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EVALUATION OF THE IMPACT OF BIOFUELS PROGRAM ON WATER AVAILABILITY OF THE CERRADO

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ABSTRACT

This study sought to evaluate the impact of the biofuels programme in the availability of closing water of the ecosystem, named Cerrado. Currently, the water resources of the cerrado, in the dry season, already suffering from an imbalance because of the evapotranspiration in the region do not precipitate in the same place, as the movement atmospheric studies presented by National Institute of Meteorology. The objective of this study was to evaluate the impact that the programme of biofuels can cause water availability in the cerrado, in the Midwest region of Brazil. The hypothesis concerns that the goal was: the expansion of crops for biofuel production will bring a negative impact on water availability in the region. Considering the increase in temperature caused by deforestation and / or extraction of native vegetation for the planting of oilseeds eligible, which also increase the water consumption and the demand that the alarming water use crops for their development throughout this cycle, it checked the impact on water resources in the region. It was done a survey of information on the water demand of native vegetation, about the crop evapotranspiration potential for the biofuels program and about the movement of atmospheric Midwest Region. The integration of this information allowed the finding that the availability of water in the region may be affected adversely, if they seek compliance with the goals of producing biofuels currently served by public agencies concerning.

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INTRODUCTION

The aim of this study was to evaluate the impact that the Biofuel program may result in water availability of the Cerrado, in the Central-West region of Brazil. The hypothesis related to this goal is the expansion of crops for biofuel production:

- H^o: will bring a negative impact to the water availability in the region.
- H^1: will not affect the availability of water.

According to the Center for Strategic Affairs (NAE) of Brazil (BRAZIL 2005a, p. 11), diesel fuel can be complemented by modified vegetable oils without changing engines. According to the cited source, even if do not exist technical or regulatory obstacles to the start of the use of biofuels in addition to diesel, its use implies availability of inputs, supply security, processing capacity by the industry and final integration amongst distribution circuits. The current scenario is to expand the acreage to meet the increase of internal and external consumption, primarily American and European. Several studies examine social, economic and financial issues, resulting from this expansion, suggesting their viability and proposing a program to expand the production of biofuels. Other studies come to do detailed analyses about the needs of the area, inputs, labor and demonstrate the availability of these resources, reinforcing the idea of expanding the already planted area. However, in the literature review performed, it was not observed any analysis of the main raw material necessary for the agricultural activity: water. Worldwide, it is estimated that 9,000 km ^{3}/year of water are accessible to human consumption and about 3,500 km^3 are stored in dams, adding a total of easy access of 12,500 km^3/year. The totalrunoff is 47,000 km³/year, but the exploitation of the remaining 34,500km³/year is difficult, costly or may cause negative impacts to the environment. Currently, approximately 6,500 km³ of water are used per year for humanity for various purposes, concentrating on the predominantly agricultural use, followed by industrial and urban (HIRATA, 2001). The amount considered of the 119,000 km³ per year of precipitation falling on the continents, approximately, only 72,000 km³/year of water returns to the atmosphere through evapotranspiration, (KARMANN, 2001). The remaining 47,000 km³/year of fresh water circulating around the planet, through runoff and underground represent the water surplus, which is the difference between the volume and the evapotranspiration (HIRATA, 2001). Evapotranspiration (ET) is the process associated with the joint soil water loss by evaporation and by transpiration from plant (ALLEN *et al*., 1998).Nowadays, the Cerrado native vegetation and agricultural exploitation have consumed 0.08961 km³/year (SILVA, 2003). However, plants with potential for biodiesel production (BRAZIL, 2005a) eligible by the Federal Government would demand together the sum of 368,599 mm^3. Considering that water figures as a limiting factor for the biofuels programme, a detailed study has been developed on the impact of this programme in water resources before its implementation.

Biofuels

Biodiesel is a generic name for fuels produced from renewable sources such as vegetable oils and animal fats, for use in compression-ignition engines, also known as diesel engines. In addition, biodiesel can be used to generate energy instead of diesel oil and fuel oil. Brazil for its vast territorial extension, associated with the excellent soil and climatic conditions, is considered a haven for the production of biomass for food, chemical and energy purposes. Studies released by the Department in charge of the implementation of the biodiesel in the United States claim categorically that Brazil is able to lead the world production of biodiesel, promoting the replacement of at least 60% of the diesel oil consumed in the world. The global demand for renewable fuels will be growing and Brazil has the potential to be a major exporter in the world, especially in the current context of climate change.

