RECENT CROP TRENDS AND RAINFALL ANALYSES FOR BRAZILIAN SOYBEAN AGRICULTURE

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Abstract

Brazil is the second largest soybean producer in the world and interannual rainfall variability is one of the most important natural hazards that affect final crop yield values. The real risks to Brazilian agriculture are complex to evaluate, as there are many variables involved, but rainfall variability still may be the limiting factor. For this study, we have chosen two representative soybean areas in Brazil: northwestern Rio Grande do Sul, located in a subtropical climate context, and northern Mato Grosso, a tropical-equatorial location. Thus, the objective of this study is to analyze the risks of rainfall variability and climate as well the recent crop trend for Brazilian soybean agriculture to answer the fallowing question: What is the difference between the two study regions in terms of soybean production, their trends, and the influence of climate? This study presents a time series analyses based on 15 years, and was defined based on the availability of data from ANA, the National Water Agency. Yearly soybean data were obtained for the period of 1998-99 to 2012-13 from 200 counties in Rio Grande do Sul and 43 from Mato Grosso. The rainfall data were collected for the same period following the agriculture soybean calendar in Brazil (October-April). R software was used to make graphic boxplots to represent the values by year, showing the spatial and temporal variations, and SPSS was used to verify the trend and to make correlations between soybean and monthly rainfall using Kendall, Pearson and Spearman tests. Results show a positive crop yield trend is present in both regions. There were positive results in 17% of all counties in northwestern Rio Grande do Sul and in 21% in northern Mato Grosso. We have found two different annual variability modes: in subtropical and temperate climates, such as Rio Grande do Sul that have observed lower rainfall variability, there is greater spatial consistency in the data and also a strong relationship with soybean crop yield. In Mato Grosso, a tropical climate that is also transitional to equatorial, the data variability is higher, and the relationship between annual rainfall and soybean production cannot be readily established. The statistical tests showed better results in south Brazil where we could identify a strong rainfall dependence period in February.

Key words: *soybeans, agriculture, climate change, rainfall*

1 - Background

Understanding the interactions between nature and society is a key issue in determining the causes and the consequences of global climate change (Arvor et al., 2013). Climate variations interfere directly on rainfall regimes, and precipitation has a major influence on the water supply to plants, and so a decisive influence on agriculture (Ayoade, 1983). In the case of soybeans in the Brazil, this is all the more important that it is one of the jewels of the exports of the country and the economic stakes are huge (Embrapa, 2014).

Brazil is the second largest soybean producer in the world and interannual rainfall variability is one of the most important natural hazards that affects final crop yield values. The real risks to Brazilian agriculture are complex to evaluate, as there are many variables involved, but rainfall variability still may be the limiting factor. For this study, we have chosen two representative soybean areas in Brazil: northwestern Rio Grande do Sul, located in a subtropical climate context, and northern Mato Grosso, a tropical-equatorial location.

This study aims to analyze the risks of rainfall variability and climate as well the recent crop trend for Brazilian soybean agriculture to answer the fallowing question: What is the difference between the southern and northern soybean regions, their levels of production, trends, and the influence of climate on these cropping regions?

1.1 The climate characterization of southern and northern Brazil

The regions selected for this comparative study have different climate conditions (Figure 1). The climate in the south of the Brazil is essentially determined by the position and intensity of the subtropical anticyclone of the South Atlantic, which is a system of semi-permanent pressure, and its associated anticyclonic circulation. In summer, this movement moves to the southeast of the country, without frequent penetration of the Mainland (Grimm, 2009). Rio Grande do Sul is affected by atmospheric sub-synoptic- and synoptic-scale systems, influenced both by factors associated with the movement of the large and the local scale, both original tropical and extratropical (INPE/CPTEC, 1986).

The synoptic climatology of the region is characterized by i) frontal systems that move in from the Pacific, through Argentina and continue to the north; (ii) systems that develop in the south and southeast of Brazil, that are associated with cyclonic eddies or troughs at higher levels, which come from the Pacific and; (iii) systems that organize themselves in the south and southeast with intense convection and which, associated with the instability caused by the subtropical jet, spread eastward across the Atlantic Ocean; (iv) systems that organize themselves in the south as a result of frontogenesis or cyclogenesis (Britto et al., 2008).

