TYPIFICATION OF THE INTERRELATION BETWEEN CLIMATIC VARIABLES AND CROPS IN THE SOUTHEAST OF SOUTH AMERICA

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1. Introduction

It is known that there are regions in the world where by their location or terrain features are similar in their ability to produce identical agricultural products, an example of this is the plains located between mid-latitudes and subtropics. The plain region of south-eastern Brazil, part of Mato Grosso, the Argentine Pampas, part of northern Argentina and Paraguay, form the clearest of cases in South America. This area is particularly important to classify the water regimes, in order to detect temporal and spatial coherences of phenomena involving water, especially in specific situations, such as droughts and floods.

In this work we are studying the regionalization of the interaction between some components of the hydrological cycle, and two of the crop with major production in the region humid and semi-humid of Argentina and central - southeastern Brazil. As variables involved in the hydrological cycle were used extreme temperatures (maximum and minimum) and precipitation, and as a variable related to the crops (soybean and corn) were introduced the yield (kg per hectare). All of the above is done in the time period named campaign. As one of the objective studied is the impact of climate variables at different vegetative states, to select those that best represent climate variables at different growth stages in the evolution of the crop.

Another objective of this work is to find ways of modeling that would establish clear conditions between growth and climate variables in the subsequent period alluded to try to extend the conclusions to longer periods where there is information on climate variables and change are not recorded data reflecting the evolution of crops.

2. Data and Methodology

In this paper we used 5 stations in Argentina and 5 stations in Brazil, which cover the entire production area, they are: Formosa (26.20 º S - 58.23 º W), Reconquista (29.18 º S - 59.67 º W), Córdoba Aero (31.32 º S - 64.22 º W), Rosario Aero (32.92 º S - 60.78 º W) and Junín Aero (34.55 º S - 60.95 º W), and 5 stations in Brazil : Vilhena (12.73 º S - 60.13 º W), Campo Grande (20.47 º S - 54.67 º W), Curitiba (25.52 º S - 49.17 º W), Irai (27.18 º S - 53.23 º W) and San Luis Gonzaga (28.4 º S -- 55.02 º W) for the period 1979-2006, which is common among all of them. The monthly data used were accumulated precipitation, maximum and minimum temperature. The database comes from the Climate Prediction Center (CPC) of the National Centers for Environmental Prediction (NCEP). Geographical location in Figure 1.

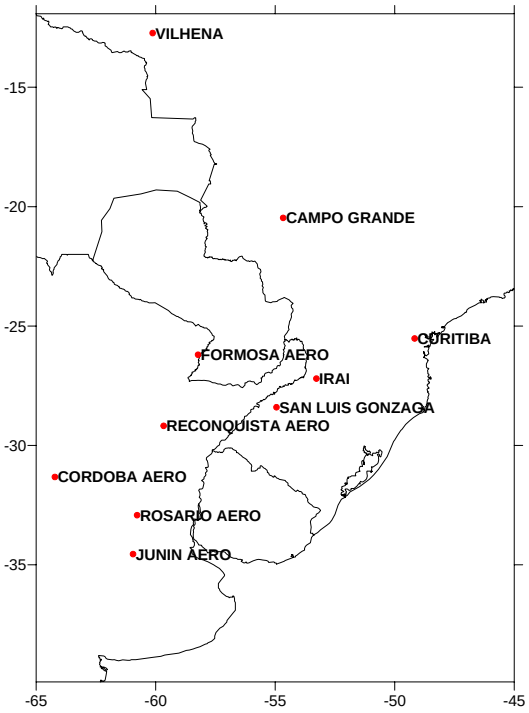

Figure 1: Location of the reference stations

Given that there is an internal variability in the variables mentioned above, were compared for each series weather station in each of the regions, through a correlation with other stations in the same region, this is done to try to work with a number that represents to the whole region, instead of the total volume of data; comparing the series each season for all regions with other stations through a correlation analysis. Stations were chosen with reference to the following criteria: complete sets without missing data, the most extensive periods possible, and series focusing on sub-areas of higher production. It is known that the major effect that technology has in recent decades, which be recognized by measuring the properties of crop growth. In the series shows a clear linear trend increasingly similar in all regions, which would measure the level of technology introduced over the years in each sub region. Explores human-induced and / or technology, in order to assess its presence and its ability to filter to turn the series into a summation of static effects.