Biofuels and Biodiesel: As a non-renewable source of energy and due to environmental problems come from the burning of fossil fuels, the search for alternative sources of energy have been intensified. Among the most promising are biofuels, derived from agricultural products such as sugar cane, oleaginous plants, forest biomass and other sources of organic matter. As an example, one can cite the biodiesel, ethanol, methanol, methane and the charcoal (ESALQ, 2007), which can be used alone or added to conventional fuels. Biodiesel replaces all or part of the diesel oil in diesel cycle engines automotive (trucks, tractors, buses, cars, etc.) or stationary (electricity generators, heat, etc.). It can be used pure or mixed with diesel in various proportions. Ecological fuel being biodegradable, non-toxic and essentially free of sulfur and aromatics, biodiesel brings a number of benefits associated with the reduction of greenhouse gases and other air pollutants, as well as reducing the consumption of fossil fuels (ESALQ, 2007).Considering so many advantages, the Brazilian Government has stimulated the production and marketing of biodiesel, being the main landmark to the publication of Decree Nº 5.488 of May 20, 2005 (BRAZIL, 2005e), which regulates law 11,097 (BRAZIL, 2005d). This Bill provides the introduction of the biodiesel in Brazilian energy matrix.

The Production of Biodiesel from Oilseeds: The advantage of biodiesel on diesel fossil based with regard to the emissions of pollutants, given that this is a product that is non-toxic and biodegradable is already known. In Europe, studies show that, compared to diesel, pure biodiesel produced from canola reduces reenhouse gas emissions in 40-60% (BRAZIL, 2005a, p. 31). From soybean, for example, it can be expected the same proportions of pollutant reduction. If, on the one hand, various oilseeds can be used in biodiesel production, on the other, its production demands considerable planting area. For example, to supply 5% of B5 diesel with local oleaginous (soy, palm oil or castor oil) would require approximately 3 million hectares (BRAZIL, 2005a, p. 12). Recent studies carried on by EMBRAPA (PERES, 2003) show the regional skills for each one of them: the soy to the South, Southeast and Midwest; castor bean to the Northeast and palm oil for the Amazon region. Sunflower, peanut and others have also been considered. Also, tropical palms are always mentioned as viable and potential producers of biodiesel (BRAZIL, 2005a, p. 37).

Water: A new paradigm: Since the beginning of the 20th century, water consumption has grown as a proportion twice as big as the world population grows (MATSUMURA-TUNDISI and TUNDISI, 2018). Although most of the surface of the Earth is composed of water, only a little volume greater than 2% of all this water is sweet and more than 90% is in polar ice or in very deep underground deposits. Only 0.001% of the planet's water, which are the existing surface fresh waters (rivers, lakes and dams), are usable by man in an economically feasible and without major environmental impacts. This small portion of water is called Water Resources (TUNDISI, 2014). Therefore, even in a country like Brazil, of continental dimensions, holder of the largest inventory of fresh water on the planet, the management of water resources is an imperative and urgent task (BICUDO, TUNDISI, J. G. and CORTESÃO, 2017).The tendency, then, is that the water will become a high-value commodity in the international market in the years to come. Developing countries, including the owners of this resource, are the ones who will suffer most as a result of the shortage, since almost all of its economy is strongly linked to exploitation of its natural resources and agricultural production for export. In order to illustrate the importance of water for agricultural production, the Table 1, below, presents the water demand for some products.

Table 1. Water in food production

Product	Water (in liters) needed to produce 1 Kg of the product
Potato	500
Wheat	900
Alfalfa	900
Sorghum	900
Corn	1100
Rice	1900
Soybeans	2000

Source: CHRISTOFIDIS (2001)

Thus, more than a right, the shortage is turning the water into a valuable commodity. It is up to the Governments of the countries in possession of these features the adoption of policies and standards to ensure the integrity and rational access to their reserves (SILVA, 2006). The growth of world demand for good quality water at a rate higher than the renewability of the hydrological cycle is, by consensus, widely known in the international scientific and technical means. This growth tends to become one of the largest anthropogenic pressures on the planet's natural resources in the 21st century. Therefore, Brazil must remove the false idea of non-exhaustion of water resources, as well as consider its possible scarcity, despite having the greater availability of water on the planet, 13.8% of the global average runoff (Ambientebrasil, 2007).

MATERIALS AND METHODS

Itwas observed that the water was not considered in the various studies on the production of biofuel, including, in the study presented by the NAE, with regard to the predictions of impacts on water resources. It was then performed a literature review on evapotranspiration and its use as an indicator to assess the possible impact on water resources against an expansion of the area destined to the planting of oilseeds for the production of biofuel. It was then determined the potential crop water demand for biofuels program. Finally, it was studied the atmospheric circulation in the mid-western region and its influence on regional cycle to determine if, under evapotranspiration, water is or not likely to precipitate in the region itself.

