ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS ASSOCIATED WITH THE PRODUCTION AND CONSUMPTION OF SUGARCANE ETHANOL IN SOUTH CENTRAL BRAZIL

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This research project covered a wide range of topics related to environmental and socioeconomic impacts of the sugarcane ethanol production and consumption in the South Central region of Brazil. With the use of remote sensing imagery and geographic information systems the project mapped the sugarcane crop expansion observed in the South-Central region since crop year 2003 as well as the dramatic reduction of straw burning practice during harvest in São Paulo state since 2006. Furthermore, the land use and land cover change (LULCC) observed since the year 2000, due to sugarcane expansion in South-Central Brazil, was evaluated based on time-series of remote sensing images (*see Figure 1*). The observed sugarcane crop expansion dynamic has supported the generation of scenarios related to plausible spatial patterns for sugarcane crop expansion in the short- and medium-terms in South-Central Brazil. These scenarios were used to drive biosphere-atmosphere interaction models, designed to assess physical-chemical changes in the atmosphere related to LULCC and to trace gases and aerosol atmospheric emissions in response to sugarcane expansion. The quantitative outcomes of these models in terms of atmospheric chemistry provided spatial-temporal distribution of green-house gases, toxic primary or secondary gases, and aerosols, which could be used to access the impacts on human health. Runoff from agricultural fields is one of the main routes of nonpoint source pollution whose main components are sediments, organic residues, pesticides, nutrients, and bacteria which can induce eutrophication in surface waters. In this topic a temporal-spatial evaluation of inland aquatic system's eutrophication was carried out by integrating *in situ* and remote sensing time series to detect change in water optical properties linked to algal blooms. In addition to this, econometric and economic models were conceived
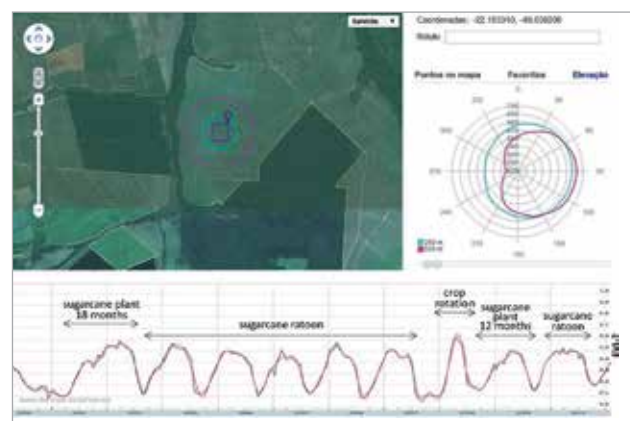

Figure 1. The bottom part of the figure represents a time-series of vegetation index values (EVI2) derived from remote sensing images (MODIS) showing a 10-year series of the crop growth cycle dynamic for a sugarcane field pixel depicted in the balloon of the virtual globe of Google Maps (www.dsr.inpe.br/laf/series)

to analyze the resulting changes of production and consumption of sugarcane ethanol in the urban network and infrastructure, in the natural environment assets, in the social well-being, in the jobs market and related scientific-technological scenario, in the agri-business economics, in agricultural financing policies, in the commodities market and food security (at national level), and in the trade balance. The knowledge gained with this work provided information to increase the understanding of the complex relationships among the sugarcane production and consumption and its related environmental and socioeconomic impacts, allowing thus a strategic contribution to public policies and actions aiming at maximizing the benefits of the sugarcane ethanol and minimizing at the same time its undesirable side effects and externalities.

SUMMARY OF RESULTS TO DATE AND PERSPECTIVES

The annual sugarcane crop mapping has been performed for the South Central region of Brazil since 2003 within the context of the Canasat project (www.dsr.inpe.br/laf/canasat/). *Figure 2* illustrates the available sugarcane area for harvest in São Paulo State from 2004 to 2011 indicating the area of sugarcane expansion. *Figure 3* illustrates the dynamic of land conversion since 2000 for the sugarcane area expanded from 2006 to 2009 in South-Central Brazil. This information was used to subsidize studies concerning the environmental and socioeconomic impacts associated to the current and predicted extensive production of ethanol in South-Central Brazil. With the use of the Dinamica-EGO modeling platform, scenarios for sugarcane expansion in the short- and medium-terms were generated. These scenarios supported several aims in the project generating annual LULCC scenarios (2008 to 2020) with the indication of sugarcane areas prone to be harvested without the straw burning practice. Maps showing the spatial distributions of algal blooms along several moments were obtained based on *in situ* measurements of an automatic data collecting system of environmental variables (SIMA), and on remote sensing and GIS techniques for a selected reservoir. A series of spatial information about the phytoplankton distribution in selected reservoirs subjected to algal blooms were obtained. An assessment of the impacts associated with sugarcane production and derived biofuel use in São Paulo State was generated based on the use of a state-of-the-art limited-area atmospheric model coupled on-line with a chemistry transport model: CCATT-BRAMS (Chemistry-Coupled-Aerosol-Tracer Transport model to the Brazilian developments on the Regional Atmospheric Modeling System). CCATT-BRAMS fed with the LULCC scenarios and estimated emissions inventories allowed an evaluation of the associated changes on the planetary boundary layer properties, hydrological cycle and air quality. With the social-economical study it was possible to assess the parameters that were used to establish public and private measures in relation to the sector.

MAIN PUBLICATIONS

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Adami M, Rudorff BFT, Freitas RM, Aguiar DA, Sugawara LM, Mello MP. 2012. Remote sensing time series to evaluate direct land use change of recent expanded sugarcane crop in Brazil. *Sustainability*. **4**: 574-585.

Rudorff, BFT, Aguiar DA, Silva WF, Sugawara LM, Adami M, Moreira MA. 2010. Studies on the rapid expansion of sugarcane for ethanol production in São Paulo State (Brazil) using Landsat data. Remote *Sensing*. **2(4)**: 1057-1076.

Macedo RC, Almeida CM, Santos JR, Rudorff BT, Soares-Filho BS, Rodrigues SH, Souza JR W. 2014. Economic impact assessment of silting-up and erosion processes: how spatial dynamic models coupled with environmental valuation models can contribute to sustainable practices in sugarcane farming. In: WEBB, E. (Org.). Sugarcane: Production, Consumption and Agricultural Management Systems. 1ed., Hauppage, NY, USA: Nova Science Publishers, 2014, p. 61-89.
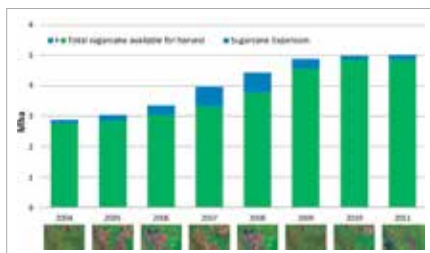
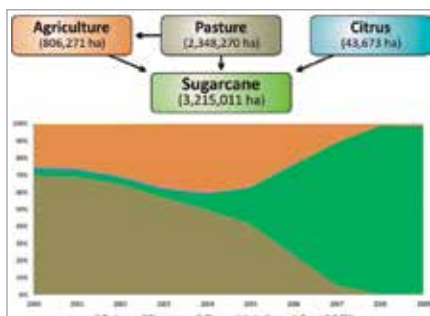Figure 2. Sugarcane area available for harvest in São Paulo from 2004 to 2011 (sugarcane expansion in blue)

Figure 3. The dynamic of land conversion since 2000 for the sugarcane area expanded during crop years 2006 to 2009, in South Central Brazil

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