# SATELLITE BASED MULTI-SCALE METHODS TO SUPPORT THE GOVERNANCE OF BRAZIL'S LOW-CARBON AGRICULTURE (ABC PLAN)

M. G. Simões[a,*], R. P. D. Ferraz[1b], A. Bégué[c], B. Bellón[c], P. L. Freitas[b], P. L. O. A. Machado[d], M. L. Neves[a], L. Skorupa[e].

[a]Embrapa Solos and UERJ, Rio de Janeiro, Brazil margareth.simoes@embrapa.br; matheusl.dasneves@gmail.com
[b]Embrapa Solos, Rio de Janeiro, Brazil (rodrigo.demonte, pedro.freitas)@embrapa.br
[c]Cirad, UMR Tetis, Montpellier, France (agnes.begue, beatriz.bellon)@teledetection.fr
[d]Embrapa Headquarters, Brasilia, Brazil – pedro.machado@embrapa.br
[e]Embrapa Meio Ambiente, Jaguariúna, Brazil – ladislau.skorupa@embrapa.br

**KEY WORDS**: Land Management Changes, Integrated Crop Livestock System, Remote Sensing, Temporal Time Series, Segmentation

**ABSTRACT**

Brazil's Low Carbon Agriculture is one the initiatives that puts the climate in the agricultural agenda towards a more sustainable and adapted agriculture under global changes. Among the several practices listed and supported by the ABC Plan, zero tillage and integrated crop-livestock-forestry systems including the recovery of degraded pasture are the most relevant ones. The objective of this paper is to present the Geo-ABC Project, a procedure to monitor the implementation of the Brazil's Low Carbon Agriculture (ABC Plan) and aiming at the development of remote sensing methods to monitor agricultural systems listed in the ABC Plan and adopted at local scale.

## 1. INTRODUCTION

There is no humanitarian goal more crucial than feeding a world population projected to expand beyond nine billion by 2050 and agriculture lies at the heart of many fundamental global challenges faced by humanity including food security, environmental degradation and climate change (Dickie et al., 2014). Several initiatives such as the Climate Smart Agriculture supported by the World Bank and FAO, the 4 per 1000 Initiative by France and supported by CGIAR, and Brazil's ABC Plan are examples of the key role played by agriculture in a more sustainable world. These developments indicate the special role to multifunctional landscapes in the process to establish a more sustainable agriculture. The purpose of this work is to present the Geo-ABC Project, an innovative project to monitor the implementation of the ABC Plan and aiming at the development of remote sensing methods to monitor agricultural systems listed in the ABC Plan and adopted at local scale. These are mixed farming systems such as integrated crop-livestock-forestry system at various combinations and at a regional scale, to monitor sustainable farming systems through landscape patterns, in order to provide spatial indicators to improve governance of the ABC Plan.

### 1.1 Project context

The increased demand for food is projected to be satisfied through productivity gains, with modest changes in crop area and livestock herds. Yield improvements are projected to account for 80% of the increase in crop output (OECD/FAO, 2016). There is some scope to increase agricultural area sustainably, mainly in parts of Latin America and Sub-Saharan Africa. This includes increased multiple cropping and shortening of fallow periods. Climate change with its severe and erratic events increases the risk of the agricultural activity and not only mitigation, but also adaptation is essential to avoid severe depletions. Adaptation includes good management practices with low carbon footprint.

Conservation agriculture is a key component of the ABC Plan and low carbon agriculture such as zero tillage, recovery of degraded pasture, and planted forests give a special role to multifunctional landscapes in the process towards a more sustainable agriculture. Indeed, landscapes must be considered as a whole system at the heart of human-nature relationships that need to be efficiently managed in order to preserve and restore ecosystem services.

Consequently, there is an urgent need to better characterize agricultural systems at global, regional and local scales, with a particular emphasis on the various pathways towards agricultural intensification, since those systems are the key for understanding land use sustainability in agricultural territories.