Evapotranspiration: The determination of the need for water for agricultural crops is conducted by the pattern of evapotranspiration. There are several methods for determining the evapotranspiration, and most estimates the potential evapotranspiration, i.e. when the soil does not have any disabilities that limit the use of water by plants. Due to the characteristics of each culture, the potential evapotranspiration varies from one culture to another. Thus, it was established a practice to determine a reference evapotranspiration (ETo), used as a basis for the determination of evapotranspiration for each culture (ETc). They can be defined as said below:

- ETo is the evapotranspiration of a reference surface completely covered by grass or alfalfa, of uniform size, in active growth phase, with very good soil moisture conditions. The use of other denominations, as potential evapotranspiration is discouraged due to ambiguities in its definition.
- ETc is the evapotranspiration of a culture under standard condition, free of pests, diseases and weeds, well fertilized, that develops in a wide area, with great soil and water supply that reaches full production under certain climatic conditions. Relations between ETc and the ETo are called crop coefficients (Kc), which are used to relate ETc with ETo, namely: ETc = Kc * ETo.

This work is based on FAO-56 (ALLEN *et al.*, 1998) about crop evapotranspiration estimation of oilseeds and sugarcane, where it was used *ETo*= 4.8, with <Kc[initial] = 0,35, *Kc*[intermediary] =1,15, *Kc*[final] =0,35> for oilseeds and <*Kc*[initial] = 0,40, *Kc*[intermediary] =1,25, *Kc*[final] =0,75> for sugar cane, in the period of one year. Thus, came the following equantions (from 1 to 3), proposed by the authors, for each of the life cycles of their respective cultures, whose curves are represented in the Charts from 1 to 7.

Equation 1 represents Non-perennial crops (castor seed, peanut, sunflower, soybeans and rapeseed):

$$ET_{c=}\begin{cases}(0{,}02758d+0{,}32241)^{*}ET_{o},\ se\ d\in[1;30]\ \text{(initial phase)}\\ K_{c}{}^{*}ET_{o}=5{,}52,\ se\ d\in[31;LI_{c}]\ \text{(intermediary phase)}\\ (0{,}02758(LF_{c}+1-d)+0{,}32241)^{*}ET_{o},\ se\ d\in[LI_{c}+1;LF_{c}]\ \text{(final phase)}\end{cases}$$

Where the duration of the life cycle of LFcastor= 240 days, LFpeanut= 120 days, LFsunflower= 150 days, LFsoy= 135 days and LFcolza= 100 days and the final day of the intermediate phase is LIC = LFc-30 since the beginning and ending cycles of these crops last, on average, 30 days.

Equation 2 represents Perennial crops (babassu and palm oil):

$$ET_{c=}\begin{cases}(0{,}02758d_{i}+0{,}32241)^{*}ET_{o},\ se\ d\in[1;60]\ \text{(initial phase)}\\ K_{c}{}^{*}ET_{o}=5{,}52,\ se\ d\in[61;365]\ \text{(intermediate phase)}\end{cases}$$

Where the duration of the life cycle of the crops, as perennial, LFbabaçu= LFdendê= 365 days and the initial cycles of these cultures lasting an average of 60 days.

Equation 3 represents Sugar cane:

$$ET_{c=}\begin{cases}(0{,}01441d_{i}+0{,}38559)^{*}ET_{o},\ se\ d\in[1;60]\ \text{(initial phase)}\\ K_{c}{}^{*}ET_{o}=6{,}00,\ se\ d\in[61;365]\ \text{(intermediate phase)}\end{cases}$$

It is known that the life cycle of sugarcane culture can last 18 months. However, in this work, it is considered only a year for calculations, there were taken 60 days for initial cycle and not considered the final phase.Given the Equations 1 to 3 that estimates the evotranspiration of each culture considered in this work, we show the corresponding charts (from 1 to 7) in the period of 365 days.

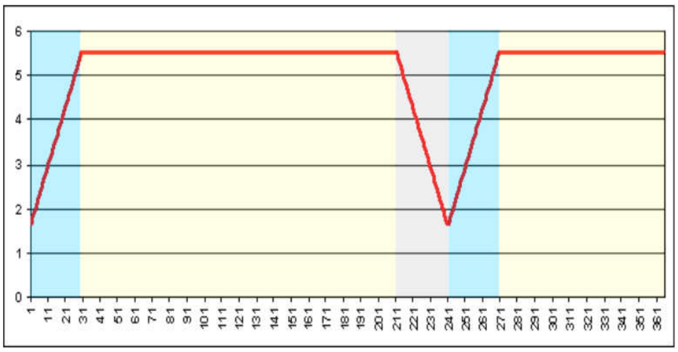


Chart 1. Estimation of evapotranspiration (in mm) of the castor oil in the period of 365 days

