

# Quantification of greenhouse gases emission from sugarcane burnings: a study case in savanna areas of Brazil

## ABSTRACT

In Brazil, the cultivation of sugar cane is regarded as emitting greenhouse gases (GHGs) when associated with the use of burnings in the pre-harvest, depending also on the physiognomy of native vegetation converted to its installation (i.e. in the format of grass, bushes or trees). This study aims at estimating GHG emissions in areas of sugarcane cultivation in the State of Goiás, core area of the Cerrado biome, between 2005 and 2009. Thus, it was considered the hypothetical use of pre-harvest burning and its gradual reduction. The areas with sugarcane fields and where fire is used were also identified, providing actual data for the recalculation of GHG emissions. The maps show a concentration of sugarcane cultivation in the southern, central and southwestern areas of Goiás. Assuming all that sugarcane production is exposed to fire (during the reference period), it was observed the emission of four greenhouse gases (methane, nitrous oxide, carbon monoxide and nitrogen oxide). The Federal Law helps restrain the use of fire, allowing the replacement of this technology. In Goiás, the extent of areas with burning cane fields are fragmented and small, emitting 105.95 Gg C-CO<sub>2e</sub> in the period studied (14.75% of total area for planting of the sugarcane), making production relatively clean.

**KEYWORDS:** *Savanna environment, Cerrado, Sugarcane, Greenhouse gases emission, Burnings.*

## RESUMO

No Brasil, a cultura da cana-de-açúcar é considerada como emissora de gases de efeito estufa (GEEs) quando associada ao uso de queimadas na pré-colheita, dependendo também da fisionomia da vegetação nativa convertida para sua instalação (i.e. graminosa, arbustiva ou arbórea). Este trabalho visa estimar as emissões de GEE em áreas de cultivo de cana no Estado de Goiás, área core do bioma do Cerrado, entre 2005 e 2009. Assim, considerou-se o uso hipotético da queima na pré-colheita e a sua redução gradativa. Também mapeou-se as áreas com canaviais e que utilizam o fogo, fornecendo os dados reais para o recálculo das emissões de GEE. Os mapas mostram uma concentração do cultivo da cana na regiões sul, central e sudoeste de Goiás. Assumindo que toda essa produção de cana seja exposta ao fogo (durante o período considerado), observou a emissão de quatro GEEs (metano, óxido nitroso, monóxido de carbono e óxido de nitrogênio). A Lei Federal auxilia a coibir o uso do fogo, permitindo a substituição desta tecnologia. Em Goiás a extensão das áreas de canaviais com queima são fragmentadas e pequenas, emitindo 105,95 Gg C-CO<sub>2e</sub> em todo o período estudado (4,87% da área total destinada ao plantio da cana-de-açúcar), tornando a produção relativamente limpa.

**PALAVRAS-CHAVE:** *Ambiente savanna, Cerrado, Cana-de-açúcar, Emissão de gases com efeito de estufa, Queimadas.*

## Alcione Borges

Economist. Doctorate Student in Environmental Sciences Program / Federal University of Goiás (scholarship from CAPES)  
Email: [agroeconomic@gmail.com](mailto:agroeconomic@gmail.com)

## Manuel Eduardo Ferreira

Geographer, Doctor in Environmental Sciences (Federal University of Goiás). Professor at the Federal University of Goiás in Cartography and Geographic Information System (Socio-Environmental Studies Institute), and associate researcher at the Image Processing and GIS Lab. (LAPIG)

## Marlon Nemayer

DTI-CNPq Scholarship Researcher, Image Processing and GIS Lab. (LAPIG) / Federal University of Goiás.

## Fausto Miziara

Sociologist. Doctor in Sociology (University of Brasília). Professor at the Federal University of Goiás (School of Agronomy)

## Francis Lee Ribeiro

Economist. Doctor in Applied Economics (Federal University of Viçosa). Professor at the Federal University of Goiás (School of Agronomy)

## INTRODUCTION

Despite considered one of the hotspots of biodiversity on the Earth (Myers *et al.* 2000), the Savanna environment in Brazil, locally known as Cerrado, has become in the recent years a very attractive region for the development of biofuels, among which the production of ethanol from sugarcane (FERREIRA *et al.* 2007; ALMEIDA, 2003). The good efficiency of ethanol from sugarcane face other biofuels and fossil fuels, such as gasoline and diesel, provides a positive reflection for the Brazilian sugarcane industry, among which the significant expansion of sugarcane plantations in this biome (MENDONÇA, 2010; GIBBS *et al.* 2008). However, the common practice of burnings in the sugarcane pre-harvest phase threatens the environmental sustainability of this cultivation due essentially to the emission of greenhouse gases.

