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CLIMATE CHANGE AND SUGARCANE IN THE STATE OF SÃO PAULO

Jurandir Zullo Junior, Hilton Silveira Pinto, Eduardo Delgado Assad, Fábio Ricardo Marin and *Giampaolo Queiroz Pellegrino*

Agribusiness accounted for 23% of Brazilian Gross Domestic Product (GDP) in 2007, being around 49.7 billion dollars the surplus of the sector's trade balance. Jobs related to agribusiness were approximately 37% of total national jobs. Brazil is the world's largest producer of sugar, alcohol, coffee, and orange juice; the second in soybeans, beef and chicken; the third in fruit and corn and the fourth in pork. It is the first exporter of sugar, alcohol, coffee and soybeans. Brazil was a global leadership of beef and chicken in 2003. Brazil sells 82% of orange juice, 29% of sugar, 28% of coffee beans, 44% of coffee, 38% of soybeans and 23% of tobacco consumed on the planet. It occupies the first place in the world of tanned leather and leather footwear. It is possible to conclude therefore from the above data that the agribusiness is a fundamental component of the country and various regions of the world.

The climate is one of the major determinants of agricultural production due to: a) natural variability of the various systems prevailing in the country; b) insufficient knowledge about their behavior and c) difficulty in forecasting. The drought that affected Rio Grande do Sul in January and February 2005, for example, had a negative impact throughout the economy of the state and not just in agriculture. The state government estimated a total loss of 300 million dollars in the budget of the year. According to IBGE – Brazilian Institute of Geography and Statistics, Rio Grande do Sul was the only state that accumulated a fall in industrial production in the first two months of 2005, a decrease of 1.6% compared to a 5.2% increase in the national average (BUENO, 2005). The most severe frost of July 18, 1975 decreased by 20% the budget of the state of Paraná, with estimated losses of 1 billion dollars and 500 million coffee trees.

Until the early 1990's, Brazilian agriculture recorded high loss rates that drastically limited their development, since they were making the sector economically unviable. According GÖEPEFERT *et al*. (1993), the 1992/93 harvest losses were about 30% for rice and 21% for beans in São Paulo; 37% for corn and 29% for soybeans in Bahia; and 81% for cotton and 32% for irrigated soybeans in the Northeast. According to ROSSETTI (2001), approximately 90% of the losses recorded in Brazilian agriculture until the early 1990's were caused by two main climate factors: a) dry spells during the critical phase (in 60% of all cases) and b) excessive rain at harvest (in 30% of all cases). These losses were related to a poor knowledge of rainfall distribution that led the farmers to plant after the first rainfalls of spring.

Based on these high loss rates of domestic agriculture, the Ministry of Agriculture – MAPA started in 1995 an official program of agricultural zoning in order to reduce climate risks associated with dry spells during the critical phases of crops and excessive rains at harvest. The practical tools used to achieve these goals have been planting calendars based on meteorological data and parameters for the main crops of the country, considering periods of planting having ten-days length, three different soil types, two or three types of cultivars and each of the municipalities of the regions potentially suitable for plantations.

The planting calendars have to be updated annually to include new crops, cultivars and climate data, and improving the methods used in zoning, being 80% the minimum probability of crops achieving economic productivity. Climate oscillations, such as those attributed to phenomena such as El Niño and La Niña began to be normally considered in the annual updates of the Zoning. This program is thus based on the integration of crop growth models, climate and soil databases, decision analysis techniques, and geo-processing tools (CUNHA, 2001). More details of the methodology normally used in Agricultural Zoning can be found in ASSAD *et al*. (2008b, 2008c) and CARAMORI *et al*. (2006).

The annual update and the continuous operation of the Program since 1995 are two aspects favorable to the improvement of Agricultural Zoning that is used as the basis of the official programs of agricultural finance and rural insurance from the federal government, that is, it is used in practice as a public policy. This provides a continuous, comprehensive and detailed monitoring of the information available in the Agricultural Zoning, by the financial institutions, government and farmers, corresponding to a practical verification of program performance. Another aspect that should be highlighted in the current Agricultural Zoning Program is the existence of a scientific community specialized in agro-meteorology, mathematical modeling and GIS, with experience in transforming scientific research in public policy, based on similar programs in Brazil since the 1970's.

Reliance in good performance of the methodology and in results available in the Agricultural Zoning are fundamental for assessing the impacts of climate change on agriculture made since the release of the third IPCC report in 2001 (IPCC, 2001a and 2001b). The fourth report, released in 2007 (IPCC, 2007), has heightened the interest of the World, including several governments and governmental organizations, by the theme of climate change. It is emphasized that this issue has been receiving special attention after the hurricane season in North America and the heat wave in Europe in 2005.