### 1.2 International context of the proposal and the project researcher's network

G20 launched in June 2011 the Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) initiative and the Agricultural Market Information System (AMIS) initiatives. G20 has consulted the GEO Agriculture Community of Practice to implement GEOGLAM with the main objective to improve crop yield forecasts as an input to the Agricultural Market Information System (AMIS) to foster stabilization of markets and increase transparency on agricultural production. The objectives of GEOGLAM are to (i) Enhance national agricultural reporting systems (ii) Establish a "global" network of experts in agricultural monitoring (iii) Create an operational global agricultural monitoring system of systems based on Earth Observation and in situ data. This initiative was further supported by the G20 meeting of agricultural vice ministers and deputies, including Brazilian governmental representatives in Mexico City in May 2012. All representatives and delegates reccognized Earth Observation as an important tool to provide information on agriculture, at the present time and in the future. The Group on Earth Observations (GEO) started in 2002 Summit on Sustainable Development in South Africa, which is a voluntary partnership of governments and international organizations with the main goal to support sustainable management of the earth's resources making use of remote sensing. Its main vision is to build a Global Earth Observation System of Systems (GEOSS) through a coordination of remote sensing activities around the globe. As one of its strategic targets GEOSS aims to expand application capabilities to advance sustainable agriculture.

The present research project proposal is aligned, with the goals of an approved EC Framework Program (FP7), called SIGMA Project (Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment in support of GEOGLAM) which intends to contribute to the establishment of a global observation system for the assessment of the impact of cropland areas and change on the environment and as such strengthen global agricultural monitoring by improving the use of Earth Observation for crop production projections. Both intensification and expansion of agricultural land are therefore the primary focus of SIGMA and the Brazilian equivalent GeoABC program which supports the ABC Plan. SIGMA uses the JECAM (Joint Experiment for Crop Assessment and Monitoring) sites (local agricultural sites of 50x50 km located on different countries) as defined by the GEOGLAM community to reach a convergence of approaches, develop monitoring and reporting protocols and best practices for a variety of global agricultural systems (see www.jecam.org).. The Brazilian JECAM sites are currently being used as study sites in this proposed project, taking advantage of the JECAM facility to access satellite data (different sensors and high periodicity).

#### 1.3 National context of this proposal and the project researcher's network

This research project proposal is aligned with the ABC Plan presented as a voluntary initiative by the Brazilian Government at the UNCCC-COP15 in 2009 in Copenhagen, Denmark.

Since 2011, the ABC Plan provides an initial credit line of R$ 2 billion (US$ 1.1 bn) over ten years to finance different low carbon agricultural practices that use technologies to reduce greenhouse gas emissions. The national goal being to reduce carbon equivalent emissions from Brazilian agriculture by up to 176 million tons by the year 2020.

Zero tillage system is one of the practices promoted by the ABC Plan, which includes crop rotation with cover crops for mulching and avoidance of soil ploughing and harrowing. Brazil is one of the largest producers of soybean worldwide and totally in zero tillage system and vast use of biological nitrogen fixation, that is no mineral nitrogen fertilizer.

This procedure preserves nutrients in the soil, thus increasing crop yields and protects the field from external erosion factors. Through the ABC program, the Ministry of Agriculture plans to expand the use of this technique to cover anarea of 33 million hectares from the 25 million hectares on which it is currently implemented. The adoption of zero tillage systems may reduce emissions by 16-20 million tons of $CO_2$ over a ten-year period.

Integrated crop-livestock-forestry (ICLF) system based on zero tillage is a more complex farming system supported by the federal government. Farmers or ranchers alternate from pasture to agriculture to forestry on the same paddock promoting continuous soil cover and carbon accumulation throughout the year. The ABC Plan aims to increase the use of ICLF system by 4 million hectares over the next decade, while reducing $CO_2$ equivalent emissions by 18-22 million tons.

