ISPRS Scientific Initiatives

FINAL REPORT

Benchmark database for tropical agricultural remote sensing application

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PROJECT

Benchmark database for tropical agricultural remote sensing application

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ABSTRACT

The project Benchmark Database for Tropical Agricultural Remote Sensing Application was developed to foster the advance of remote sensing technology focused on agricultural application by creating and sharing a benchmark database that can be used by the remote sensing community. The area selected for this project was Luís Eduardo Magalhães (LEM) municipality, which is an important Brazilian agricultural area in the Northeast of the country. Two field campaigns were conducted between 26-30th June 2017 and 14-19th March 2018, period corresponding of second and first Brazilian crop harvests, respectively. Information over 700 points was gathered, including geographic coordinates, type of crop and phenology phase and photographs. The delimitation of the fields visited during the two campaigns was carried out based on satellite images. Based on information collected in situ, optical remote sensing time series images (Sentinel-2/MSI and LANDSAT-8/OLI) and NDVI profiles (MODIS/TERRA), we created monthly field references maps (for the fields visited) covering one crop year (June 2017 – June 2018). Apart from the monthly reference maps, the database contains a set of multi-temporal remote sensing images, from both active and passive orbital sensors (Sentinel-1, Sentinel-2/MSI, LANDSAT-8/OLI), correspondent to the LEM area, along the development of the main annual crops. The database is freely available for the remote sensing community, providing means for developing and testing different approaches for tropical agricultural applications such as cropping mapping.

OBJECTIVES proposed and achieved:

- Collect in situ information about crops (mainly soybeans, cotton, maize and beans), including geographic coordinates, type of crop and phenology phase, in Luís Eduardo Magalhães (LEM) municipality, Northeast of Brazil, during two dates (first and second harvests).

- Acquire a set of multi-temporal remote sensing images, from active and passive orbital sensors, free available for the study area, covering the period of developing of first and second harvests crops.

- Create monthly reference maps for the study area, based on visual interpretation of optical remote sensing images and field data, for the period of development of the main annual crops found in the area.

- Create a database containing the boundaries of the crops fields, which were selected in the field campaigns, the monthly reference maps, and the multi-temporal images pre-processed.

DATA COLLECTION AND ACQUISITION

Field data collection (two campaigns)

The area selected for this project was Luís Eduardo Magalhães (LEM) municipality, located in the West of Bahia State, in Northeast of Brazil, in the Cerrado Biome (Brazilian Savannah) (Figure 1). This region is situated in the newest Brazilian agricultural frontier known as MATOPIBA, an acronym formed by the initials of the states of Maranhão (MA), Tocantins (TO), Piauí (PI) and Bahia (BA). MATOPIBA is being stand out in the production of soybean, maize, cotton and rice, having produced 9.4% of the 2014/2015 Brazilian grain harvest (Portal Brazil, 2015).

Figure 1. Location of Luís Eduardo Magalhães (LEM) municipality (red dot), Brazil.

It is relevant to emphasize that LEM was emancipated as municipality only in the year 2000, and therefore official agricultural data exist only since 2001. Even so, in such a short time it is possible to observe the high agricultural dynamic of this area (e.g. increase of area cultivated with cotton and beans, introduction of sorghum, reduction of rice) (IBGE, 2016a). According to IBGE statistics (IBGE, 2016b), LEM also presented 1.700 hectares of coffee in 2015, being that other perennial crops are not expressive. In addition, this municipality is relatively close to an airport (90 km from Barreiras, BA), and distances matter because in relatively recent farming municipalities the road network is deficient and mostly unpaved. This need to be taken into account to optimize the time spent in the fieldwork and costs.

Two field campaigns were conducted in LEM between 26-30th June 2017 and 14-19th March 2018, period corresponding of second (dry season) and first (rainy season) Brazilian crop harvests, respectively. Information over 700 points was gathered (Figure 2), including geographic coordinates, type of crop and phenology phase and photographs. Some examples of photos taken in the field are shown in Figures 3 and 4.