The significance of climate to agriculture, as mentioned above, makes it one of human activities potentially more vulnerable to changes described in the IPCC reports. According to SEGUIN (2007), climate change is not the only factor that will affect the European economy in coming decades, but have a very significant impact on crop productivity and geographical distribution of potential agricultural areas. According to BATTISTI and NAYLOR (2009), the increase in temperatures will seriously affect agriculture in tropical and subtropical regions, and, if nothing is done, at least half of the world population will face a drastic shortage of food until the end of the century.

ASSAD *et al*. (2004) and PINTO *et al*. (2001 and 2002) assessed the impact of climate change described in the third IPCC report, in the agro-climatic zoning of arabica coffee, in four Brazilian states: São Paulo, Minas Gerais, Parana and Goias. They concluded that increases of 1 °C, 3 °C and 5.8 °C in mean temperature may lead to reduction in areas with low climate risk and their changeover to higher altitude areas, considering the commercial varieties currently used and no adaptation or genetic modification. According to ZULLO Jr. *et al*. (2006), the low climate risk areas for Arabica coffee in São Paulo can decrease from 78.7% of total surface (current situation) to 58.9% (increase of 1 °C), 30.3% (increase of 3 °C) and 3.3% (increase of 5.8 °C). For corn, the estimated average decrease of areas with low climatic risk for planting between October and December in loam soils, was 1% (an increase of 1 °C), 33% (increase of 3 °C) and 84% (increase of 5.8 °C).

Replacement by crops or species more tolerant to drought and heat can be a way of adapting agriculture to climate change. PINTO *et al*. (2007), for example, pointed out that the loss of current areas of low climate risk for Arabica coffee in the southeast region of Brazil may be compensated by new areas of low climatic risk for another kind of coffee more tolerant to high temperatures and that is cultivated in the state of Espírito Santo: the Robusta coffee. Similarly, the current areas of high climatic risk due to low temperatures and high risk of frosts may be benefiting from the rise in global temperature. Such potential areas correspond to the states of Rio Grande do Sul, Santa Catarina and the southern Parana, Brazil, Uruguay and northern Argentina.

WREGE *et al.* (2007) found that rising temperatures could reduce the current areas of low climate risk for the production of temperate fruits in the state of Rio Grande do Sul due to the reduction in the number of chilling hours that are required for their development. ASSAD *et al.* (2008d, 2006 and 2005) concluded that the size of areas with low climatic risk in the Agricultural Zoning for soybean, bean, corn and upland rice decreases when average temperature and precipitation increase, for plantings in November. Other studies show similar assessments on the impact of climate change on domestic agriculture, such as those of PINTO *et al.* (2008 and 2005), NOBLE *et al.* (2005), ASSAD *et al.* (2007b and 2007c) and ZULLO JR. *et al.* (2008).