The measurement of the impact of the ABC Plan is also envisaged by the federal government as presented during the UNCCC-COP15 and also important for the governance of the low carbon agriculture.

#### 1.4 Methods

Different methodological approaches are being USED to evaluate how local variables can be scaled-up to be monitored at a regional scale (Bégué et al., 2015). In particular, the developed methodologies focus on the use of spatial, temporal and textural indicators derived from coarse-resolution satellite images to represent crop systems at a landscape level. Crop distribution modelling, up-scaling methods based on satellite-derived variables (temporal, spectral and spatial indicators) and Object Based Image Analysis (OBIA) techniques are being applied and tested in the study area of the State of Tocantins and at ICLF system sites.

#### 1.5 Preliminary Results

At the state scale (regional scale), a landscape stratification has been carried out through segmentation of coarse-resolution satellite derived variables (Bellón et al., 2017). A principal component analysis transformation has been used on a MODIS NDVI annual time-series (250m spatial resolution MOD13Q1 product) to obtain the principal vegetation physiognomic and phenologic characteristics on the first three principal component images. In addition, a textural index (GLCM homogeneity index) has been calculated for MODIS NDVI images of three different dates within the annual series, *ie* before the growing season, middle of main plant cycle and middle of following plant cycle (Haralick & Shanmuga, 1973). The derived radiometric (principal component) and textural indices have been segmented using the multiresolution segmentation algorithm of the Definiens Developer software and the optimal segmentation parameters were evaluated by a statistical unsupervised evaluation method (Johnson & Xie, 2011) (Figure 1).

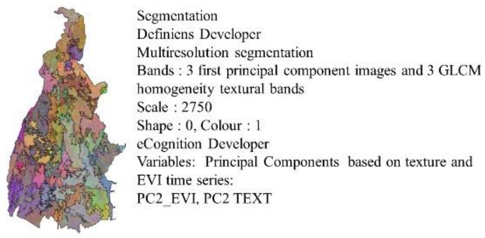


Figure 1 – Regional scale landscape stratification of MODIS NDVI derived radiometric and textural indices (Bellón et al., 2017) in homogeneous areas based on radiometry and texture using OBIA.

At local scale, temporal profiles were analyzed by experts in order to detect the different behavior of vegetation index on different agricultural systems (figure 3).

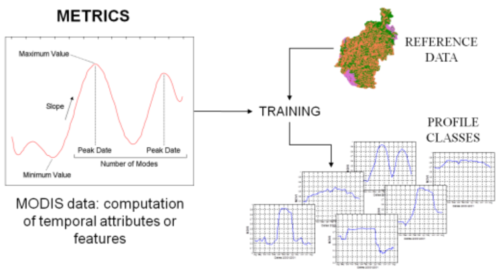


Figure 3 – Computation of MODIS temporal attributes

ICLF systems commonly presents a mixed growth of both crop and pasture grass (figure 4). This procedure adopted by farmers enables both plants to take advantage of the residual rains in the humid season and pasture formation in the dry season due to the deep rooting of the forage grass.

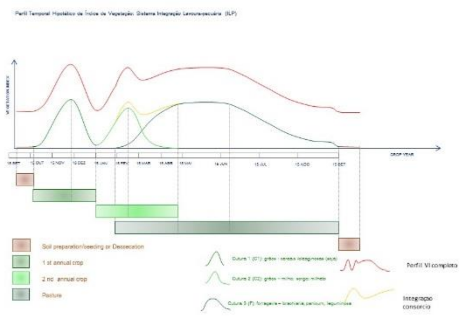

Figure 4 – Integrated Crop-Livestock Hypothetical temporal profile

The study area was a 190-ha farm paddock in the State of Goias, Brazil. The soil type was a clayey and acidic Ferralsol under degraded pasture grass, mostly Urochloa spp. Pasture was recovered using grain crop after liming and fertilizer application. By the end of October 2006, the soil was prepared using a heavy disc harrow and soybean was sown by mid November. After harvest of soybean by mid March 2007, maize together with pasture grass (Urochloa ssp) was sown and after harvest of maize in June-July, the area was kept under pasture grass for beef cattle. Between October-November 2007, soybean under zero-tillage was sown in the area followed by maize or sorghum between March and June. Regrowth of pasture grass allowed enabled grazing by beef cattle. This double cropping followed by grazing pasture was kept until 2012.