The agricultural frontier for ethanol activity in Brazil has been now concentrated in the Midwest region of the country, more specifically in the savanna environment (locally known as Cerrado), already heading other important biomes like Pantanal and Amazonia, and making this activity essential to the economic and environmental monitoring (ALVES AND WANDER, 2010; RIBEIRO *et al.* 2009). In the specific case of Goiás, a state located in the core area of the Cerrado (central area in Brazil), the production of sugarcane ethanol is intensified since 2000, becoming coexistent with the already established production of grains (soybeans), cotton, rice and livestock (dairy and cut) (CASTRO *et al.* 2010), and an attractive region for the production of this renewable fuel (ALVES AND WANDER, 2010).

However the disorganized growth of sugarcane cultivation in Goiás, based on the expansion of cultivated area rather than on the increase of productivity gains (CASTRO *et al.* 2010), is mentioned as

a serious environmental problem, especially for the occupation of areas of native vegetation (forests and savannas) and for the use of burning in the pre-harvest phase of this cultivation (OMETTO *et al.* 2005; BORJA, 2007). Thus it is emitted a large amount of greenhouse gases (direct and indirectly) to the atmosphere, causing several social and environmental damage.

Concerned about the levels of atmospheric concentration of greenhouse gases (GHG) resulting from this agricultural practice, in 1998 the Brazilian government met the requirements of the United Nations Framework Convention on Climate Change, by determining the gradual reduction of burning use at the mechanized areas by 2020 (in some regions, this period was reduced to 2014). Within this analytical perspective, this article aims at estimating the GHG emissions at sugarcane plantation

areas in Goiás from 2005 to 2009. In order to meet this result the possibility of the use of two different and substitutes technologies will be considered: with and without the use of burnings. Following that the sugarcane expansion areas fields with burning scars will be identified by means of geo-referencing, providing actual data for the recalculation of GHG emissions.

## METHODOLOGY

### Study area

This research is restricted to the State of Goiás, central area of Cerrado biome, due to its natural features, agricultural development (the second largest producer of ethanol in Brazil since 2009) and government incentives, factors that helped the establishment and expansion of sugarcane cultivation in the region (Fig. 1).

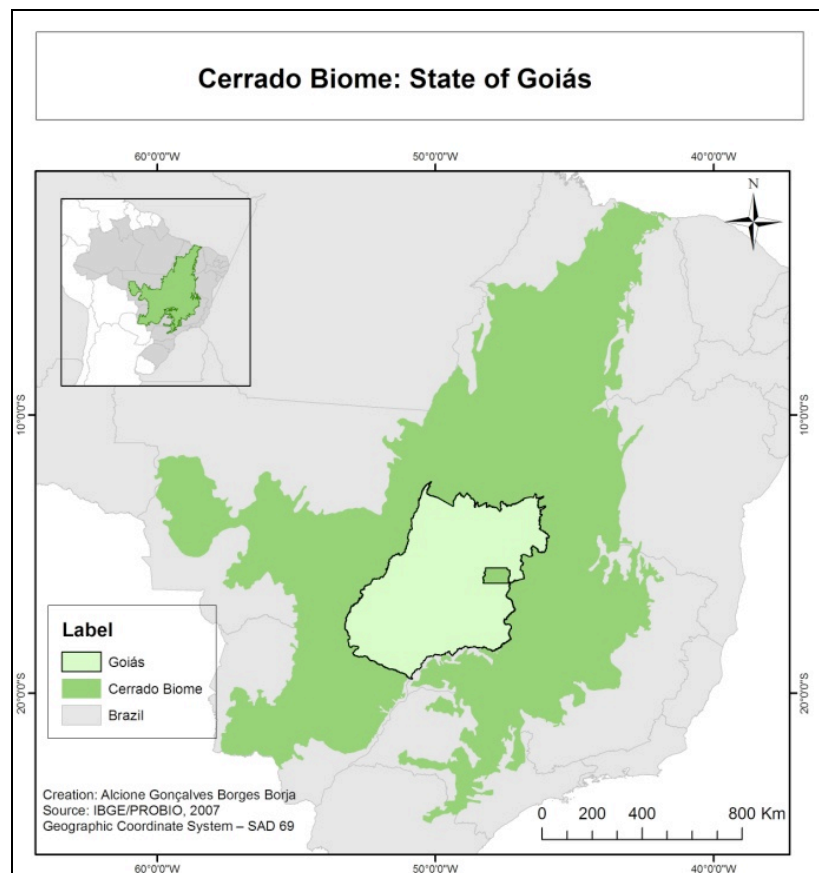


Fig. 1 - Study area, with the limits of the Brazil, Cerrado biome and the State of Goiás.