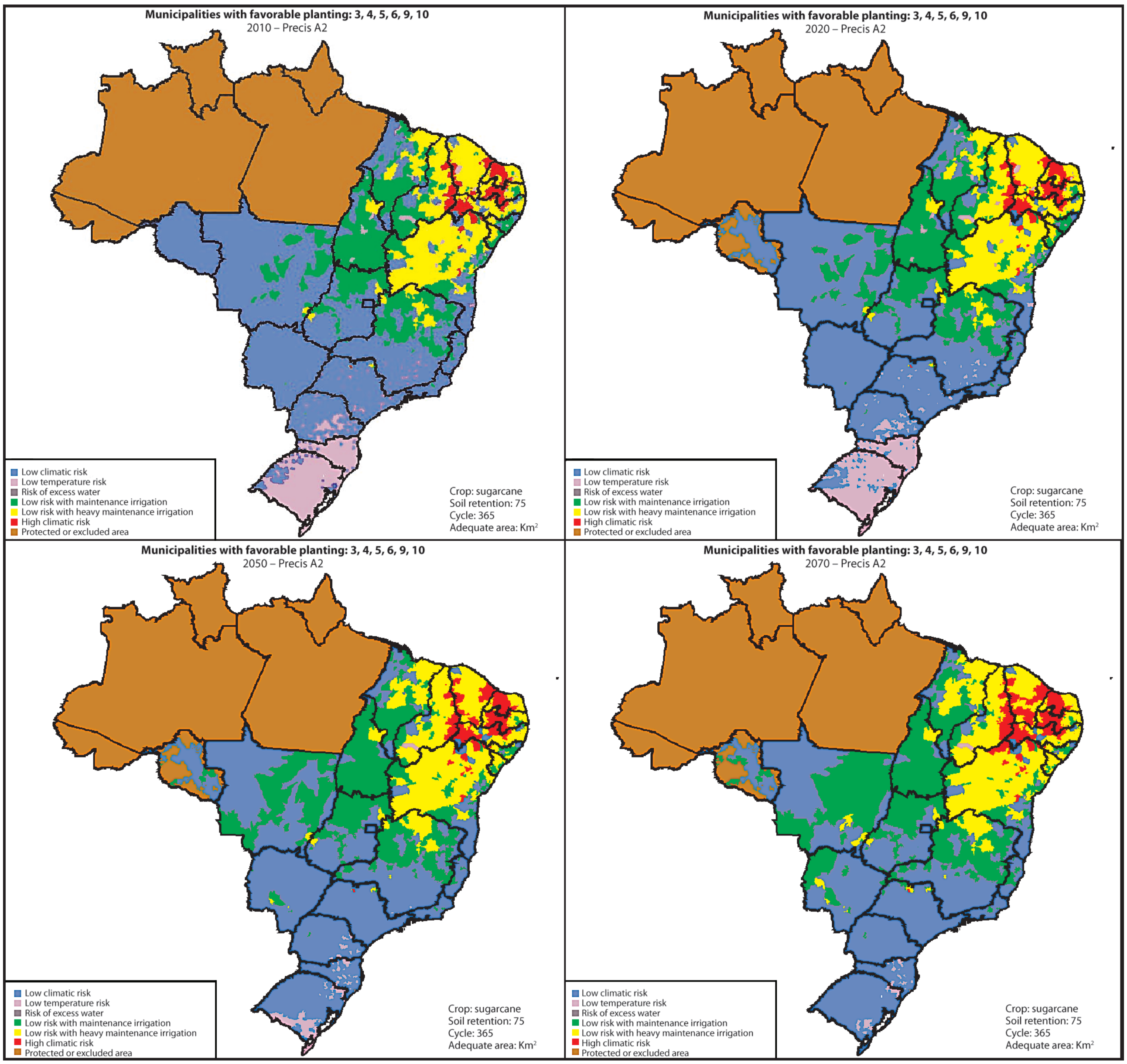
In general, all these studies have found a great vulnerability of Brazilian agriculture, linked to climate changes described in the third and fourth IPCC reports, provided that adaptation and mitigation are not well developed and made effective in the coming years. Despite this increasing vulnerability, agriculture has significant capacity to adapt to new climatic conditions, considering: a) the limits of biological tolerance; b) the existent technological challenges; c) the available natural resources; and d) the time available to apply appropriate solutions. ASSAD *et al.* (2007a) highlighted the following items necessary for the adaptability of the main crops in Brazil: a) heat tolerance throughout the country; b) drought tolerance to the South and Northeast; and c) soil management to increase the capacity of water conservation. The biodiversity of the *Cerrado* and the Amazon regions can contain genes that may be used to adapt the existing crops to environmental stresses. The diversity of environmental conditions in Brazil can be a great advantage in adapting agriculture to new climatic conditions.

Another feature of the studies cited above is that, in general, they used climate change scenarios in the order of 1 °C and 5.8 degrees on the values of temperature and 0% to 15% for total rainfall in all evaluated regions. There is considerable interest on climate change and a huge amount of studies have (and are) been carried out which are throwing light into this area and are making considerable contributions to our understanding of the potential implications, as described by VALVERDE and MARENGO (2007), and ASSAD *et al.* (2008). This study includes the results of nine crops (cotton, rice, coffee, sugar, beans, sunflower, cassava, maize and soybean); it uses two emission scenarios of greenhouse gases (A2 – high emission and B2 – low emission), four different periods of time (currently, 2020, 2050 and 2070); and spatial resolution of 50km in all states of the country, excluding the Amazon region.

The results for all crops, except for sugarcane and cassava, confirm those obtained in previous studies. The soybean crop is the most affected, with losses up to 40% in 2070, with an estimated loss worth UD$ 3.8 billion/ year in the worst scenario. Arabica coffee could lose up to 33% in the low climate risk area in São Paulo and Minas Gerais, although there is an increase in productivity in the south of the country. Corn, upland rice, beans, cotton and sunflower will also experiment a significant reduction in the low climate risk areas in the Northeast region, with significant loss of production. CASSAVA may have an overall gain in the low climate risk area, but may register losses in the Northeast region. The losses in grain crops could be about US$ 3.7 billion in 2020 and about US$ 7 billion in 2070. Such changes have the potential to change the geography of agricultural production in Brazil, if no measures for mitigation and adaptation to climate change is taken.

