company or domestic employer, or by the exercise of the work of the insured in a way that causes bodily injury or functional disturbance, causing death, loss, or reduction of the ability to work, classified as permanent or temporary (Brazil, 1991).

According to França and Nogueira (2021), the Brazilian states that have the highest number of accidents are also identified as soybean producers and, among the reasons that lead this branch to present such high levels of accidents, is the greater demand for the product, as well as the evolution of the methods for its production. In other words, more is demanded from the worker in relation to the working day, but adequate working conditions and training for new machines are not always available. Innovation and improvements for production are kept in mind, but this does not mean that this line of reasoning has been expanded to the employee.

Some of the Regulatory Standards (RS) can be applied in the context of agriculture in order to contribute to the safety of workers, such as: RS – 12 assesses safety in machines and equipment; RS – 31, more comprehensively, deals with safety and health at work in agriculture, livestock, forestry, and aquaculture; RS – 33 contributes to the regularization of activities that take place in confined spaces; and RS – 35 establishes requirements for working at heights (BRAZIL, 2022a).

According to the Brazilian Institute of Geography and Statistics (IBGE, 2007), in order to organize information on production units and understand their statistical effects on the economy, the National Classification of Economic Activities (CNAE) was created. Contrary to the common interpretation, the economic factors of soy encompass much more than just the cultivation part. In CNAE 2.0, codes 01.15-6 and 46.22-2 are used to deal, in due order, with soybean cultivation and soybean wholesale trade (IBGE, 2007). Still on CNAE 2.0 and soybean cultivation, the category includes seed production together with cultivation, yet it does not include certified seed production, soil preparation services, soybean oil production, and biofuel production (Mozena *et al.*, 2020).

Even with technological changes, laws, and new codes, there is still some difficulty in obtaining data from the sector, especially when the issue of work accidents is addressed. According to Begnini and Almeida (2015), the lack of information related to the number of accidents in work activities is noticeable. This situation arises due to the following situations: part of this population does not have formal ties to work, that is, they do not have a formal contract or own the site; and there is still a lack of interest and perception of the importance of these data.

Considering the importance of soybean cultivation in Brazil, as well as its impacts and consequences on the lives of producers and rural workers, the present article aims to answer the following research question: Are there correlations between the variables productivity, number of accidents, and product price in the period from 1999 to 2018, in Brazil, in the soybean cultivation field? In addition, an analysis of the profile of these accidents was also performed.

In the development of the article, Pearson's statistical method is applied, which uses a methodology that manages to quantify the correlation between two variables, meaning the influence that one variable has on another. Therefore, it is possible to mathematically verify the relationships between the study parameters.

Materials and methods

A systematic literature search was carried out to obtain greater knowledge of the topic addressed by the article and, consequently, to generate results with greater reliability. Different databases were used, namely: Scielo, Scopus, Web of Science, and Google Scholar. Each database received a different configuration for the material search, however they all had a common filter, that is, the year of publication of the material should be between 2000 and 2021. Table 1 exemplifies this search process.

The method here used for preparing the systematic review, following Thomé *et al.* (2016), involves the following phases: review planning (definition of the question); literature search (definition of database, keywords, search criteria, review of titles and abstracts, exclusion criteria, and full reading of articles); interpretation; and, finally, the presentation of the results.

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Table 1. Research and Databases

Database	Words + operators	Filters	Thematic area
Scielo	(soy) OR (soybean) AND (Brasil) OR (Brazil) AND ("work accident") OR ("occupational accident") OR ("labour accident")	Article only Topic	Areas of applied social sciences, humanities, multidisciplinary , health sciences and engineering
Scopus	(soy OR soybean) AND (brazil OR brasil) AND (workers OR producers) AND (work OR occupational OR labour)	Article only Topic	----
Web of Science	(soy OR soybean) AND (Brazil OR Brasil) AND producers	Article only Topic	----
Google Scholar	(soy OR soy beans) AND "workplace accidents" AND Brazil	All types of literature All fields	-- --

The results obtained in the four databases add up to 526 documents. Scielo, Scopus, Web of Science, and Google Scholar presented, respectively, 47, 53, 196, and 230 articles. The first step to filter the most relevant papers for the study was to analyse each of the databases again and remove identical articles. Then, the titles of the articles were read and those with a theme related to the studied subject were selected.