### Database and processing stages

Based on the methodology of international policies on climate change and on the information in relation to Greenhouse Gas (GHG) emitted as a result of inadequate management with the use of fire in sugarcane pre-harvest (*Saccharum spp.*), in this case the state of Goiás - period from 2005 to 2009, this article follows the calculations guidelines used in the first Greenhouse Gas Anthropogenic Emissions Inventory (MCT 2002), which adapted the methodology presented in the Fourth Module of the Intergovernmental Panel on Climate Change - Reference Manual (IPCC, 1997).

Attending to the last guideline suggested by the manual, which proposes the inclusion of a law to reduce GHGs, here follows Borja's (BORJA, 2007) proposal, which considers the Decree Law No. 2.661/1998, paragraph IV which regulates the gradual reduction of fire use in a quarter (minimum) of the mechanized agricultural area, every 5 years, not exceeding the limit of 2020. With such methodological grounds, all the sugarcane production in Goiás is considered to be done in mechanized areas and

due to this two different scenarios are proposed: 1) with 100% use of fire and with gradual reduction (from 2005 to 2009 - study period - with 50% reduction).

Finally, it is also analyzed the data from CANASAT Project (2010) sugarcane plantations, based on satellite data (Landsat-TM), to identify and track the spatial distribution of sugarcane plantations in the State of Goiás from 2005 to 2009. This data was analyzed together with images of fire scars, generated WIST NASA (2010) by the MODIS (Product MCD451A) sensor, pointing out the burning areas in the sugarcane plantations in Goiás between 2005 to 2009. From this data it was recalculated the actual emission of anthropogenic gases based on the Inventory Methodology (BORJA, 2007; MCT, 2002).

### RESULTS AND DISCUSSION

The current warming in the international demand for ethanol from sugarcane was motivated by replacing fossil fuels (from the Kyoto Protocol) and too by the increase in sale of flex fuel cars (ie. biofuels). This scenario has leveraged the

sugarcane sector in Goiás, making it one of the most promising activities of the agribusiness in the region.

Over the past five years the production of sugarcane in the state of Goiás has nearly tripled, going from 15.642.125 tons in 2005 to 44.064.470 tons in 2009 (CANASAT, 2010). Despite the good productivity (average of 80 tons / ha – 2006 to 2009), the productive expansion basis in this period happened due to the increase by 260% in the planted areas, going from 200 thousand hectares in 2005 to over 520 thousand hectares in 2009 (SEPLAN/SEPLIN, 2010). With this productive supply, Goiás became the fourth largest sugarcane producer in Brazil and the second largest ethanol producer in the country (SIFAEG, 2010).

Considering this productive scenario and assuming this total sugarcane production disposition at fire in the pre-harvest, the emission annual average (BORJA, 2007; MCT, 2002) is estimated, in Gig gram ( $Gg = 10^9$ ), of methane ( $CH_4$ ), nitrous oxide ( $N_2O$ ), carbon monoxide (CO) and nitrogen oxides (NOx) from 2005 to 2009 in, respectively, 11.97, 251.47, 0.59 and 21.42. According to this