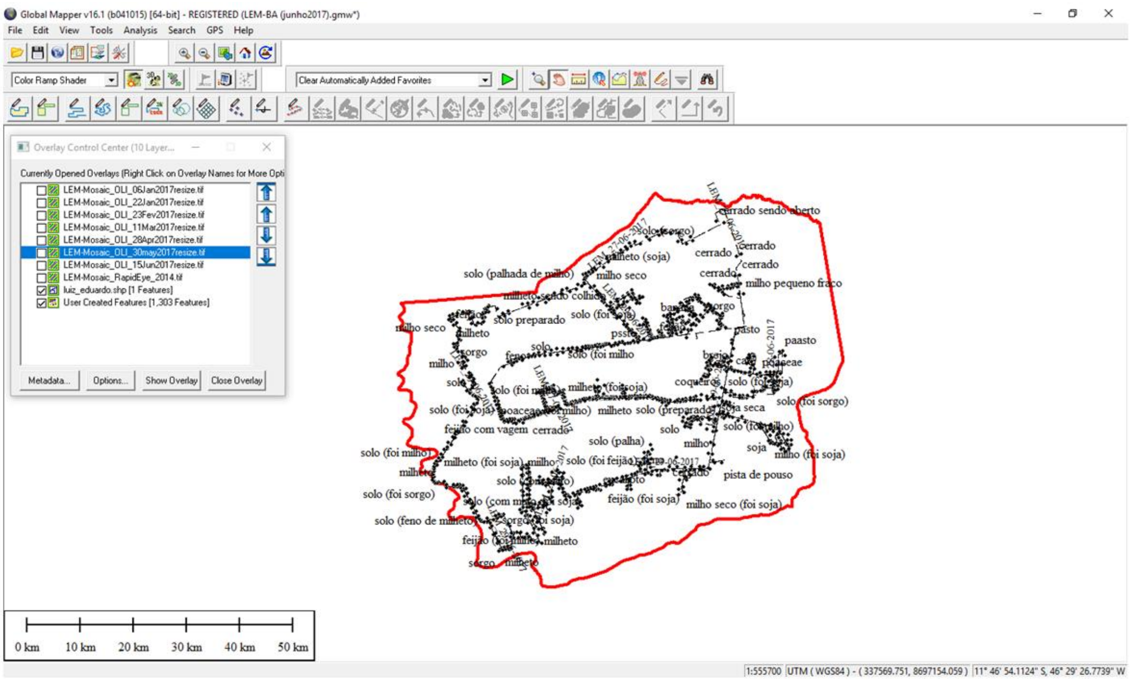


Figure 2. Global Mapper window showing the shape of LEM municipality (in red), the route travelled and the points from where field information was gathered during the first field campaign.

Figure 3. Photographs taken during the first field campaign (26-30th June 2017).

Figure 4. Photographs taken during the second field campaign (14-19th March 2018).

In each field campaign there were three people involved in the data collection, one driving, one navigating and taking notes and one taking photographs. We travelled with a 4x4 truck across LEM collecting information about the land use of the agricultural fields during one week in winter 2017 and another week in summer 2018. In each campaign, a mosaic composed by the most recent Operational Land Imager (OLI)/Landsat-8 or MultiSpectral Instrument (MSI)/Sentinel-2 images available was used to navigate along the municipality online by using a GPS device connected to a laptop and the Global Mapper software (Global Mapper Software LLC designs, Parker, CO) (Figure 5). High resolution image were used as auxiliary data (Google Earth). The focus was on crops, but other classes were mapped as well (e.g. Cerrado, pasture).