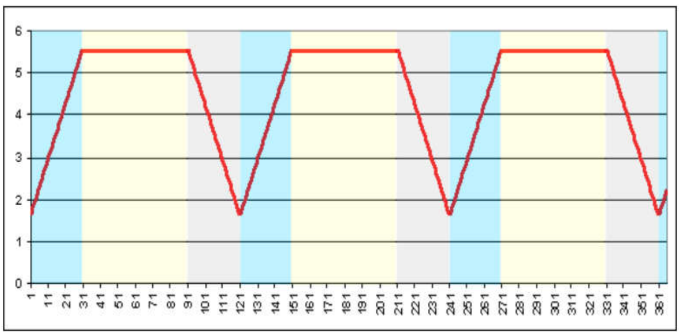


Chart 2. Estimation of evapotranspiration (in mm) of peanuts in the period of 365 days

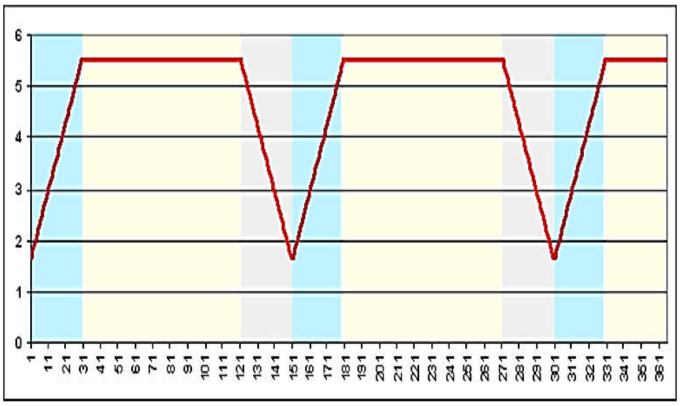


Chart 3. Estimation of evapotranspiration (in mm) of the sunflower in the period of 365 days

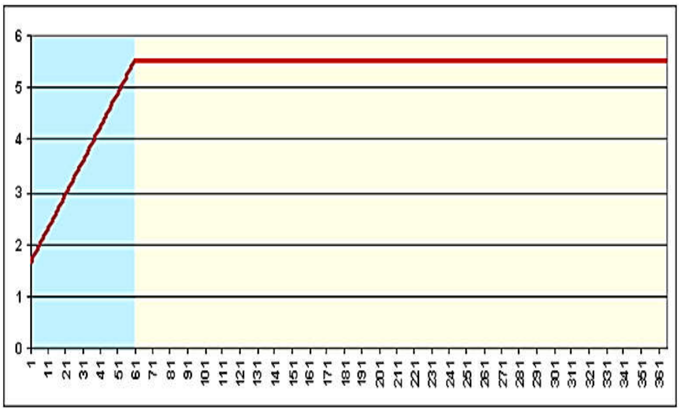


Chart 4. Estimation of evapotranspiration (in mm) of palm oil (dendê) and babassu oil in the period of 365 days

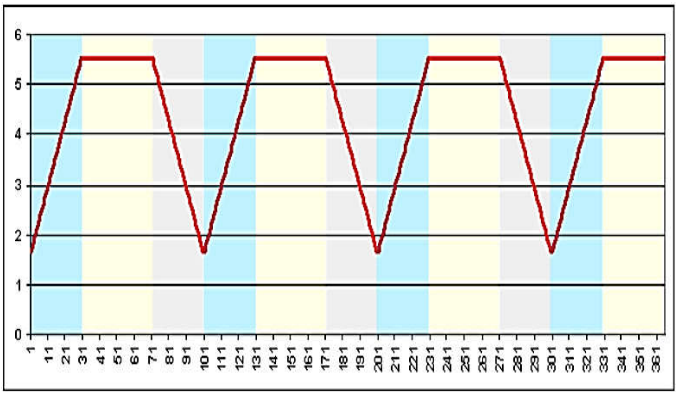


Chart 5. Estimation of evapotranspiration (in mm) of the rape in the period of 365 days

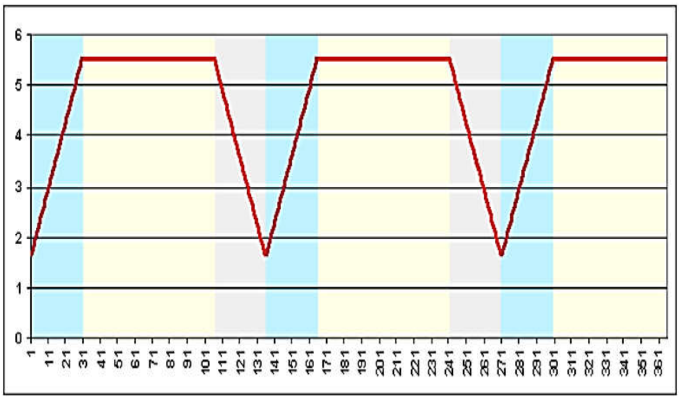


Chart 6. Estimation of evapotranspiration (in mm) of soybean in the period of 365 days