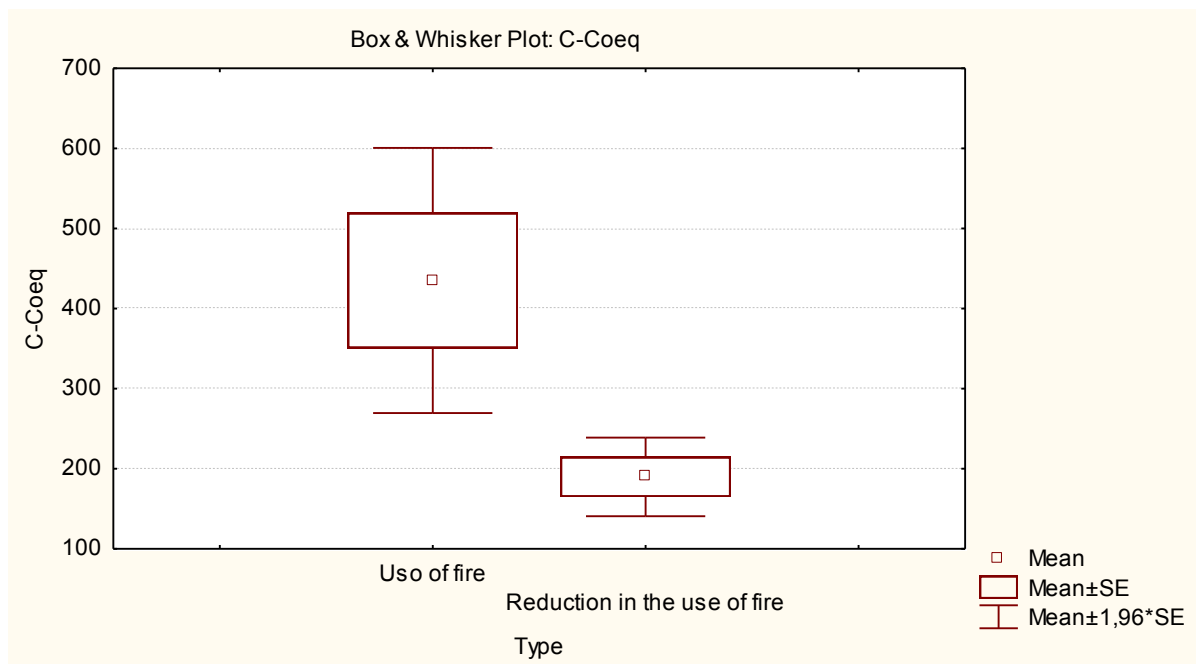


Fig. 2 - Carbon dioxide equivalent emission in accordance with the use of burnings during the pre-harvest and with the reduction of burnings.

data, the sugarcane burning emits a smaller quantity of direct GHGs, i.e. CH<sub>4</sub> and N<sub>2</sub>O, both being authorized to receive carbon credits by the agricultural projects about Clean Development Mechanism (CDM) activities. The gases not listed in the Kyoto Protocol (CO and NO<sub>x</sub>) had higher emissions, making the CO emission worrying, once it can indirectly interfere in the CH<sub>4</sub> concentration in the atmosphere.

Moreover, the gases CH<sub>4</sub> and N<sub>2</sub>O can be transformed into one single international unit of measurement that expresses the quantity of these gases in equivalent terms of carbon dioxide (CO<sub>2</sub>), called equivalent carbon dioxide (C-CO<sub>2e</sub>). In this sense the emitted quantity of CH<sub>4</sub> and N<sub>2</sub>O is multiplied by its respective Global Warming Potential (GWP), i.e. by 21 and 310 (UNFCCC 2006), respectively, resulting in an annual average equivalent gases emission of 251.37 and 182.90 Gg C-CO<sub>2e</sub>, or in an annual emission total of 434.27 Gg C-CO<sub>2e</sub> (with the complete burning of the sugarcane).

Even as a facilitator for the

management of sugar cane, the use of fire in the pre-harvest is an issuing agent of greenhouse gases, especially of direct gases (ie. CH<sub>4</sub> and N<sub>2</sub>O), which are considered more harmful to the global warming among the analyzed gases (MCT, 2002; UNFCCC, 2006). Therefore the possibility of reduction in the use of fire in the sugarcane pre-harvest, through the application of Decree Law 2.661 (1998), favors the reduction of these gases emissions by 50% between 2005 and 2009 (Fig. 2)

As a comparison to an actual scenario, the sugarcane expansion in the region of Goiás was also analyzed through CANASAT (2010) data and with the respective burnt area - based on MODIS sensor - MCD451A product (WIST NASA 2010), to detect the planted area growth and its possible negative effects generated by the use of burning as pre-harvest technology in five consecutive periods: 2005/2006; 2006/2007; 2007/2008; 2008/2009 (Fig. 3)

The establishment and expansion of sugarcane cultivation

are recent in the state of Goiás. Data from CANASAT (Fig. 3a) indicates that the real expansion of the sugarcane sector in the region of Goiás is highly fragmented (average of 4185.80 polygons) and scattered throughout the state, focusing on the central-south region, fertile and mechanized areas, previously, used for the planting of soybeans.