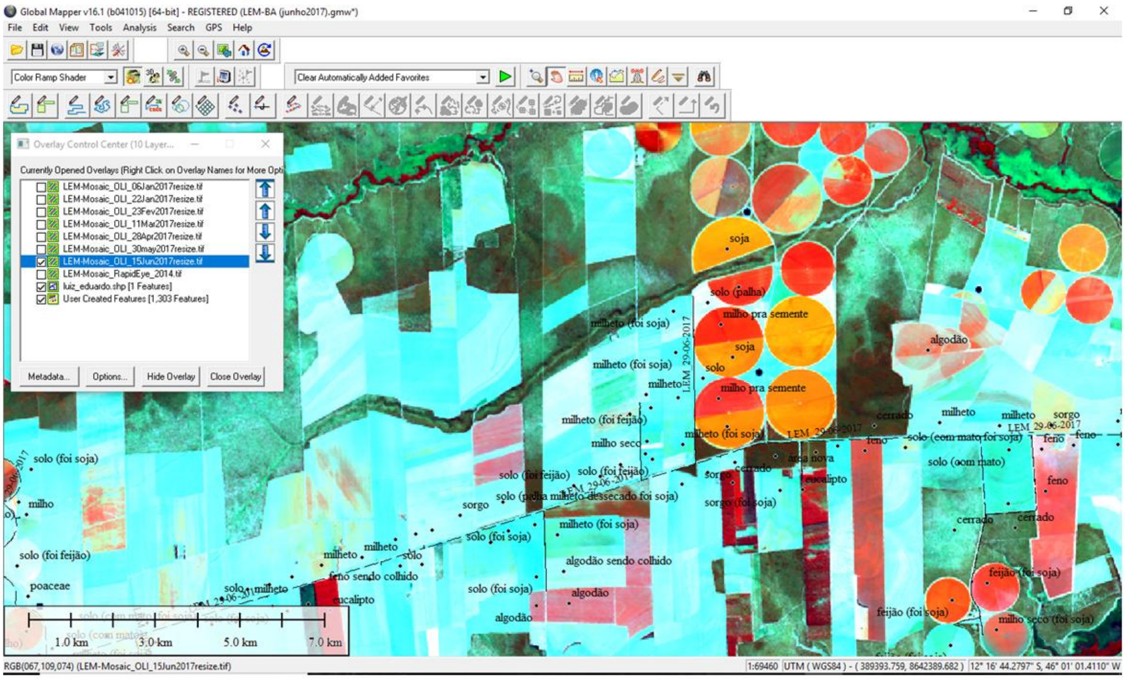


Figure 5. Global Mapper window showing a Landsat-8/OLI image, from 15 June 2017, of an area of LEM municipality, with the field information about land use classes observed.

Optical Remote Sensing Images

A time series of optical images of Sentinel-2/MSI and Landsat-8/OLI have been acquired from June 2017 to June 2018. The main characteristics of OLI and MSI sensors are presented in Table 1.

The images of the OLI sensor correspond to the WRS-2 220/68 and 220/69, and were acquired in surface reflectance (Level 2 product) from the United States Geological Survey Earth Resources Observation and Science Centre (http://espa.cr.usgs.gov/ordering/new). The MSI images correspond to the tiles 23LLG and 23LMG, and were acquired in top-of-atmosphere reflectance (Level-1C product) from the Copernicus Open Access Hub (https://scihub.copernicus.eu/). We converted the Level 1C images into atmospherically corrected surface reflectance using the Sentinel-2 Atmospheric Correction (Sen2Cor) algorithm (European Space Agency – ESA).

Table 1. Main characteristics of OLI/Landsat-8 and MSI/Sentinel-2.