Then, the abstracts were read in order to select papers that address the social aspects of workers in the soybean industry, accident analyses, and historical series, as well as interpretations of the soybean trade in recent decades. An illustration of the process is shown in Figure 1, below, representing the entire review process performed.
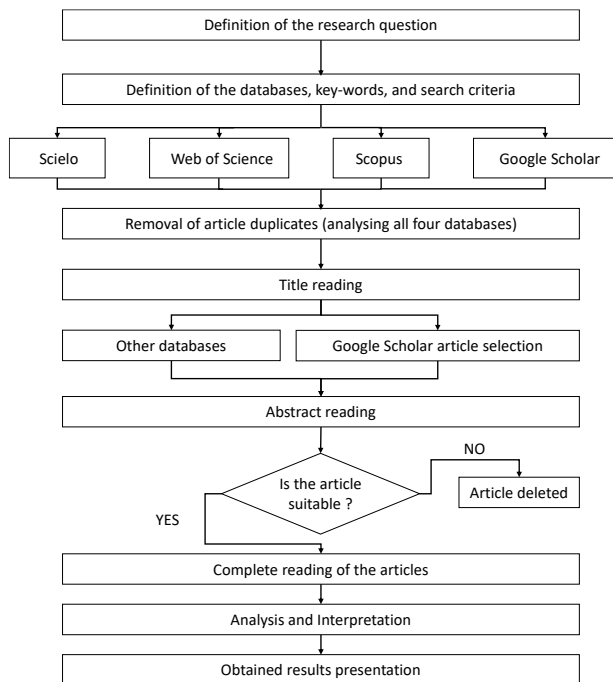
Figure 1. Study process.

Through the process of bibliographic research, information related to the subject of the article was found, such as the expansion of soybean cultivation in Brazil, importance of agribusiness in generating jobs, possible causes of work accidents, and possible actions that can be taken to control the risks in these environments.

Pearson's statistical method

The method chosen for static validation was that of Pearson's correlation coefficient, which can be defined as a measure of bivariate association (represented by strength) of the degree of relationship between two variables. The objective of this coefficient is to measure a correlation in direction and degree of a linear relationship (Figueiredo Filho and Silva Júnior, 2009).

According to Figueiredo Filho and Silva Júnior (2009), two concepts are key to the understanding of Pearson's correlation coefficient: association and linearity. In statistics, two variables are associated when they have similarities in the distribution of their scores, meaning the variables can be associated from the distribution of their frequencies or sharing of variance. In the case of Pearson's method, also known as Pearson's r, the last parameter is used, being, then, a measure of the variance shared between two variables. On the other hand, the linear model assumes that a change in variable X will generate a similar impact on variable Y.

Graphically, the linear relation illustrates the pattern of relationship between two variables through a straight line. Therefore, Pearson's correlation (r) requires a sharing of variance, and that this variation is linearly distributed (Figueiredo Filho and Silva Júnior, 2009). This way, Pearson's correlation ranges from -1 to 1. The sign indicates positive or negative direction, and the value suggests the strength of the relationship between the variables. A perfect correlation will indicate that the score of one variable can be determined exactly by knowing the score of the other. However, a correlation of zero value indicates that there is no linear relationship between the variables (Figueiredo Filho and Silva Júnior, 2009).

According to Figueiredo Filho and Silva Júnior (2009), there are numerous classifications about the values of r,

however, in general, it is considered that an *r* with a value above 0.7 characterizes a strong relationship, while those below 0.3 are understood as weak. Briefly, the closer to one (regardless of the sign), the greater the degree of linear statistical dependence between the variables. And the closer to zero, the lower the strength of this relationship.

To calculate the coefficient, some procedures are performed. The first step is to choose the two variables that are to be analysed and then pair them into twos. In this way, a variable *X* is linked to its pair, which is the variable *Y*. The last step is to identify them in the same way, as it can be noted from the following example, presented in Table 1:

Table 1. Example of Pearson's coefficient procedures.

ID	X	Y
1	29	0.49
2	40	1.59
3	54	1.68
4	55	1.82
5	72	3.10

Source: Adapted from Figueiredo Filho and Silva Júnior (2009).