According to data provided by CANASAT, the expansion exceeded double the planted area of sugarcane in 2005 (217,898.04 ha) to the current 451,075.04 ha in 2009. However, was observing in 2009 a decrease of 1.63% in the planted area in compared with 2008. The year 2008 also showed the greatest area available for expansion (142,843.51 ha), favoring the consolidation of the ratoon sugarcane area in 2009 (more than triple the ratoon area in 2005).

Despite this positive expansion, there was also growth in burnings (Fig. 3b) in sugarcane areas in Goiás from 2005 (7724.81 ha) to 2008 (23,866.11 ha), followed by a

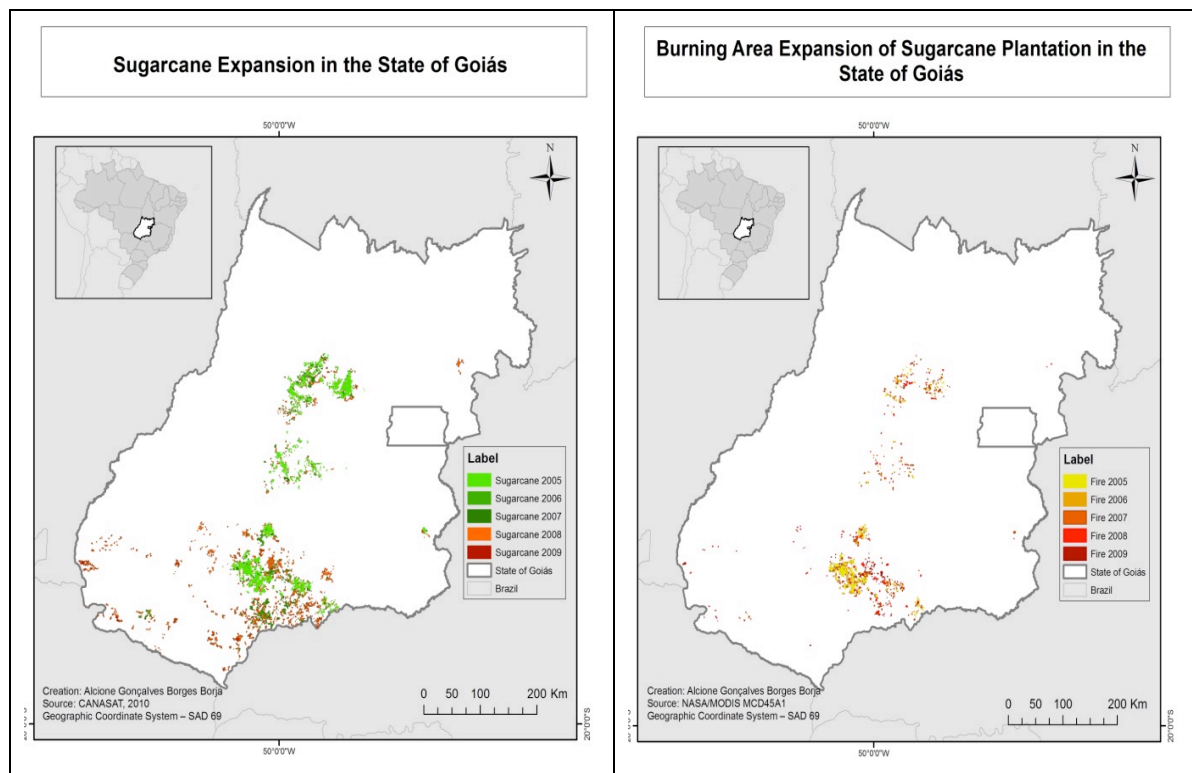


Fig. 3 - Temporal map of sugarcane expansion in the State of Goiás – Brazil, between 2005 and 2009 (3a - left) and its respective burning areas for the same years (3b - right).

period of regression in use of fire (14,389.73 ha). The burnings of sugarcane occur mostly at the stage of ratoon sugarcane (Fig. 4), i.e. from the second cut rods on. The year 2008 is sui generis for presenting a large burning area in the plantation expansion phase (8240.52 ha), however it is not clear whether the fire was imposed before the sugarcane planting or in the pre-harvest.

when supplying a truly cleaner production cycle.