In most of the Rio Grande do Sul, rainfall regimes are uniform, with the highest concentration of precipitation during the August-September-October quarter (beginning of soybean seedlings). During the summer (from October to April), 'Mesoscale Convective Complex' (CMC) type systems are common and represent a large part of the total precipitation (Britto et al., 2008; Grimm, 2009).

The Brazilian Amazon is characterized by two main types of climates: 'Equatorial' climates on the greater part of its territory, and the "tropical" climates in alternating seasons, towards the eastern and southern limits (Davis et al., 2011). In the Brazilian Center-West region, the climate is characterized by dry winters and wet summers. Dry weather during half of the year (winter) has its origin in the stability generated by the influence of the subtropical anticyclone of the South Atlantic and small ridges that form on the South American continent (Nimer, 1989; Alves, 2009). The variability of rainfall during austral summer is high in the Center-West region, and is directly related to weather conditions resulting from the interaction between phenomena belonging to different temporal and spatial scales, from global to local (Nimer 1989; Alves, 2009).

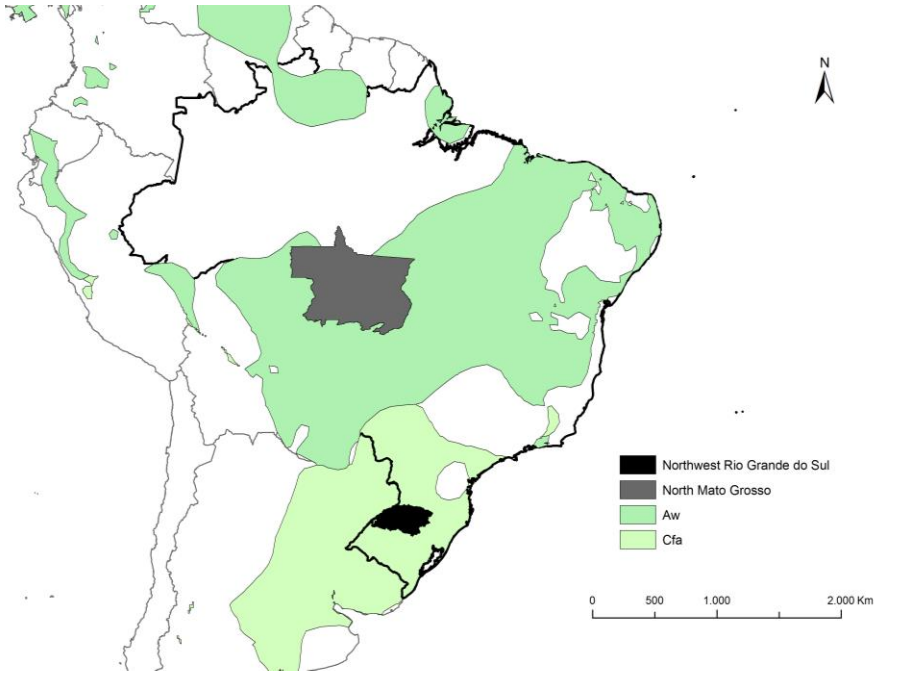

Figure 1 - Study areas localization and climate characterization in Brazil

2 - Methods

This study presents a time series analyses based on 15 years of data, and was defined based on the availability of data from ANA, the National Water Agency. Yearly soybean data were obtained for the period of 1998-99 to 2012-13 from 200 counties in Rio Grande do Sul and 43 from Mato Grosso. The rainfall data were collected from the same period fallowing the agriculture soybean calendar in Brazil (October-April).

R software was used to make graphic boxplots to represent the values by year, showing the spatial and temporal variation, and SPSS was used to verify the trend and to make correlations between soybean and monthly rainfall using Kendall, Pearson and Spearman tests.

2.1 Soybean data

Production and return data are available from the IBGE (automatic recovery system - SIDRA) for the periods from 1998-1999 to 2012-2013. We used these data to compare different levels of agricultural dependence on rainfall variability (Carmello et al., 2014).