Sugarcane, however, showed different results from the crops assessed. Its development is directly influenced by changes in weather conditions observed during the length cycle that takes one year to 18 months. The best performance of current sugarcane varieties is observed when there is a hot and humid season, with intense solar radiation during the growth phase, followed by a dry period in the early stages of maturation and harvest. This corresponds, in practice, to regions with water deficit between 10 mm and 180 mm. Irrigation is needed to ensure the re-growth where the annual water deficit is between 180 mm and 400 mm. Over this value, irrigation would have to be increased significantly. The maximum rates of growth and biomass accumulation are obtained when the air temperature is between 22 °C and 30 °C and no growth above 38 °C, being restricted due to the risk posed by frost greater than 20%, below to 19 °C). The diversity of climatic conditions in Brazil allow to have two harvests per year: from May to December, in the Central-south region, and from September to April, in the North and Northeast regions.

Thus, based on these parameters, it is observed that, as shown in Figures 1 and 2, the sugarcane can be doubled its area in the coming decades, from a potential value of six million hectares for approximately 17 million hectares in 2020, in a scenario of low emission of greenhouse gases (B2), and 16 million ha for the high emission scenario (A2). Thus, the value of production, which was estimated at 17 billion dollars in 2006, could reach 29 billion dollars in 2020, in the B2 scenario. In scenario A2 (high emission of greenhouse gases), the potential area could reach 16 million hectares.