In the future, the introduction of new clean technologies (and affordable) may change the current demand expectations for ethanol from sugarcane, changing the entire scenario of sugarcane productive growth in Goiás and through the world. However, until now, the expansion of this planting for the production of ethanol fuel sets Goiás as a competitive state in the search for a renewable substitute for oil, opening space to expand its national

BORJA, A.G.B. **Potencialidade do canavial brasileiro em mitigar os gases de efeito estufa**. 2007. 183p. Dissertation (Masters degree) – Universidade Federal de Mato Grosso do Sul, Campo Grande-MS, em consórcio com a Universidade de Brasília e a Universidade Federal de Goiás/Escola de Agronomia e Engenharia de Alimentos, 2007. Available at: <<http://www.dominiopublico.gov.br/download/texto/cp049792.pdf>>.

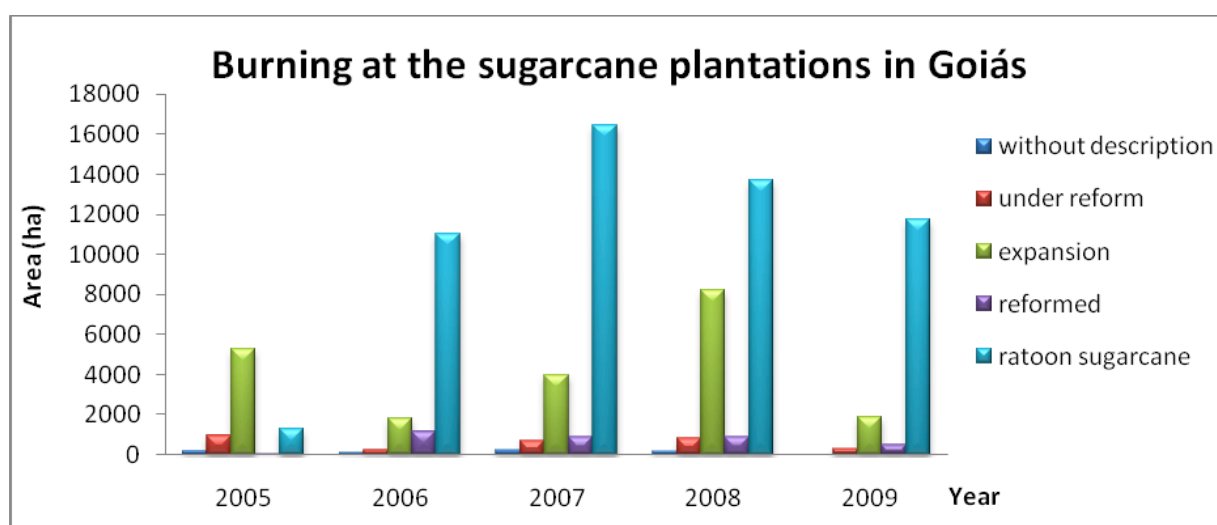


Fig. 4 - Burnt area in the sugarcane plantations in Goiás State by type of planting, as observed through MODIS sensor imagery (MCD45A product).

## FINAL DISCUSSIONS

The burning in the sugarcane pre-harvest is a harmful practice to the environment and society, should be abandoned. State of Goiás does not present itself as a big follower of the use of fire technology. Within the period 2005 and 2009, with the consolidation of the areas planted with sugar cane the practice of using fire, have been issued 105.95 Gg CO<sub>2</sub>e-C, corresponding to 5% of the areas with sugarcane. Thus, considering the percentage of expansion and burning in the sugarcane plantation areas, the ethanol sector in Goiás may become an example in Brazil

and worldwide tradability.

## REFERENCES

ALMEIDA, M.G.de. **Cultura ecológica e biodiversidade**. Mecator - Revista de Geografia da Universidade Federal do Ceará, v. 02, n. 3, 2003, p.71-82.

ALVES, N.C.G.F.; WANDER, A.E. **Competitividade da produção de cana-de-açúcar no cerrado goiano**. Informações Econômicas, v. 40, n. 7. Available at: <[http://www.alfa.br/biblioteca/artigos/artigo\\_20091123d.pdf](http://www.alfa.br/biblioteca/artigos/artigo_20091123d.pdf)>. Access in: Nov. 2010.