To find the crop trends we applied the Mann-Kendall test to the soybean serial data. The purpose of this test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time (Mann 1945, Kendall, 1975).

2.2 Rainfall data

The monthly precipitation data from October to April for each year, which correspond to the agricultural calendar of the soybean in the regions of southern and central-western Brazil (Almeida et al.., 2007; Arvor, 2013) were provided by ANA, the National Water Agency, from the hydrological information system - HIDROWEB, administered by the Agency and available on the internet (Figures 2 and 3).

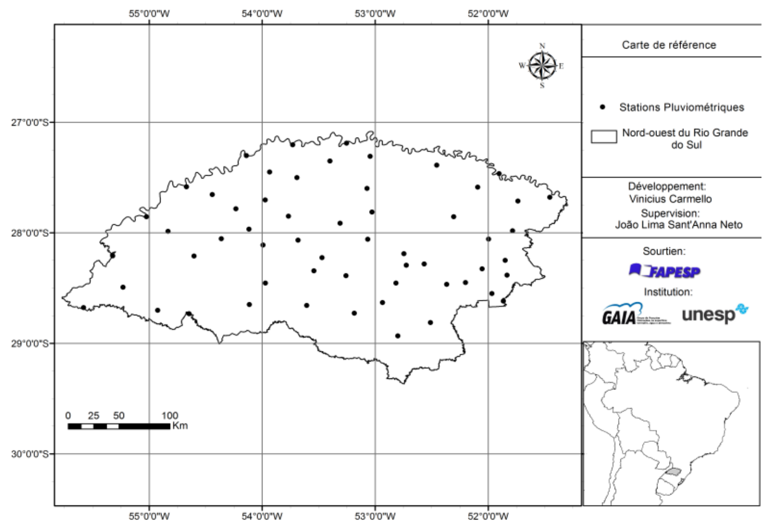

Figure 2: Distribution of the forty-two rainfall stations in the northwest of Rio Grande do Sul

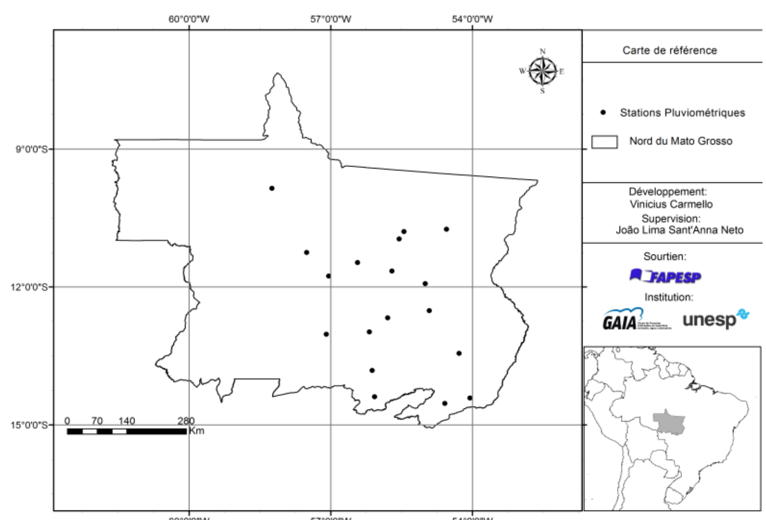

Figure 3: Distribution of eighteen rainfall stations in the north of Mato Grosso

Pre-treatment followed the directions of Zandonadi (2013) to check the consistency of the rainfall data provided by the ANA. We chose to use the best series, and in the absence of data, we followed the methodology of Fante and Sant'Anna Neto (2013) to complete the series. Thus, the main factors in the choice of the replacements were the availability, reliability and the geographical location of the necessary time series (Blain, 2009). In order to characterize the variability, we used the technique of the percentiles of the cumulative rainfall values (Insaf et al., 2007; Silvestre et al., 2013).

2.3 Technical applied and results representation

The Box Plot chart, or diagram, is quite well known in the area of statistics, and most statistical software presents this chart. To build it, the data must be sorted, from lowest to highest value, and must be calculated summary statistics known as quartiles, which divide the data set into four parts, with the first quartile (Q1) for which 25% of the observations are at or below its value, the second quartile (Q2), also known as median to which 50% of the observations are equal or are below it , and the third quartile (Q3), between 75% of the observations at or below its value (Silvestre, et al, 2013; Bussab e Morettin, 2002).