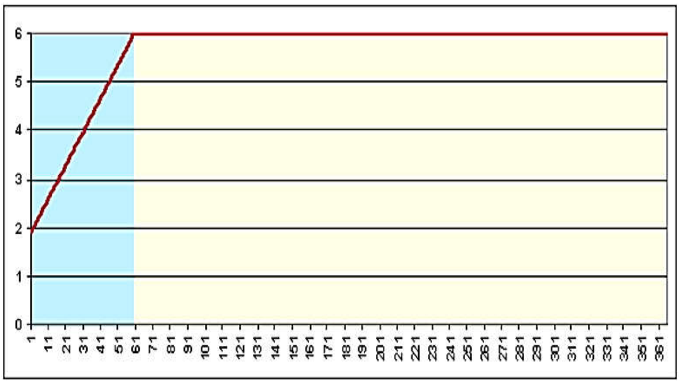


Chart 7. Estimation of evapotranspiration (in mm) of sugarcane in the period of 365 days

Calculation of evapotranspiration for oilseeds in the Midwest: Several studies have been conducted in order to determine the degree of evapotranspiration in different cultures and environments. In this paper, the focus is the evapotranspirationof oilseed made eligible by the Brazilian Government for the biofuels program, mainly asregards the region of Cerrado. Table 2 introduces water availability for plants and the evapotranspiration in dense Cerrado, strictusensu, and in planted grazing. In Table 3, the calculations of evapotranspiration of oilseeds, based in Equations 1 to 3, are presented in general.

Table 2. Evotranspiration in the Cerrado

Evapotranspiration (ETc)	(mm)/year	(m)	Demand (1000m^3)
Annual Pasture (Cerrado)	1115	1,115	33.450.000
Cerrado Stricto Sensu	924	0,924	27.720.000
Dense Cerrado	948	0,948	28.440.000

Source: SILVA (2003)

Table 3. Calculations for evotranspiration of oilseeds

Oleaginous	ETc (mm)/year	ETc (m)	Demand (1000m^3)
Castor Bean / 240 days	1841,96	1,841957	38.681.093
Peanut / 120 days	1536,04	1,536037	691.216.740
Sunflower / 150 days	1726,73	1,726728	259.009.200
Dendê / Perennial	1899,45	1,89945	769.277
Babassu / Perennial	1899,45	1,89945	569.835
Soybeans / 135 days	1726,73	1,726728	1.036.036.800
Sugar cane / 545 days	2067,51	2,067507	186.075.630
Rapeseed / 100 days	1611,50	1,611499	1.933.799.040

According to the report of NAE (BRAZIL, 2005a), the area required to supply 5% of B5 diesel with local oleaginous, and using only soy, palm oil 'dendê' and castorseed, would be about 3 million hectares, as shown in Table 4.

Table 4. Estimated area to produce B5

Region	Vegetable oil for B5 (1000m^3)	Raw materi-al	Area (1000 ha)
Soutth	7.200	soybeans	600
Southeast	15.840	soybeans	1.320
Northeast	5.400	castor bean	600
North	3.240	palm oil	35
Midwest	4.320	soybeans	360
Total	36.000		2.916

Fonte: BRASIL (2005a, p. 38)