	OLI/Landsat	MSI/Sentinel-2
Bands wavelengths range or central wavelength (nm)	1 – 433-453 2 – 450-515 3 – 525-600 4 – 630-680 5 – 845-885 6 – 1560-1660 7 – 2100-2300 8 – 500-680 9 – 1360-1390	1 – 443” 2 – 490* 3 – 560* 4 – 665* 5 – 705‘ 6 – 740‘ 7 – 783‘ 8 – 842* 8A – 865‘ 9 – 945” 10 – 1375” 11 – 1610‘ 12 – 2190‘
Spatial resolution	30 m (15 m pan)	*10/’20/”60 m
Temporal resolution	16 days	10 days
Radiometric resolution	12 bit	12 bit

SAR Remote Sensing Images

A time series of C-band SAR Sentinel-1A images with VV and VH polarizations were acquired, from June 2017 to June 2018 from the Sentinel Scientific Data Hub in Interferometric Wide Swath (IWS) mode, Ground Range Detected (GRD) Level 1 product and were pre-processed using the Sentinel-1 Toolbox 5.0. The main characteristics of C-SAR/Sentinel-1 are presented in Table 2.

Table 2. Main characteristics of C-SAR/Sentinel-1.

	C-SAR/Sentinel-1
Centre frequency	5.405 GHz
Bandwidth	0-100 MHz
Polarisation	HH+HV, VV+VH,VV, HH
Data quantisation	10 bit

The process pipeline involved the application of orbit file, radiometric calibration, terrain correction and linear transformation to dB. During the application of the orbit file, the orbit state vectors provided in the Sentinel-1A metadata, which are generally not accurate, were refined with precise orbit files available days-to-weeks after the generation of the product. Then, digital pixel values were converted radiometrically, and calibrated backscatter to sigma nought calibration coefficient to get the value to the antenna from a unit area on the ground related to ground range. Next, a Range Doppler terrain correction was employed using a Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) to compensate distortions due to image data that is not directly at the sensor’s Nadir location. The images were georeferenced to the WGS84 system. Finally, both bands, VV and VH, were scaled to dB.

DATABASE

The database is compose by crop field boundaries, monthly reference maps and remote sensing images (optical and SAR).

Crop Field Boundaries

Although we have said in the proposal that the delimitation of the filed boundaries would be done after the first field survey, we have done that only after the second campaign, so we can choose the fields that were visited in both periods. The plan was to visit the same fields, but this was not always possible (difficulty accessing areas because of rain, closed gate, etc). After the second field campaign, we delimited the boundaries of 794 crops fields (Figure 6) selected in situ using high spatial resolution image data (RapidEye) and s time series of Landsat-8/OLI and Sentinel-2/MSI images.

Figure 6. The 794 crop field boundaries (in black) of LEM database over a false-colour composition of the Sentinel-2/MSI image from 20th April 2018.

The original polygons match the boundaries of the crop fields in the high resolution images (5 m of RapidEye). However, to avoid errors on edge pixels we defined the polygons considering a 60 m wide buffer inside the crop field boundaries (Figure 7).