The advantage of the Box Plot is to provide a quick visualization of the distribution of data, and if the distribution is symmetric the cash register is balanced with the median positioning itself in the center of the same. To asymmetric distributions, there is an imbalance in the box, with respect to the median.

3 - Results

3.1 Crop trend analyses

The positive crop yield trend is present in both regions. There were positive results in 17% of all counties in northwestern Rio Grande do Sul and in 21% in northern Mato Grosso. In Brazil, despite the lower intensity of positive trends in Rio Grande do Sul (17% of all cities analyzed), these increases are concentrated in the south and east of the region analyzed. In northern Mato Grosso the concentration of points with positive trend is in the central region, from north to south.

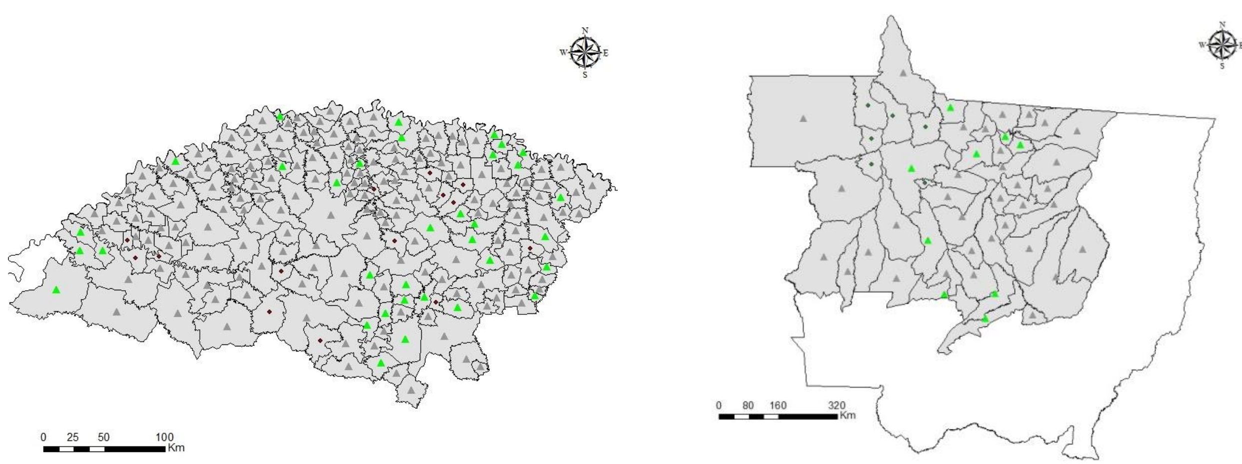

Figure 4 – Examples of soybean crop trend in south and north Brazil. Green dots indicate locations with significant increases in yield.

3.2 - Characterization of the production in Brazil of the Rio Grande do Sul

Although they are in the same nation State, Northwest of Rio Grande do Sul and northern Mato Grosso differ quite expressive though soybeans have been deployed initially in the State of southern Brazil, who today holds the largest agricultural income is the Mato Grosso. Soybean performance data (Figure 5) present a very different profile between the two regions. Yields are generally higher (more than 2500 kg/ha for all years studied) and less irregular in Mato Grosso: If the climate plays a role in Mato Grosso, it is less and probably a different spatio-temporal scale.

Annual data of the production of soy in Rio Grande do Sul are weaker and don't reach yields close to those of Mato Grosso than in the wettest years (2002-2003, 2009-2010, 2010-2011 and 2012-2013) on the other hand, in the Northwest of the Rio Grande Sul, the dry years (1998-1999, 2004-2005 and 2011-2012) are most often characterized by a decline in yields.
There are however counter examples, especially during years where the differences of rain between the stations is important, which translates into average yields (2001-2002, 2007-2008).