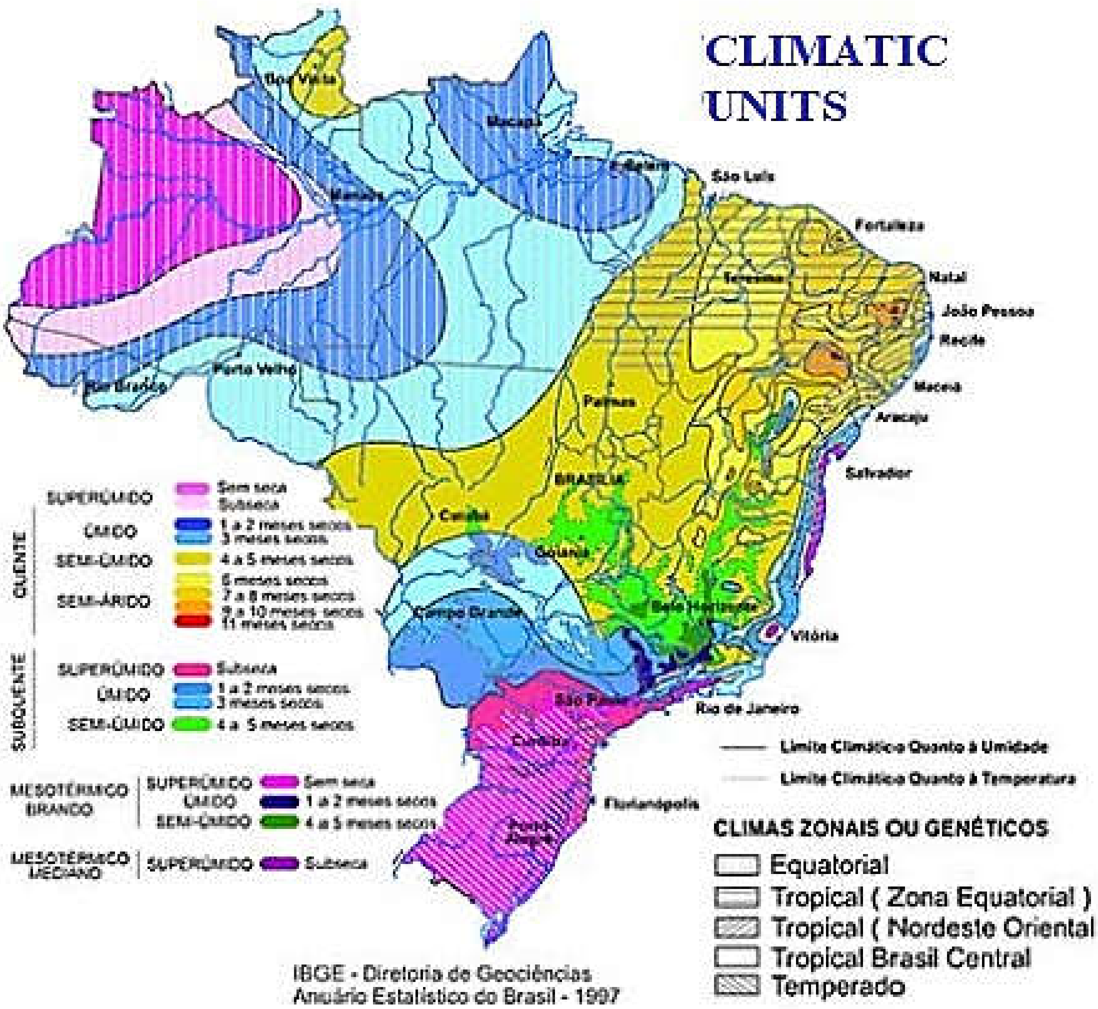
The values shown in Table 5 relate to the evapotranspiration of oilseeds in the native vegetation in the Cerrado and refer to the first year of planting. From the second year, the values are different, because the perennial crops are already at their maximum development. That is, the coefficients (Kc) of perennial crops are already at its maximum value of 1.15 (ALLEN *et al*., 1998), which considerably increases the value of evapotranspiration and, consequently, water demand.

Table 5. Evapotranspiration of reference to the Cerrado (E.T. =936 mm/year)

Culture	E.T. (mm/year)	E.T. relative (%)
Castor Bean (Mamona)	1841	196%
Peanut (Amendoim)	1536	164%
Sunflower (Girassol)	1726	184%
Palm Oil (Dendê)	1957	209%
Babassu (Babaçu)	1957	209%
Soybeans (Soja)	1726	184%

Source: BRASIL (2005a, p. 38)

for a long period of time, measured in months or years (INMET, 2005). Climatic variations are the oscillations that occur in the atmospheric variables and which together affect the climate. The Earth has been going through a lot of changes, alternating periods of glaciation and inter-glaciation, where large climatic oscillations occurred. There is evidence and several scientists around the world agree that human activities, in search of economic development, the comfort and the facilities of modern life, are causing climate changes so unnatural, whether by the emission of pollutant gases, either by replacement of natural vegetation for cultures related to farming activities (NOBRE *et al*., 2007; MARENGO, 2006). In the Midwest, where the Cerrado ecosystem is concentrated, cultures related to farming activities have ostensibly been happening since the '70 (MARENGO, 2006). In the current Brazilian climatic units map (Map 1) it is noted that the Midwest offers a regular distribution of rainy and dry periods well defined. The dry season varies from 4 to 5 months (dark yellow), between the months of May to September.