The first column (ID) records the identification of each observation, and the variables *X* and *Y* are two measures for which the correlation is studied. The first step to estimate Pearson's correlation coefficient (*r*) is to standardize the observations, that is, to find the score corresponding to the variables studied, which is obtained through the following equation:

$$Z_x = \frac{(X_i - \underline{X})}{S_x}$$

where X_i represents the value of the observation, $\underline{X}$ represents the mean, and S_x indicates the value of the standard deviation. This must be done for all values of *X* and then repeated for all values of Y, thus finding Z_y.

After that, the cross product of the standardized values of X and Y ($Z_x * Z_y$) must be added. Table 2, below, illustrates this procedure:

Table 2. Example of Pearson's coefficient procedures (continuation).

ID	Z_x	Z_y	$Z_x * Z_y$
1	-1.286	-1.345	1.73
2	-0.613	-0.16	0.098
3	0.245	-0.052	-0.013
4	0.306	0.008	0.027
5	1.348	1.46	1.978

Source: Adapted from Figueiredo Filho and Silva Júnior (2009).

Using the sum of $Z_x * Z_y$, it is possible to obtain *r* through the following equation, where *n* corresponds to the number of samples:

$$r = \frac{1}{n-1} * \sum \frac{(x_i - \underline{X})}{s_x} * \frac{(y_i - \underline{Y})}{s_y}$$

For this example, the result found is = 0.955, indicating a strong relationship between *X* and *Y*.

In order to structure the study-base, quantitative data related to the number of work accidents was obtained from the Statistical Yearbook of Work Accidents (AEAT). This number, referring to the whole country, was comprised of: typical accidents with CWA (Communication of Work Accident); in-commute CWA; CWA related to illness; and no CWA. The data here used considers the sum of all these accident subdivisions for the period ranging from 1999 to 2018 (Brazil, 2018).

The productivity and production data are from the National Supply Company (CONAB). Historical series of crops and cultivation were analysed in a way that, for productivity, there are data from the years between 2008 and 2017, while for production, data was found ranging from 1999 to 2018 (Brazil, 2022b).

The price of soybeans, available on an annual basis, is from the International Monetary Fund - Primary Commodity Price System, covering the period from 1999 to 2018 (IMF, 2021).

Using the previous example of how to reach Pearson's coefficient, this study's *ID* corresponds to the years of study, the variable *X* is the number of work accidents, and finally, *Y* is replaced by the variable that seeks the relationship: productivity, production, and price of soybeans.

Results and discussion

By gathering bibliographic data, a large base was obtained, focused on the years 1999 to 2018, which mainly demonstrated the evolution and number of accidents related to soybean cultivation. With this, several other variables related to soybeans in Brazil were also studied, in this case, the focus turned to productivity, production, and the price of soybeans. Table 3 shows all the data obtained in the research.

Table 3. Soybean cultivation data.

Year	Number of Accidents	Production (Ton. x 10³)	Productivity (Ton/Worker)	Price (Dollar/Ton)
1999	35	32.344,60	-	$174,92
2000	120	38.431,80	-	$183,05
2001	134	41.916,90	-	$168,75
2002	195	52.017,50	-	$188,87
2003	249	49.792,70	-	$233,19
2004	285	52.304,60	-	$276,63
2005	330	55.027,10	-	$223,15
2006	286	58.391,80	-	$217,45
2007	497	60.017,70	-	$317,32
2008	832	57.165,50	706,01	$452,94
2009	1101	68.688,20	813,20	$378,55
2010	1196	75.324,30	843,02	$384,95
2011	1288	66.383,00	670,13	$484,25
2012	1383	81.499,40	765,48	$537,76
2013	1397	86.172,79	766,47	$517,20
2014	1273	97.093,96	823,13	$457,81
2015	1171	95.697,60	783,45	$347,36
2016	1319	115.026,67	924,82	$362,71
2017	1330	123.258,56	956,73	$ 358,82
2018	1423	119.718,10	-	$ 342,53

Regarding the number of accidents (Table 4), it is understood that the value presented is formed by the sum of four subdivisions of accidents, namely: typical accidents, accidents that happened during commute, illness-related accidents, and the category without CWA. Table 4 displays the identified development of each division over the years.