The campaign of soybeans, in both countries, ranging from November to May, which identifies the different stages of cultivation: the months of

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November and December are considered for sowing in January, February and March are the months of appeals flowering, April and May are the months used for the harvest.
The campaign of corn in Argentina runs from September through May, for planting are considered the months of September through November; the quarter in December, January and February is the flowering and harvesting are taken for the months of March to May. In Brazil the campaign begins in November and ends in June, November and December are taken for planting, January, February and March for flowering, and harvest for the months of April, May and June.
As a variable that identifies the crop was used the series of yield (tons per hectare), the data were provided by Food and Agriculture Organization of the United Nations. (http://faostat.fao.org).
The present series of annual performance trend, it is filtered through a polynomial of second degree because they are estimated to fall by technological advances that occurred throughout the years. (Cunha et al., 1999). The technological trend to was removed using the following formula:

$$Rci = Ri - [R(xi) - R(x0)]$$

Rci = yield corrected in the year i.
Ri = original performance of the year i.
R (xi) = i performance of the year estimated by the polynomial of 2nd grade.
R (x0) = initial performance of the year estimated by the polynomial of 2nd grade.
As methods of synthesis and characterization exploratory discriminant analysis was used, represented by the hodógrafas, which show us the paths given by the monthly values of the two variables taken consecutively.

3. Results

From an initial classification of extreme temperatures and precipitation, we distinguished that in Argentina variables behave similarly in all the selected reference stations (except magnitudes due to its geographical location), the months with more precipitation are also the months with higher temperature, and vice versa. In Brazil, this analysis allowed us to identify a marked difference between the stations chosen. The stations located further north show us that there is little variation in temperature along the months while the rainfall varies between 0 and 150 (C. Grande) – 300 (Vilhena) millimeters. In the southern stations the precipitation is maintained at values between 100 and 200 millimeters, and the temperature varies between 20 and 32 degrees, so it is necessary to divide into sub-regions. These sub-regions of Brazil are the two stations located further north in the area of Mato Grosso and on the other hand, the two stations in the south and Curitiba station.
When you enter crops in the study, we use the value of the yield (a date by campaign). The campaign begins a year and ends in the following year. It is for this reason that 27 campaigns are analyzes for both crops (soybean and corn), beginning with the 1979-80 campaign and ending in the 2005/06 campaign. These 27 yields data for each country and crops, is divided into three categories: poor yield, medium yield and high yield. If we study the behavior of the maximum temperature and precipitation along both campaigns, the date of each yield (high, poor, medium) were averaged.
In Figure 2, in the case of Argentina for corn (upper left) is not seen a change as far as the temperature between the three types of yield, but there is a change in rainfall between 200 and 400 mm, for example Reconquista in the campaigns of high yield are the most precipitation accumulate, whereas in the case of Formosa, the campaigns of precipitation had higher average yield. Córdoba and Junín doesn't shown major changes among the three types of yields. In the case of soybean (upper right) all stations have a variability in rainfall between different yields, with values that reach 500 millimeters in Rosario.
In Brazil (below) the two crops behavior are similar, with little change in the maximum temperature and variations between 100 and 500 mm precipitation.
One way of assessing the behavior of the variables analyzed along each type of campaign (poor, medium and high performance), is through the accumulated anomalies. They took five campaigns for each type of yield and the average was calculated, and then the anomaly with respect to that particular month was calculated, these anomalies were accumulating, to see the behavior of variable throughout the campaign. In Figure 3 we have represented what happens with the maximum temperature (higher) and precipitation (bottom) in Rosario, as in other stations something similar happens.
In the cultivation of corn (left), the maximum temperature is in the case under the cumulative performance is positive, the maximum temperature was higher than the average, but in the early months is the accumulated negative, that is made colder than the average.
In the case of campaigns with medium yield the cumulative remains positive and without much variation. In campaigns with the accumulated high yield starts positive and ends negative, that is, in most months of the campaign, the maximum temperature was lower than the average. The rainfall is more erratic behavior between stations, for poor yield, the accumulated is negative, as Córdoba and Junin, in the last months of the campaign there was an upswing, that is why we came with all the negative anomalies in the months and harvest are positive anomalies. While