Source: Brazilian Institute of Geography and Statistics (1997)

Map 1. Map of climatic units of Brazil

Climatology of the Midwest region: here at different time intervals, the concepts of weather and climate are indispensable. Weather, in a given region can be considered as the sum of the action of various atmospheric variables, such as, the rain, the sun and the wind, in a short period of time. However, climate is the average behavior of the atmosphere

Winter with dry season and Summer with rainy season: In the Midwest, the winter season is characterized by drought and with low levels of relative humidity. Climatology explains that there is a decrease in rainfall due to the invasion of cold air (high pressure of polar origin), removing moisture from the region. From mid-July to mid-September, starts the predominance of hot and dry air mass in the Centre of Brazil, leading to a drier atmosphere. In the Midwest, the summer is characterized by the rainy season due to the arrivals of cold fronts along with the moisture from the Amazon, which is transported by low-level Jet-JBN, and counterclockwise circulation of winds in the upper atmosphere around 12 km of altitude. The cold front joint combination with the interaction of the Amazon moisture mass, form a weather system known as the South Atlantic Convergence Zone – SACZ (BETTS, 2009). This system, when formed, offers a high support in the rains of the Midwest and Southeast regions for several days, weeks, or more, being what most contributes to the rains in the Midwest. Part of the South-East rainfall is due to the Midwestern evapotranspiration as a function of the low-level Jet-JBN, carrying moisture to the Southeast.

Considerations for anomalies of precipitation in Central-Western Brazil

According to Diniz and Rebello (2002), extreme climatic fluctuations on seasonal scale in the Tropics (geographical parallel distant 23 degrees 27 minutes and above and below the equator, respectively, called the Northern Tropic of Cancer and the South Tropic of Capricorn) and high variability in precipitation with negative anomalies have caused large consequences in the sectors of water supply in urban centers, in agriculture and hydropower planning of the country. Diniz and Rebello (2002) check and compare the totals of rainfall that occurred with the normal monthly, for the months of January and February, of INMET 90 network of weather stations. INM*Et al*so examines the negative anomalies patterns maps of monthly rainfall, using decisintervals through 1961 to 2000.

With that, it was found the strong reduction in rainfall over the southeastern region, states of GOs and DF and the impact on hydroelectric. Diniz and Rebello (2002) using the annual chart of the last five years about the capacity of reservoirs in the region, provided by the national system operator – ONS. According to Diniz and Rebello (2006), for the examination of the causes of these anomalies of precipitation, the climatic wind fields were used and analyzed for the months of January and February, the average monthly circulation anomalies in the levels of 850 and HPa 200 global model generated from the National Centers for Environment Prediction (NCEP), about South America, for the determination of the deficiencies of the wind flow patterns on both levels.

At 200 HPa, atmospheric blocking situation was observed on the SE, GO and DF and absence of the SACZ. In low levels, at 850 HPa, it was verified the existence of stronger jets responsible for the transport of moisture to the South as proposed by Vargas *et al*. (2000, apud DINIZ; REBELLO, 2006) and the absence of moisture in the State of Goiás as shown in Figure 1, letters c and f. Nobre, Sampaio and Salazar (2007) make a relevant relationship regarding the changes of land use and hydrology, showing that the effect of deforestation and climate change directly affects the hydrological cycle at all scales of time: on time scales of days to months lead to changes in the incidence of floods; in seasonal to amongst annual time scales, changes in the characteristics of drought is the main hydrological manifestation; and, in years to decades, the interconnections in global atmospheric circulation patterns, caused by ocean-atmosphere interaction, affect the hydrology of some regions.