Table 4. Description of Accidents

Year	Typical	Illness	Commute	No CWA
1999	34	0	1	-
2000	114	1	5	-
2001	131	0	3	-
2002	179	0	16	-
2003	232	2	15	-
2004	259	3	23	-
2005	289	7	34	-
2006	251	5	30	-
2007	456	1	29	11
2008	645	4	84	99
2009	863	6	94	138
2010	913	5	100	178
2011	971	10	98	209
2012	1017	12	150	204
2013	1027	8	144	218
2014	1107	7	159	0
2015	1019	2	120	30
2016	1131	6	124	58
2017	1154	6	113	57
2018	1232	2	139	50

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After compiling the data, graphs were prepared for better representation. Figure 2 shows the relationship between accidents and the price in dollars across the studied years. A priori, it is already possible to notice a similarity between the variables, since both follow the same growth pattern.
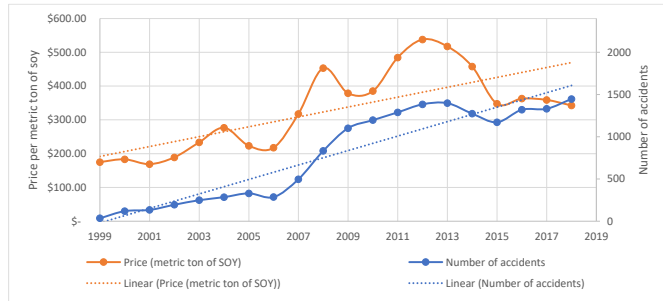

Figure 2. Soybean Price and Number of Accidents.

Regarding production, indicated in Figure 3 below, there is also a great similarity, keeping the proportions between both *y* axes the same growth pattern is repeated once again.
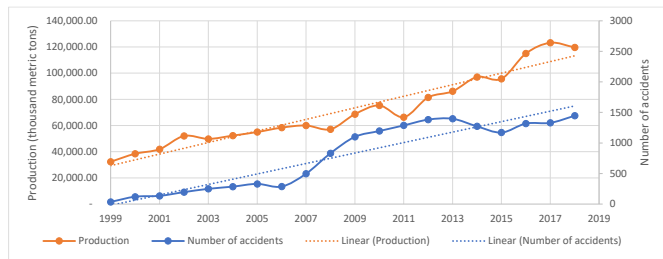

Figure 3. Soybean Production and Number of Accidents.

In Figure 4, which indicates the relationship between productivity and work accidents, there is a pattern that, at first, was similar. However, is important to note that, since only the years 2008 to 2017 were found and indicated, there is less data to be analysed here.
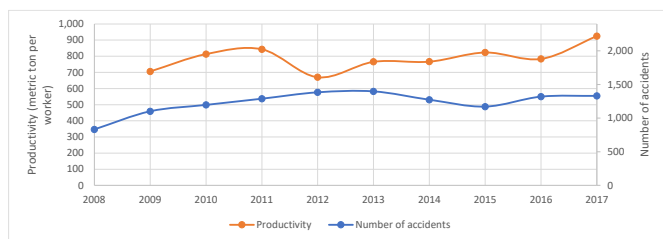

Figure 4. Productivity and Number of Accidents.

The figures provided an overview of how the soy market works and its impacts on labour, health, and work-related accidents. However, only through this analysis it is not possible to state, statistically, whether there is a strong relationship between the studied variables or not. Thus, the previously described Pearson's method was used, which is based on analysing the strength of the relationship between two variables.

Therefore, the entire calculation procedure was carried out to understand which of the data is most strongly related to the number of accidents. After the calculations were done in order to obtain Pearson's *r*, the results are available as follows, in Table 5.

Table 5. Pearson's *r* results

Analysed Variable	Pearson's *r*
Soy Productivity	0.333
Price	0.872
Production	0.856

With these data it is possible to statically define a degree of relationship between the variables studied and the number of work accidents. The first variable was soybean productivity, a measure that related the number of active links and the amount of soybean produced by these, and, contrary to what was expected, the increase in productivity did not have great significance in an increase in the number of accidents, indicated by the weak degree of relationship of only 0.333.