BRAZIL. Decree Law nr. 2661, July 8th 1998. **Covers about the establishment of precaution rules relating to the use of fire at agropastoral and forestry practices, gives other supplies**. Available at: <[http://www.planalto.gov.br/ccivil\\_03/decreto/D2661.htm](http://www.planalto.gov.br/ccivil_03/decreto/D2661.htm)>. Access in: Jun. 2006.

CANASAT. Available at: <<http://150.163.3.3/canasat/mapa/>> Access in: Dec. 2010.

CASTRO, S.S.de. *et al.* **A expansão da cana-de-açúcar no cerrado e no Estado de Goiás: uma análise espacial do processo**. Boletim

Goiano de Geografia, v. 30, n. 01, 2010, p.171-191.

FERREIRA, M. E. *et al.* **Desmatamentos no bioma Cerrado: uma análise temporal (2001-2005) com base nos dados MODIS.** In: XIII SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 2007, Florianópolis. Anais... Florianópolis: INPE, 2007. p.3877-3883.

GIBBS, H. *et al.* **Carbon payback times for crop-based biofuel expansion in the tropics: the effects of changing yield and technology.** [S.l.]: Environmental Research Letters. 2008. Doi: 10.1088/1748-9326/3/3/034001.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE - IPCC. **Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories:** Workbook. Module 4: Agriculture. Bracknell: UK.1997.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA; CENTRO NACIONAL DE PESQUISA EM MONITORAMENTO E AVALIAÇÃO DE IMPACTO AMBIENTAL – CNPMA. **Primeiro Inventário Brasileiro de Emissões Antrópicas de Gases de Efeito Estufa.** Relatório de Referência: Emissões de gases de efeito estufa na queima de resíduos agrícolas. Brasília: Ministério de Ciência e Tecnologia – MCT, 2002. 106f.

MENDONÇA, M.L. Brazil: Sugar cane plantations devastate vital Cerrado region. **Pacific Ecologist: Agroenergy and alternatives.** Available at: <<http://www.pacificecologist.org/archive/17/pe17-brazil-sugar-cane-devastation.pdf>>. Access in: Nov. 2010.

MYERS, N. *et al.* **Biodiversity**

**hotspots for conservation priorities.** [S.l.]: Nature, v.403, 2000, p.853-858.

OMETTO, A.R.; MANGABEIRA, J.A.de; HOTT, M.C. **Mapeamento de potenciais impactos ambientais da queima de cana-de-açúcar no Brasil.** In: XII SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, Goiânia, Brasil, 16-21 abril 2005. Anais... Goiânia: INPE, 2005, p. 2297-2299.

RIBEIRO, N.V.; FERREIRAJR, L.G.; FERREIRA, N.C. **Expansão da Cana-de-açúcar no Bioma Cerrado: Uma análise a partir da modelagem perceptiva de dados cartográficos e orbitais.** In: XIV SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 25-30 de abril de 2009, Natal. Anais... Natal: INEP, 2009, p. 4287-4293.

SECRETARIA DO PLANEJAMENTO E DESENVOLVIMENTO - SEPLAN-GO e SUPERINTENDÊNCIA DE ESTATÍSTICA, PESQUISA E INFORMAÇÃO - SEPLIN. **Goiás em Dados, 2010.** SEPLAN-GO / SEPIN / Socioeconomic Statistic Management. 2010. Available at: <<http://www.seplan.go.gov.br/sepim/>> Access in: Nov. 2010.

SINDICATO DA INDÚSTRIA DE FABRICAÇÃO DE ETANOL DO ESTADO DE GOIÁS – SIFAEG. Available at: <<http://www.sifaeg.com.br/index.html>>. Access in: Dec. 2010.

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE – UNFCCC. **GHC Data 2006: highlights from Greenhouse Gas (GHC) emissions data for 1990-2004 for Annex I Parties.** p.24. Available at: <[http://unfccc.int/files/essential\\_background/publications\\_htmlpdf/application/pdf/ghg\\_booklet\\_06.pdf](http://unfccc.int/files/essential_background/publications_htmlpdf/application/pdf/ghg_booklet_06.pdf)>. Access in: Oct. 2006.

WAREHOUSE INVENTORY SEARCH TOOL - **WIST NASA.** Available at: <<https://wist.echo.nasa.gov/wist-bin/api/ims.cgi?mode=MAINSRCH&JS=1>>. Access in: Dec. 2010.