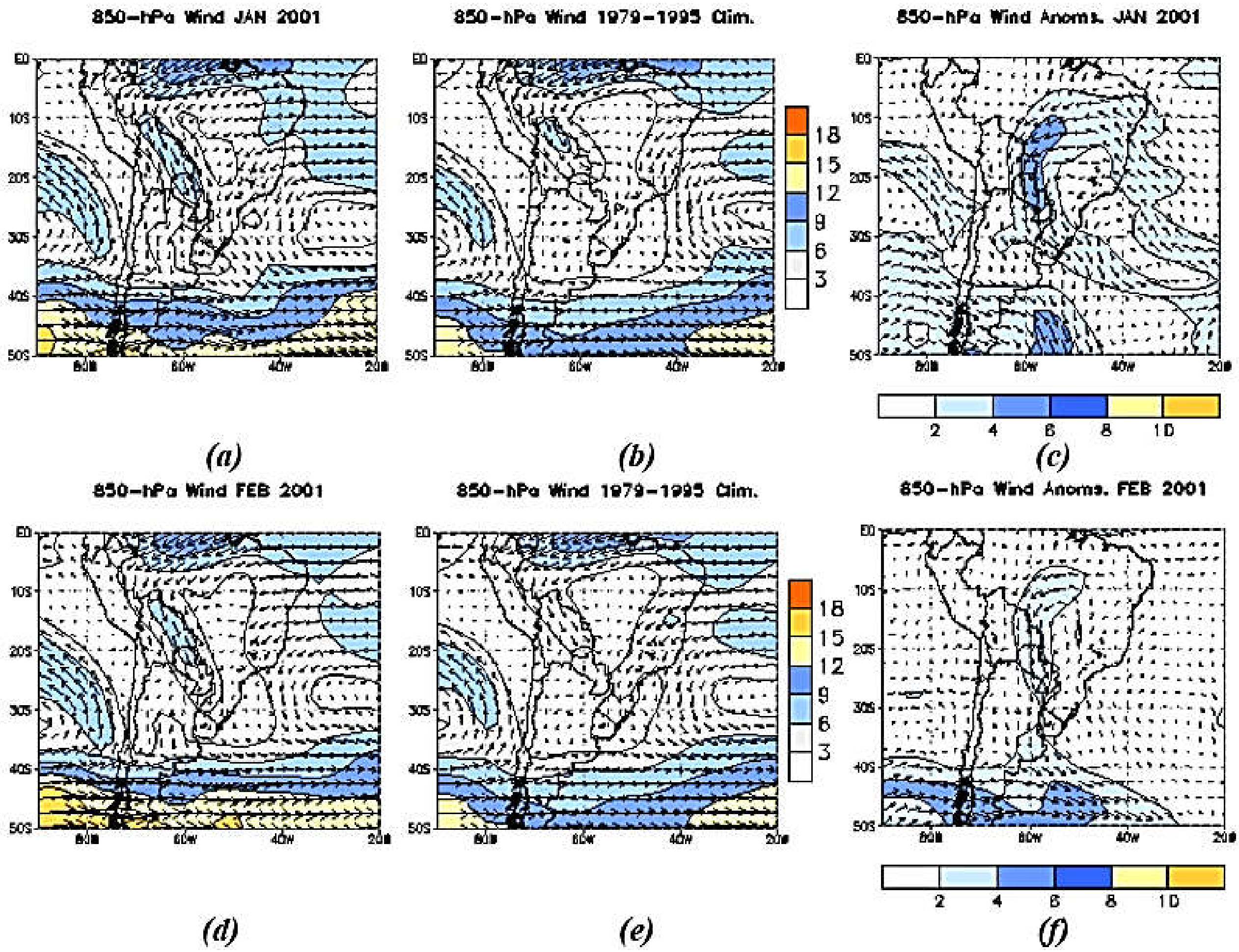


Figure 1. Wind fields at 850 hPa, in January and February 2001, regarding the data between 1979 to 1995 (DINIZ; REBELLO, 2001)

Studies reveal that occurrences of rains in South America are related to meteorologicalphenomena belonging to various temporal and spatial scales, ranging from the global scale(ElNiño-La Niña), 30-60day Oscillation (Madden& Julian Oscillation) and the SACZ as well as the local weather conditions that affect mainly in Midwestern regions precipitation, Southeast, Northeast and North South sector of southern region (CARVALHO *et al*., 2002a).

Conclusion

The theme of biofuels is current and has been constantly emphasized by writing and television media throughout these past few months. The information transmitted to the public, in general, have been almost always imprecise, especially as regards the demand for natural resources such as water, for all purposes of production. In this sense, not only the public, but mainly the decision-makers agents do not always have managed to discern the certainties and uncertainties regarding the sustainability of the present program and, especially, the future. This research is intended to contribute to the studies and projections of environmental impact from biofuels program on water availability of the Cerrado, considering the demand of water resources needed for the production of oilseeds elected. It is known that both the pastures as the existing cultures in the region under study have scary amounts of water demand, considering the current data and climate surveys of the Intergovernmental Panel on Climate Change – IPCC. This work found that the demand for water for the sustainability of the programme will be, for some oilseeds, practically doubled up. Currently, the water resources of the Cerrado, in the dry season, already suffer an imbalance on the basis of evapotranspiration in the region do not precipitate in the same locationas the atmospheric circulation studies presented by the National Institute of Meteorology. Considering the increase in temperature caused by deforestation and/or extraction ofnative vegetation to plant oilseeds eligible – which also increases water consumption – everything leads us to believe that the impact on water resources in the region should be negative. Water is a critical natural resources for the sustainability of the cerrado. Considering that the appropriation of the water resources in a region is related to the availability and the demand, it is fundamental to consider this balance as key for future decisions for developments specially related do biofuel production. All of these factors justify future works that seek to further study about the variables here exposed and their interrelationships. This can, for example, be approached from techniques of modeling and simulation of environmental systems.

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