However, the other two data in Table 5 showed a strong correlation (*r* close to 1) between accidents and soybean production, as an *r* of 0.856 was found. This indicates that there is an almost linear relationship between the two variables, in other words, when production increases, the number of accidents will also increase.

As for the soybean price variable, there is an even more dependent relationship on the number of accidents seeing that a maximum *r* was reached, indicating the strongest relationship between the analysed data. This corroborates the assumption that an increase in price will have a consequence almost proportional to the number of accidents in soybean cultivation.

According to Barrozo and Rosa (2018), soybean production in Brazil went through several phases, ranging from the introduction of soybeans in the first crops of the state of Rio Grande do Sul, to the expansion towards the central-west region and now, a new milestone, the second expansion to MATOPIBA (North and Northeast regions). All this development occurred due to the commercialization of the product, however, along this path and with the modernization of the field, negative impacts were generated on the socioeconomic aspects of soybean cultivation.

Brazil is the second largest soybean producer in the world and the largest exporter of the product. Conquering this place in the international market generated impacts on the quality and safety of workers. Mozena *et al.* (2020) concluded that, for the period ranging from 2008 to 2018, most work accidents in soybean cultivation were classified as typical accidents. In addition, in the characterization of the field, workers tend to be impacted by few occupational illnesses. For the analysis of this entire period, it was concluded that it is a relationship between productivity and the number of typical accidents is possible.

Santos *et al.* (2021) analysed the conditions that could lead to the emergence of so many accidents in the main agricultural activities (classification in which soy is included) between 2013 and 2018, namely: combination of environmental factors with uncontrolled risks and human factors, lack of training and low education (in relation to basic education). Considering the accident profile of rural workers, the most affected parts of the body are the hands and fingers and, in some cases, the lower

limbs; the most common injuries were fractures, cuts, and lacerations, generally without risk to the worker's life.

Silva *et al*. (2020) discussed the growth of soy production and the dependencies and risks that this growth generated for producers. High production ends up leading to high-risk situations that often indicates a lack of security to obtain a greater result in the harvest. To avoid risks, it was concluded that strategies are needed, such as, for example, acting as a group, using different lands in different locations, adopting reduced prices for seed demand, and harvesting storage. This way, it is possible to avoid certain risks and maintain constant profit. That is, there is always a fixed income and, thus, there is no need to withdraw resources from some other area, such as worker safety.

Conclusions

The period from 1999 to 2018 was marked in Brazilian agriculture by the great development of production and technology in the field of soybean cultivation. Over these years, the cultivation of this commodity provided an economic and territorial expansion that ended up influencing labour aspects in various parts of the country.

This article aimed to verify if there are indeed correlations between the variables productivity, number of work-related accidents, and price of the product, for the period ranging from 1999 to 2018, in Brazil, in the field of soybean cultivation. In addition, it was also presented as one of the objectives to understand the profile of work accidents in this field.

With all the data collection and statistical analysis done following Pearson's method*,* it can be seen that the strongest correlation is between the number of accidents and the soybean price. The second strongest correlation is between the number of accidents and soy production. Productivity, with Pearson's *r* equal to 0.333, is classified as having a weak relationship with work accidents. In other words, unlike the other two relationships (price and production), a change in productivity values does not impact the number of accidents.

In relation to the occupational accident profile in the Brazilian soybean growing sector, for the period from 1999 to 2018, there is a tendency for a greater occurrence of typical accidents, meaning those that occur during the execution of the labour and that do not have a history of generating high numbers of occupational illnesses. The number of commuting accidents is significant, but it does not appear as in most cases. Finally, the soybean cultivation field has also a large number of accidents in no CWA (without Communication of Work Accident).

Thus, with the data obtained and the variables studied, it is understood that the result of the existing relationships could be altered if the coverage of the variables (in years) were greater. Thus, a greater reliability of the value of Pearson's *r* coefficient could be acquired, since a larger number of samples could clarify the question of linearity. However, there is a difficulty in identifying older data, due to factors that range from producers and databases not recognizing the relevance of this material, to the great informality of the field, or even due to the governmental issues with system changes and adoption of new legislation.

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