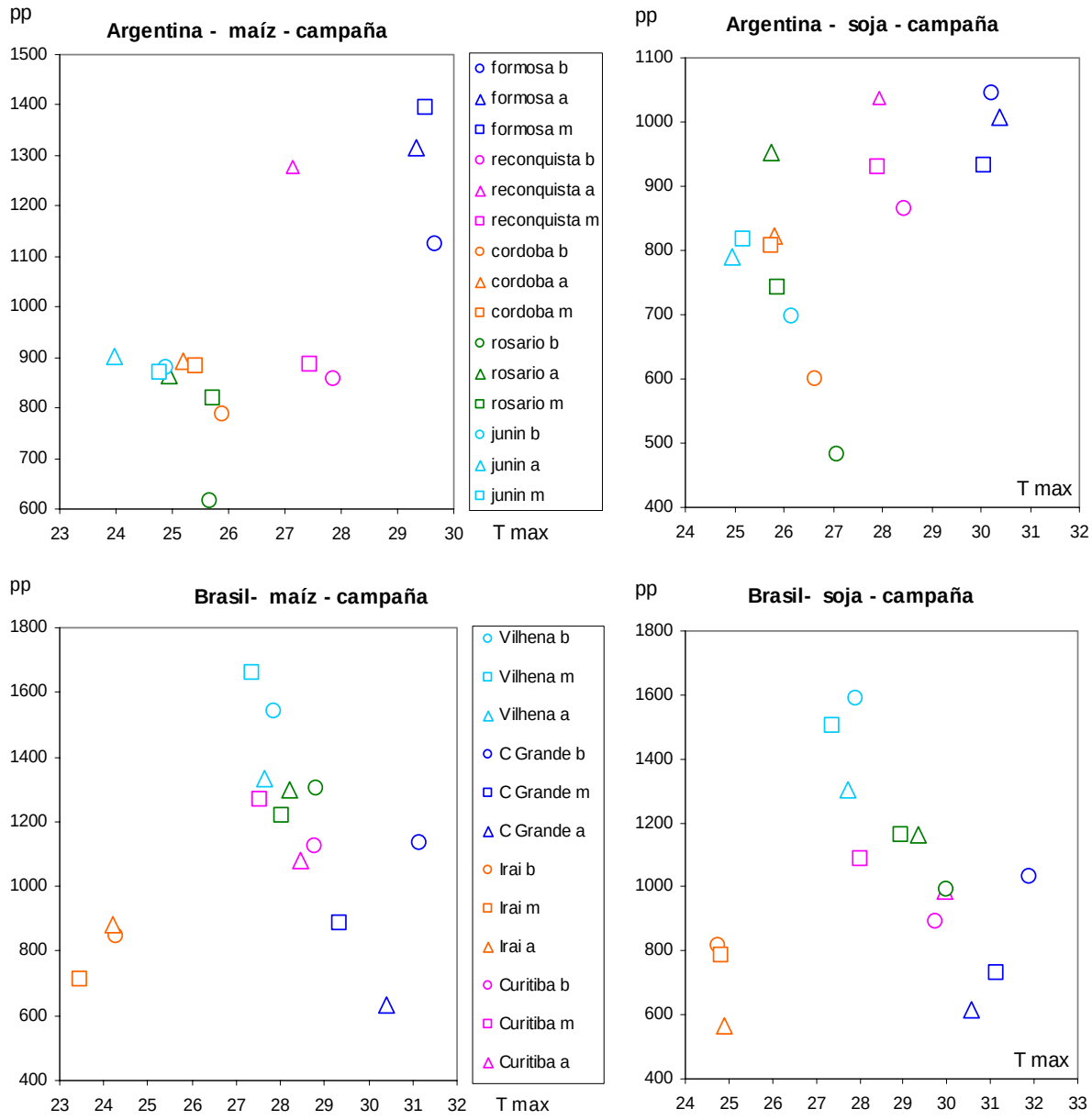

Figure 2: The relationship between temperature and precipitation, Argentina (higher) and Brazil (bottom), during the campaign of corn (left) and soybean (right) for different types of income: poor (circle), medium (square) and high (triangle).