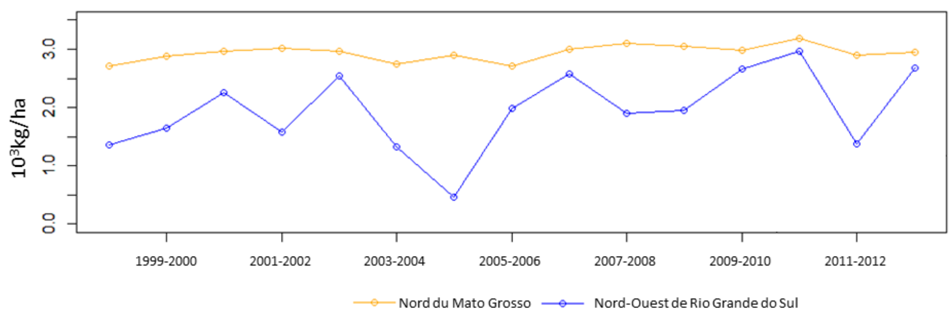

Figure 5: Annual changes (1998-2013) yields (103 kg/ha) of soy in the Northwest of Rio Grande do Sul and Mato Grosso North regions. Source of data: IBGE (2015)

3.3 Rainfall variability

We have found two different annual variability modes: in subtropical and temperate climates, such as Rio Grande do Sul that have observed lower rainfall variability, there is a greater consistency between data and also a strong relationship with soybean crop yield. In Mato Grosso, tropical climate and also transitional to equatorial, the data variability is higher and the relationship between annual rainfall and soybean production cannot be readily established.

The statistical tests showed better results in southern Brazil where we could identify a strong rainfall dependence period in February. Weather anomalies with the most agricultural impact in the south of the Brazil are related to the rain (Britto et al., 2008; Grimm, 2009). The annual distribution of rainfall totals in the Northwest of Rio Grande do Sul is fairly homogeneous (Figure 6).

The lowest rate of precipitation in the Northwest of Rio Grande do Sul is registered for the 2011-2012 year by station of Santo Antonio das Missões (South Brazil), with 493 mm. The highest value was recorded by the station of Guaraní das Missões in 2002-2003, with 1860 mm.

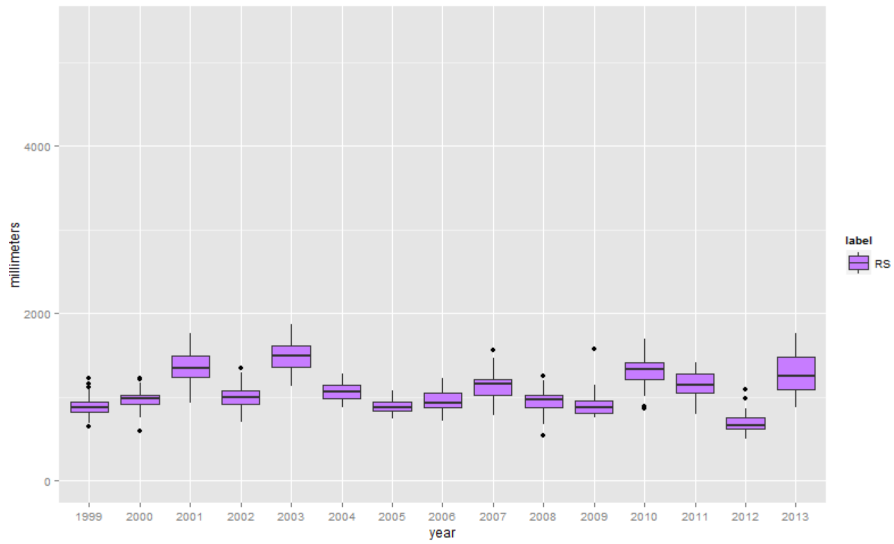

Figure 6 – Rainfall variability representation for northwestern Rio Grande do Sul

The average regional rainfall is 1070 mm. The agricultural year 2002-2003 can be considered to be the wettest for the majority of the stations, 2003-2004 being rather the one closest to the 'normal' and driest 2011-2012. In addition to these years types, the years 2000-2001, 2009-2010, 2010-2011 and 2012-2013 were very wet (1998-1999, 2004-2005 and 2008-2009 being dry or very dry, with 1999-2000 and 2001-2002 rather normal). In the case of Mato Grosso, Figure 7 does not show a greater homogeneity of years types based on the stations. This situation is explained by the greater area of the region but also by the diversity of the geographical factors (latitude, topography and vegetation, for example) that determine the variability of climate (Nimer, 1989; Arvor et al., 2013).