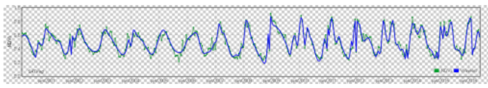

Figure 5 Perfil Temporal Hipotético de Índice de Vegetação

## CONCLUSIONS

The complete set of methodological approach establishes methodological protocols to obtain systematic spatial indicators, at multi-scale level providing metrics to the ABC Plan

Regarding public policies, GeoABC will provide spatial-temporal metrics that can be used as inputs for monitoring the the goals of the ABC Plan. At the scientific context, those methods will provide inputs for scientific studies: on the dynamics of land use related with the adoption of low carbon agriculture, for assessment of trends and establishment of future scenarios (land use dynamics); on the dynamics of land use, based on the expansion of low carbon agriculture related to the mitigation of environmental impacts (environmental impacts); on the dynamics of land use, based on the expansion of low-carbon agriculture production related to the mitigation of the greenhouse effect: (a) carbon stocks in soil and biomass; (b) reduction of GHGS; (c) water balance-ecosystem services; (iv) on the dynamics of land use, based on the expansion of low-carbon agriculture production and the relation with Climate Change (climate change).

**ACKNOWLEDGEMENTS**

Capes/Cofecub Programme (Project GeoABC Nº 845/15)

**REFERENCES**

Bellón, B., Bégué, A., Lo Seen, D., Simões, M., Ferraz, R., Lebourgeois, V., Gaetano, R. 2016. A remote sensing multi-scale approach for agricultural systems zoning. To appear in *Proceedings of the Global Land Project 3rd Open Science Meeting, Beijing, October 24-27, 2016.*

Bégué, A., Arvor, D., Lelong, C., Vintrou, E., Simões, M., 2015. Agricultural system studies using remote sensing. In: Tenkabail, P.S. (ed.) Land resources monitoring, modeling, and mapping with remote sensing. Boca Raton: CRC Press, 2015. cap. 5, p. 113-130.
http://ainfo.cnptia.embrapa.br/digital/bitstream/item/137467/1/2015-136.pdf

Haralick, R. M., Shanmugam, K.K. 1973. Textural features for image classification. IEEE Transactions on systems, man, and cybernetics, (6), 610-621.

Dickie, A., Streck, C., Roe, S., Zurek, M., Haupt, F., Dolginow, A., 2014. Strategies for mitigating climate change in agriculture: abridged report. Climate Focus and California Environmental Associates and The Climate and Land Use Alliance. Available at www.agriculturalmitigation.org

Johnson, B., Xie, Z. 2011. Unsupervised image segmentation evaluation and refinement using a multi-scale approach. ISPRS Journal of Photogrammetry and Remote Sensing, 66(4), 473-483.
OECD/FAO, 2016. OECD-FAO Agricultural Outlook 2016-2025, OECD Publishing, Paris.
http://dx.doi.org/10.1787/agr_outlook-2016-en

Simões, M., Bégué, A., Ferraz, R. 2015. Methodologies and technological innovations for low-carbon agriculture monitoring and planning for the ABC Plan governance support - Geo ABC. In: World Congress on Integrated Crop Livesctock Forest Systems; International Symposium on Integrated Crop-Livestock System, 3, Brasília, DF. Towards sustainable intensification: proceedings. Brasília, DF: Embrapa
http://ainfo.cnptia.embrapa.br/digital/bitstream/item/137498/1/2015-140.pdf