Formosa, Reconquista and Rosario, all along the campaign had negative anomalies.

For the medium yield, Reconquista is very similar to what happened with the poor yield, throughout the campaign anomalies were negative, and Rosario Junín, have negative anomalies at the start of the campaign and end with a rebound in precipitation, but as the final balance was a deficit in rains. Formosa, with negative anomalies beginning and end campaign with a positive cumulative precipitation. Finally, Córdoba, introduced a succession of positive and negative anomalies, resulting in a small deficit of rainfall in the campaign.

For the campaign of soybeans (right) with the maximum temperature, you can see for poor yield,

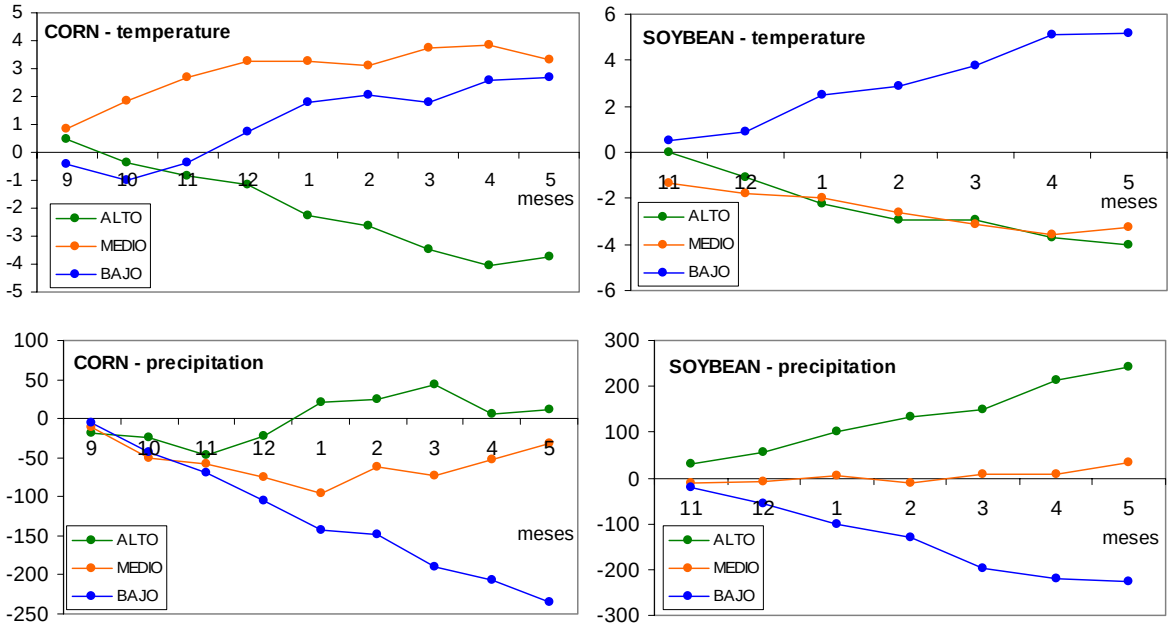

Figure 3: Accumulated anomalies of the average of five years (low (blue), medium (red) and high (green)). To the maximum temperature (higher) and precipitation (bottom) in the case of corn (left) and soybean (right).