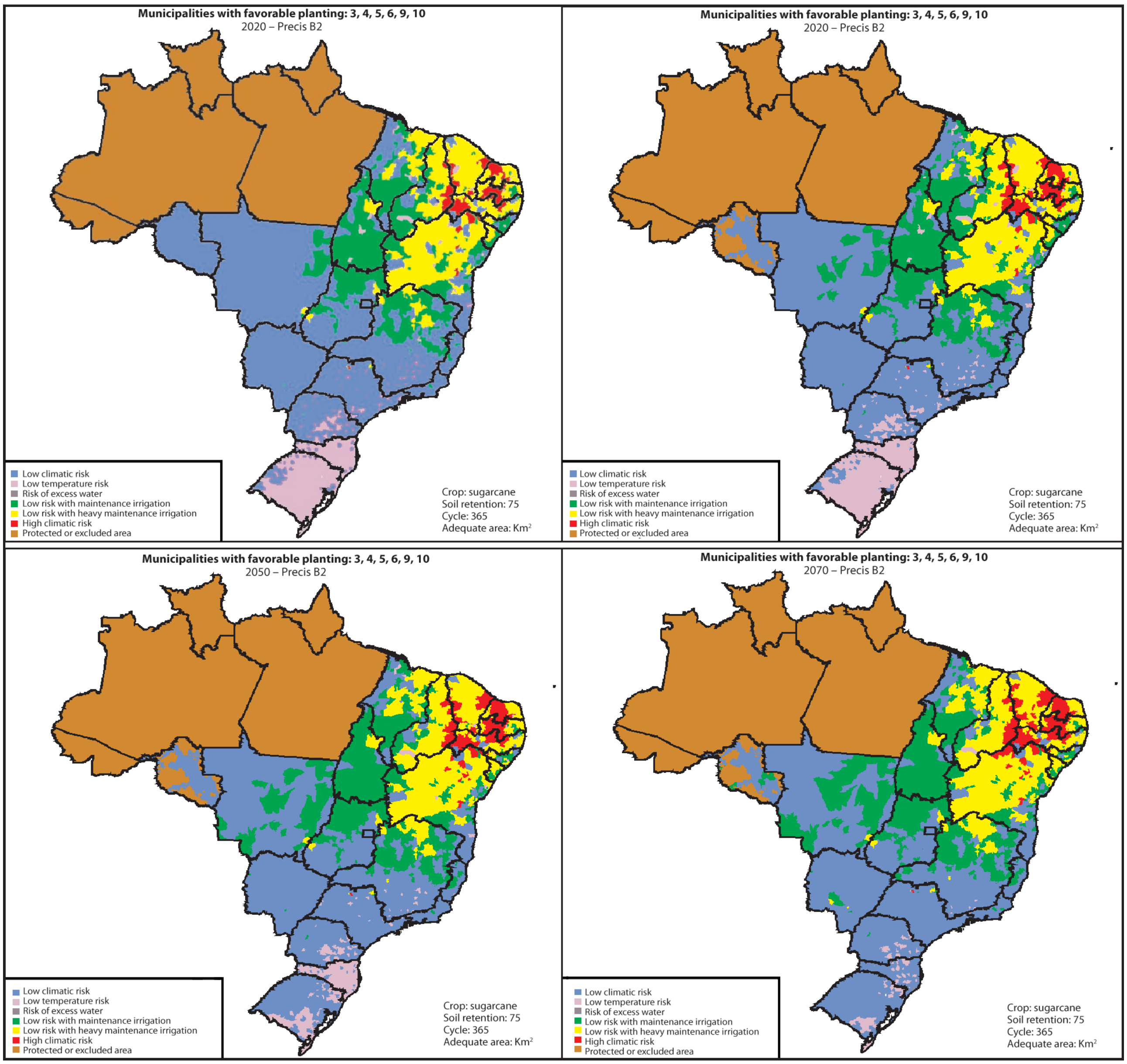


Source: ASSAD *et al.* (2008a).

FIGURE 1 Areas with low climatic risk (blue), risk of low temperatures (pink), low risk with irrigation (green and yellow) and high climatic risk (red) to the development of sugarcane, considering a high emission of greenhouse gases for four periods: current climate conditions (top left), 2020 (top right), 2050 (bottom left) and 2070 (bottom right).

Areas located at high latitudes in the Southern region of Brazil, which currently have high risk of frost that could affect crop – growing, may turn into areas with potential production, especially from 2050. Areas in the Midwest region, that currently have high production potential, could become increasingly dependent on irrigation of 50mm or so, during the driest period of the year. The continued increase in temperatures will result in greater use of irrigated crops. According to MARIN *et al*. (2007), a temperature increase of about 4 °C will lead to water restriction in 80% of the State of São Paulo, including in regions where there sufficient rainfall during the dry season for crops to mature.

The possibility of increasing suitable areas for sugarcane production, even with changes in current climate conditions, shows that in addition to mitigating emissions of greenhouse gases by replacing fossil fuels, sugarcane has a much greater



Source: ASSAD *et al.* (2008a).

FIGURE 2 Areas with low climatic risk (blue), risk of low temperatures (pink), low risk with irrigation (green and yellow) and high climatic risk (red) to the development of sugarcane, considering a low emission of greenhouse gases for four periods: current climate conditions (top left), 2020 (top right), 2050 (bottom left) and 2070 (bottom right).

capacity to adapt to climate change described in the IPCC reports, that the other eight cultures assessed by ASSAD *et al.* (2008a), considering current varieties and planting techniques. This increases interest for the use of sugarcane as a primary energy source in Brazil and beyond to expand further cane plantation areas, particularly if no measure of adaptation is developed for other major crops of the country.

This expansion, however, should be properly planned, considering the possible impacts associated with the environment, energy sector, food security and nutrition, national economy, demographic dynamics, culture and human health. A poorly planned expansion can have disastrous consequences and cause negative many impacts. The degraded pasture land area in Brazil is estimated at approximately 100 million hectares and can be used for sugarcane expansion avoiding food production areas or environmental preservation areas.

Various factors need to be considered: a) sugarcane expansion implications; b) production methods of cane main products (sugar and alcohol); and c) impacts directly associated with sugarcane performance (i.e. environmental, food security and nutrition, population dynamics and human health). Brazil should take this great opportunity for business and developmen, but should consider all the economic, social and environmental impacts based on strict technical and scientific criteria.

Adaptation to climate change is complex, and the sugar and alcohol sector needs to confront this challenge that requires coordinated and cooperation by experts in various subject areas such as climate, environment, GIS, population dynamics, food security and nutrition, health, science communication, public policy and scientific and technological development. The long historical experience of State of São Paulo in the development of sugar and alcohol industry, puts the state in a strong position to face the future development of sugarcane.

It is emphasized that the main objective of the scenarios of impacts cited in this paper, is avoid that a strategic sector for Brazil, such as agribusiness, do have information about all possible adverse effects caused by the climate changes and the effects on the major crops in the country. Despite the current usefulness of these scenarios, it is clear that considerable more research is needed to better understand these potential problems. These scenarios are just a starting point for the establishment of public policies aimed at adaptation Brazilian agriculture to climate change.

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