The average annual rainfall over the period of study is 1733 mm, more so than in the Rio Grande do Sul. In the case of Mato Grosso, 2000-2001 and 2004-2005 were in 2003-2004 was extremely wet and dry years. In the years 2011-2012 and 2012-2013, although some stations are classified in "extreme drought", there was a prevalence of rains.

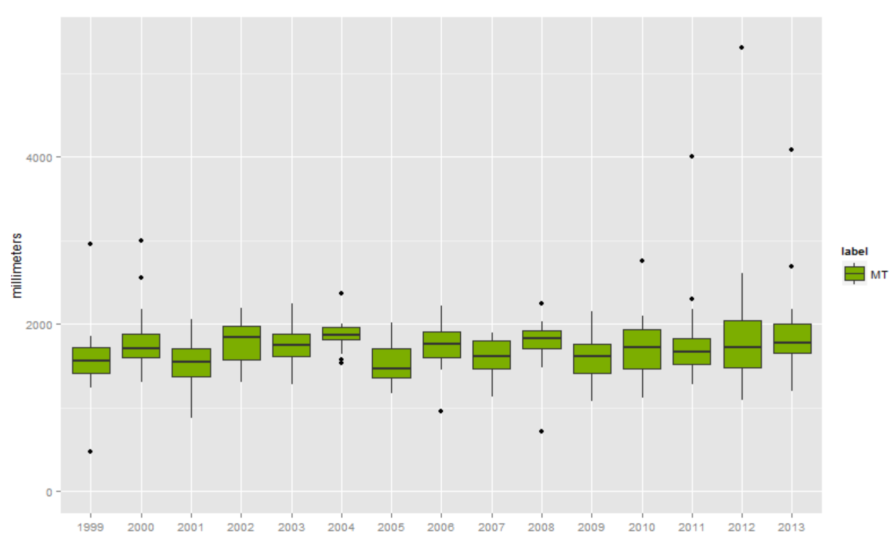

Figure 7– Rainfall variability representation for North Mato Grosso

3.4 - Discussion on the relationship about rain-yields

The annual analyses is important as a preliminary study to verify the correlation between variables, as between rainfall and yields. We can identify the annual variation of both.

There was relation between soybean yield and rainfall variability? It was possible to see that the soybean performance data (Figure 5) presented a very different profile between the two regions. Yields are generally higher (more than 2500 kg/ha for all years studied) and less irregular in Mato Grosso: If the climate plays a role in Mato Grosso, it is less and probably a different spatial-temporal scale.

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In this study, we showed our annual analyses but we also applied the monthly statistical correlations to find the period where the soybean plant is potentially more vulnerable to the rainfall to validate the results. In Brazil, we could find better results in the south than in the north, especially during January and February the most important period to soybean plant development.

So, we can say the Brazilian soybean areas still are vulnerable to rainfall distribution during short periods such as ten, fifteen, or twenty dry days, represented by month analyses. Thus, dry periods still can influence the final crop numbers specially if it happens during important phenomenological periods.

Conclusion

This is a preliminary study but It was clear that the northwestern Rio Grande do Sul presents marked annual variations, in counterpoint to the standard production presented by northern Mato Grosso where yields are above 2,500 kg/ha in all years studied, indicating that, in addition to this production control (low oscillation) northern Mato Grosso presents income that can be considered in every year.

This preliminary study shows that agricultural yield of soybeans in northwestern Rio Grande do Sul are enough directly marked by the influence of annual precipitation, unlike the Mato Grosso. The study of the Rio Grande do Sul area is certainly smaller, but precipitation is much more homogeneous, a dry (or wet) year being at the same time for all stations. However, in Mato Grosso, the relationship between yields and rain can be established at the annual scale: the larger surfaces cultivated, the greater abundance average rains and heterogeneity between the stations for a year contribute to smooth returns values. The relationship between the two variables must therefore be sought in another space-time scale.

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