as happens with corn, at the end of the campaign they present a positive accumulation of between 3 and 6 degrees, except in the case of Formosa, where in the early months of the campaign presents a deficit and the last 2 months only accumulated very little so the final balance is positive. The campaigns average, are negative throughout the campaign in all cases, with a slight upturn at the end, but also gives a cumulative negative balance. Finally campaigns for high yield, the behavior is similar to the medium yield, resulting in a negative balance of maximum temperature anomalies, meaning that the temperature was lower than the average. For precipitation, in poor yield the three stations located further south, had an accumulated deficit of rainfall throughout the campaign. Formosa had a good start in the first few months, but after he was presenting negative anomalies which resulted in a cumulative total of close to 0 mm. And Reconquista, the first few months had accumulated positive and then it began to introduce negative anomalies which resulted that throughout the campaign we had a deficit of precipitation. For the medium yield campaigns, each station is unique; Formosa began with positive anomalies to finish with a deficit of precipitation. Reconquista, with negative anomalies begins and ends with positive, resulting in a positive cumulative precipitation. Córdoba, presents the most positive anomalies of the months leading to a cumulative of about 50 mm. more than average. Rosario, no variations to what is a medium precipitation. And Junin, which is the largest cumulative positive enough.

For high yield, Formosa does not vary much from the average. Reconquista, has accumulated a significant positive. Cordoba has positive anomalies, but very small. Rosario, has a cumulative positive, which will be phased in over time. And Junin, has accumulated a final positive, but there are months where anomalies were negative.

For Brazil (Figure 4), beginning with maximum temperature (higher) for corn (left), along the campaign with poor yield, is a positive cumulative maximum temperature. In the case of medium yield, the cumulative maximum temperature is negative. In the case of high yield, the accumulated is positive, but close to zero. There were no differences between the regions. For precipitation (bottom), on yield under the three stations located further north presented as a final balance cumulated precipitation positive, with some ups and downs throughout the campaign. In the two stations farther south, we have a cumulative negative throughout the campaign that at the end of it, shows positive anomalies that make the deficit of rainfall is low. In the case of medium yield, the stations are behaving different, with accumulated some positive and others negative, but there is no overall pattern that difference by location. For the campaigns of high yield, the same thing happens again, but this time we can see how the two of the north have a negative cumulative precipitation, while, between, the three remaining two have accumulated positive and the remainder is held near the average, except in recent months where the accumulated negative.