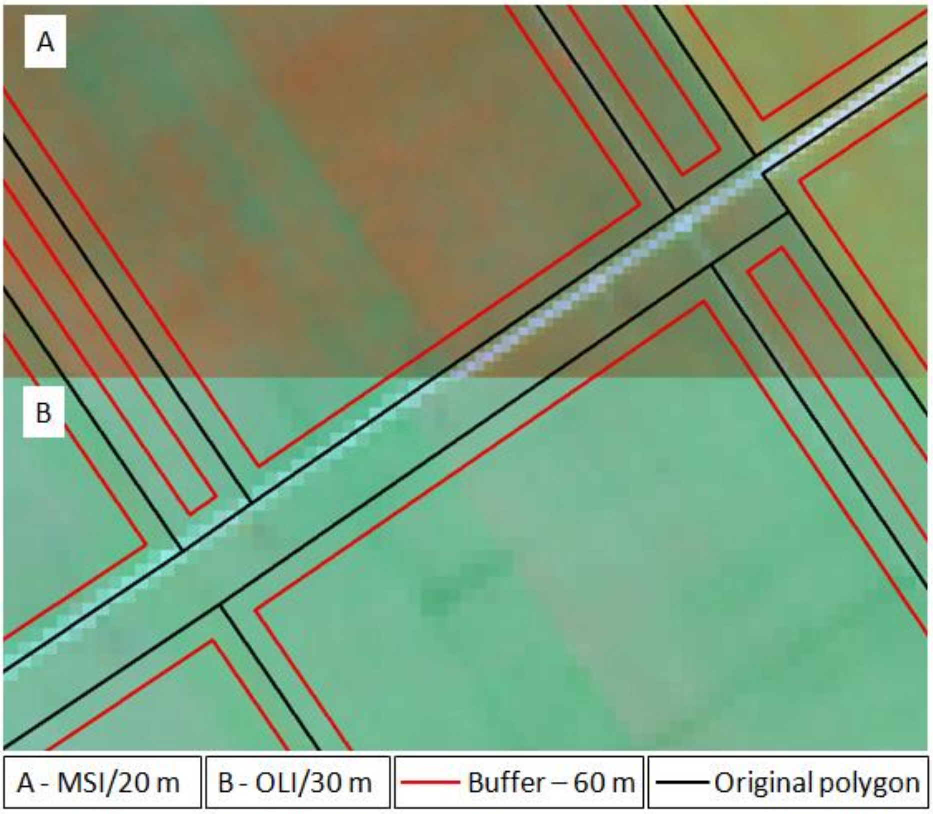


Figure 7. Illustration of crop field boundaries over false-colour compositions of (A) Landsat-8/OLI and (B) Sentinel-2/MSI images. In black are the original polygons and in red the final boundaries considering a buffer zone of 60m.

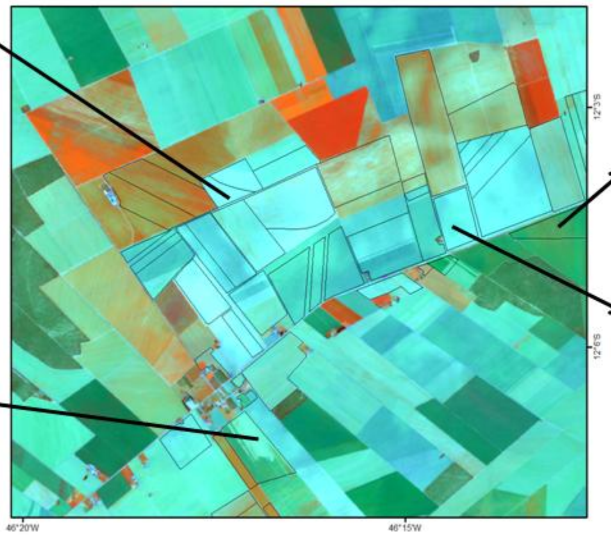
Reference maps

To be precisely, we are not providing the maps per se, but the classification (i.e. land use classes) of each of the 794 crop fields, on a monthly basis, for the period between June 2017 and May 2018. In Figure 7 we give an example of the classification of four crop fields.

Based on information collected in situ, optical remote sensing time series images (Sentinel-2/MSI and LANDSAT-8/OLI) and NDVI profiles (MODIS/TERRA), we created monthly field references maps (for the fields visited) covering one crop year (June 2017 – May 2018). For June 2017 and March 2018 reference maps, for each field we attributed one class (e.g. maize, cotton) based on the field information. The other reference maps were elaborated by an experienced image interpreter. For the visual interpretation of the images, NIR-SWIR-Red false-colour compositions were generated for each date (OLI R5-G6-B4 and MSI R8A-G11-B4). The land use classes mapped in the LEM area were: soybean; maize; cotton; coffee; beans; wheat; sorghum; millet (commercial and non-commercial millet); eucalyptus; pasture; hay; grass (areas cultivated with some type of grass, but it was not possible to identify for what purpose - hay production, to recover area affected with nematodes etc.); crotalaria; maize+crotalaria (maize cultivated in consortium with crotalaria); cerrado; conversion area (an area that was previously cerrado and it has been recently deforested, but it was not possible to identify for what purpose – pasture, crop cultivation etc.); uncultivated soil (bare soil, soil with crop residues from previous harvest, and soil with weeds); other non-commercial crops (NCC); and not identified (planting observed in the images between August and November, in areas irrigated by central pivot, it might be beans, however it is not possible to assure the type of crop).