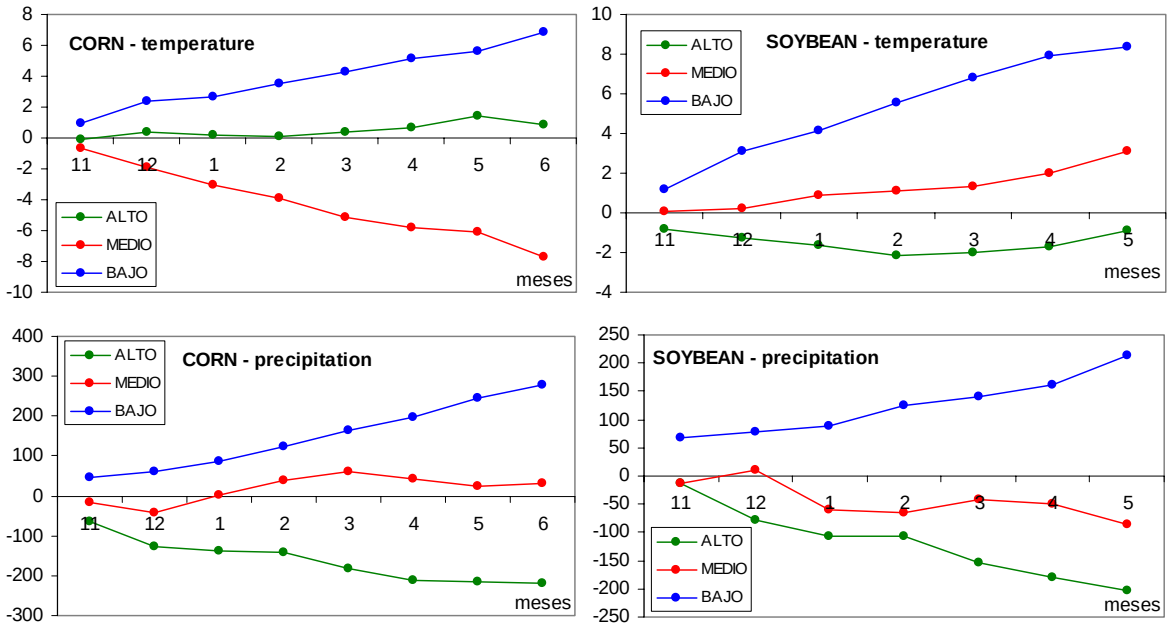

Figure 4: Accumulated anomalies of the average of five years (low (blue), medium (red) and high (green)). To the maximum temperature (higher) and precipitation (bottom) in the case of corn (left) and soybean (right).

For soybeans (right) with the maximum temperature (higher), on poor yield, the behavior is very similar to that seen in corn. For the medium yield, are two stations that are more different, Campo Grande and Curitiba, which had accumulated negative, and now they are positive. For high yield, repeating the pattern of corn. In the case of precipitation, the patterns do not differ much with corn, poor yield, stations further north have accumulated positive and negative in the south. Medium yield, but remain near the average value. And high yield, all three of further north have accumulated rainfall negative and the other two stations, one begins with positive values to finish the campaign with a deficit of rainfall, and the other has accumulated positive at the end of season resemble the average value. It's good to clarify that if you compare Argentina with Brazil, in the case of high yields, in Argentina the accumulated precipitation is positive, while in Brazil is negative.

As the same way we classificate a watershed, it's used to characterize what would be the watershed producing corn and soybeans. Indeed it was chosen two variables along the campaign: a so-called "index" which is defined as the precipitation / performance and the maximum temperature at different time intervals (sowing, flowering, harvest). In Figure 5, is graphed the maximum temperature versus this index for corn and soybeans in each of the reference stations in Argentina and Brazil. In Argentina, in the case of corn (upper left), centers of mass show temperature range and maximum value index among which are the reference stations. As a general feature all stations behave similarly. The months when take place the planting and harvesting present values of maximum temperature of 2 to 3 degrees lower than those who are considered for flowering, in contrast, the value of the index shows little variation between the different stages of growth, with a value slightly lower during planting. For soybeans (lower left), the months of harvest are the lowest maximum temperature present, less than 5 degrees during sowing and flowering. As with corn, the index values are similar in all three phases for each station.

In Brazil, for corn (above, right), each season presents a different behavior, Vilhena (blue) station is located further north, it is observed that there is no difference between the maximum temperature in the three stages of the crop , But it is a notable variation in rainfall (value is reflected in the index). Campo Grande (red) and IRAI (green) are comparable to those stations where Argentina to plant flowering and the maximum temperature is similar to and during the harvest is smaller, and the values of the index did not differ between the stages. Curitiba (purple) and San Luis Gonzaga (light blue) maintain the behavior of the two previous seasons for temperature, but not for the value of the index, which is now higher during the harvest. In the case of soybeans (lower right), the behavior of the stations is particular, three of them do not show major differences between the three stages, while Curitiba and San Luis Gonzaga repeated the pattern seen with corn.

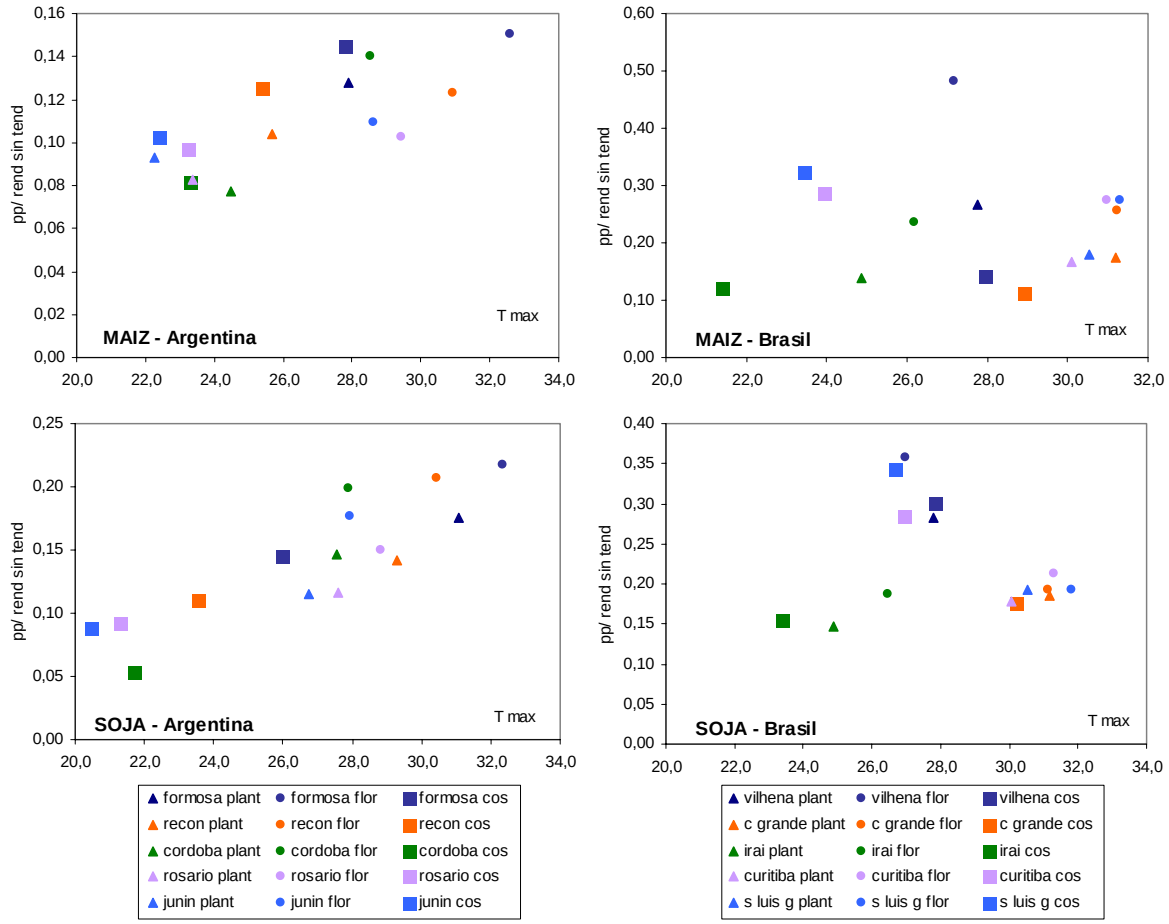

Figure 5: Places of mass versus the maximum temperature index (precipitation / performance without trend) for each stage of the crop (triangle: planting, circle: flowering, square: harvest), home to one of the 5 reference stations (ARG (left), blue: Formosa, red: Reconquista, green: Cordoba, lilac: Rosario, light blue: Junin. BRA (right), blue: Vilhena, red: Campo Grande, green: IRAI, lilac: Curitiba, heavenly: SL Gonzaga). For the Corn (top) and Soybean (below).

4. Conclusions:

Analyzing two of the areas of increased production of corn and soybeans in the world (Food and Agriculture Organization of the United Nations) can be identified in each country, at least two climatic zones uniform. Therefore, it is proposed that the representativeness of these sub-regions can be estimated by reference stations. But certain differences in the geographical location of the regions shows that the campaigns are growing at rates similar to maximum and minimum temperatures in Argentina and in the case of Brazil is due to make an exception to the area of Mato Grosso, the which has a particular behavior. Study of different types of returns (low, medium and high) for each crop, is observed that the variables studied show a different behavior between the zones, mainly in rainfall.

The index (precipitation / performance) and the maximum temperature allowed locate geographically disadvantaged regions and well or basins involved in the analysis.If it divides the campaign of soybeans in three stages: sowing, flowering and harvest, and were studied as a function of the maximum temperature and the index that includes the area of climate variability of each stage is well differentiated, showing the different characteristics of each region, which has priori this indicate that the maximum temperature represents a significant variability in precipitation and evaporation allowed to discriminate the relationship between climate and culture.

References:

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