Attribute	Value
Lat	-12.0673048
Long	-46.2895576
Area Ha	41.43006274
Land use Jun/2017	millet
Land use Jul/2017	millet
Land use Aug/2017	millet
Land use Sep/2017	soil
Land use Oct/2017	soil
Land use Nov/2017	soybean
Land use Dec/2017	soybean
Land use Jan/2018	soybean
Land use Feb/2018	soybean
Land use Mar/2018	soybean
Land use Apr/2018	soil
Land use May/2018	soil

Attribute	Value
Lat	-12.0738694
Long	-46.2073177
Area Ha	234.7582515
Land use Jun/2017	soil
Land use Jul/2017	soil
Land use Aug/2017	soil
Land use Sep/2017	soil
Land use Oct/2017	soil
Land use Nov/2017	soil
Land use Dec/2017	soil
Land use Jan/2018	maize
Land use Feb/2018	maize
Land use Mar/2018	maize
Land use Apr/2018	soil
Land use May/2018	soil



Attribute	Value
Lat	-12.1211671
Long	-46.2825636
Area Ha	136.1738141
Land use Jun/2017	soil
Land use Jul/2017	soil
Land use Aug/2017	soil
Land use Sep/2017	soil
Land use Oct/2017	soil
Land use Nov/2017	soil
Land use Dec/2017	soil
Land use Jan/2018	soybean
Land use Feb/2018	soybean
Land use Mar/2018	soybean
Land use Apr/2018	soil
Land use May/2018	soil

Attribute	Value
Lat	-12.0730925
Long	-46.2386013
Area Ha	100.4358537
Land use Jun/2017	cotton
Land use Jul/2017	cotton
Land use Aug/2017	soil
Land use Sep/2017	soil
Land use Oct/2017	soil
Land use Nov/2017	soil
Land use Dec/2017	soil
Land use Jan/2018	soybean
Land use Feb/2018	soybean
Land use Mar/2018	soybean
Land use Apr/2018	soil
Land use May/2018	soil

Figure 7. Example of crop field boundaries (in black) of LEM database over a false-colour composition of the Sentinel-2/MSI image from 20th April 2018.

Satellite images

The database has 116 Sentinel-2/MSI (58 images for each tile) and 52 Landsat-8/OLI images (26 images for each tile) in reflectance and 30 pre-processed C-band Sentinel-1 images. The dates of image acquisitions are presented in Table 3.

Table 3. Landsat-8/OLI, Sentinel-2/MSI and Sentinel-1 image acquisitions dates over LEM.

Year	**Month**	**Date Landsat-8/OLI**	**Date Sentinel-2/MSI**	**Date Sentinel-1**
2017	June	15	04, 24	12, 24
	July	01, 17	09, 14,	06, 30
	August	02, 18	03, 18, 23	11, 23
	September	03, 19	07, 12, 27	04, 16, 28
	October	05, 21	02, 17, 22	10
	November	06, 20	06, 11, 16, 26	03, 15, 27
	December	08, 24	01, 06, 16, 21, 26	09, 21
2018	January	09, 25	05, 10, 15, 25, 30	02, 14, 26
	February	10, 26	04, 09, 14, 19, 24, 30	07, 19
	March	14, 30	01, 06, 11, 16, 21, 26, 31	03, 15, 27
	April	15	05, 10, 15, 20, 25, 30	08, 20
	May	01, 17	05, 10, 15, 20, 25, 30	02, 14, 26
	June	02, 18	04, 09, 14, 19, 24, 29	07, 19

Access to the database

The LEM database will be freely available at http://www.lvc.ele.puc-rio.br/downloads/Databases/LEM/home.html.

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