The MORINGA Processing Chain: Automatic Object-based Land Cover Classification of Tropical Agrosystems using Multi-Sensor Satellite Imagery

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A timely monitoring of agricultural land changes and cropping practices over space and time is one of the prerequisites identified by the GEOGLAM initiative to improve performances of Early Warning Systems for food security, hence contributing to the establishment effective and well-targeted management plans over agricultural territories. The use of remote sensing data in support of expert knowledge is a common practice in this context because of their objective look and the opportunity they offer to generate and update information on agricultural land dynamics in a timely and comprehensive manner. Three years into ESA Sentinel missions, providing optical and radar imagery at high spatial resolution and low revisit time, new scenarios are emerging in remote sensing for the characterization and monitoring of land surfaces, including the systematic generation of Earth Observation derived datasets such as Land Cover maps [1]. This is especially true for tropical countries, where climatic and environmental conditions have long limited the exploitation of satellite imagery for this task, in contexts where user needs are even more significant.

Indeed, Remote Sensing is continuously proving to be an effective tool for the collection of spatialized information on agricultural practices [2]. Taking advantage of our experience within the GEOGLAM-JECAM network, in the last years we have been developing a specific methodology to improve agricultural Land Cover mapping in challenging tropical agro-systems [3], typically dominated by the presence of smallholder rainfed agriculture. In order to address the specificities of such areas (small field sizes, landscape heterogeneity and fragmentation, strong cloudy conditions especially during the cultural season), our proposed solution leverages the coupling of Very High Spatial Resolution imagery (Spot6/7, Pléiades, ...) and optical decametric satellite image time series such as Sentinel-2 and Landsat 8, and is based on an object-based supervised classification approach. This work led to the development of a fully functional processing chain prototype, named MORINGA, and currently constitutes our major contribution to the Scientific Expertise Centre for Land Cover (CES OSO) of the French THEIA Land Data Services Centre.

More in detail, the proposed methodology has been designed to provide fine-scale agricultural land cover classification using multi-sensor satellite imagery. An overall scheme is depicted in the attached abtract figure. In the typical

MORINGA workflow, the input dataset always includes a single VHR scene acquired at the peak of the growing season, when landscape heterogeneity is at its most. Several HR optical time series covering at least the annual cropping season are also taken into account, as well as digital elevation and slopes. Reference data for supervised classification is generally constituted by integrating in-situ data collection (mainly on cropland) and photo-interpretation. The general workflow can be easily extended to enable the use of other types of imagery (e.g. radar imagery).

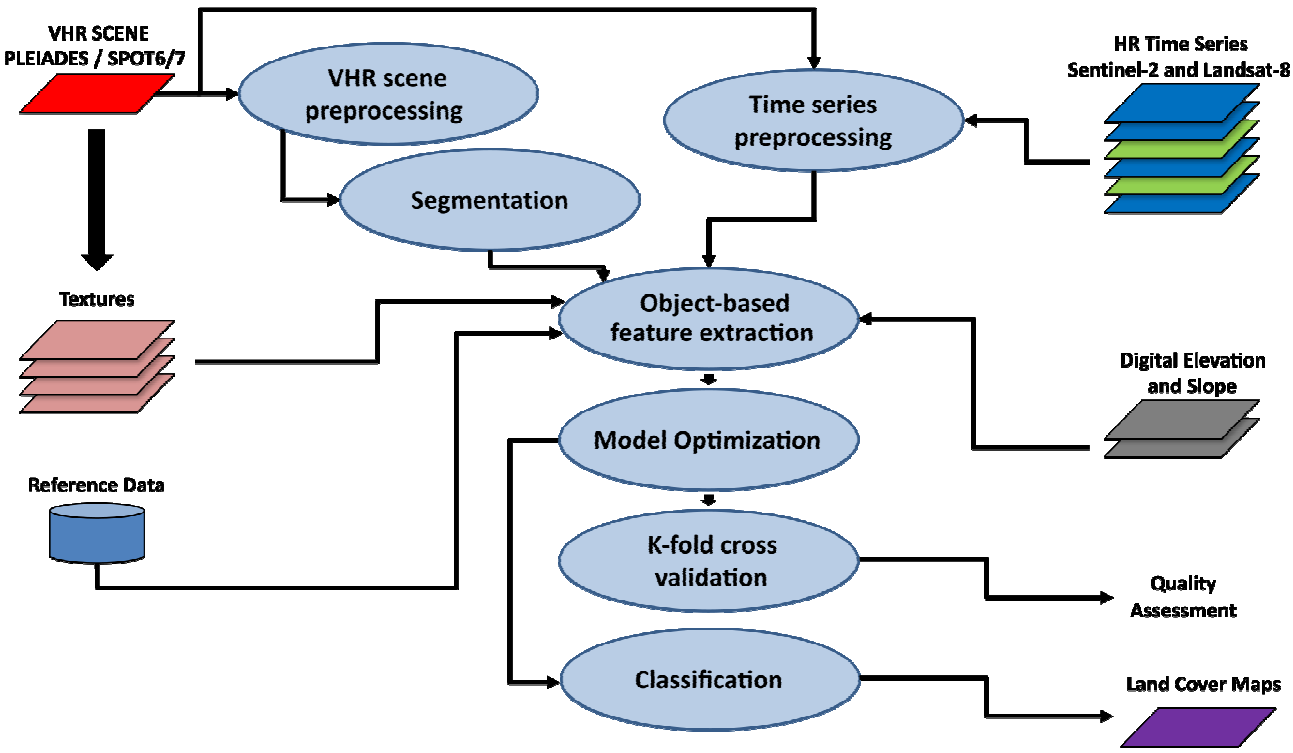
The proposed general classification scheme consists of several main steps: (1) VHR segmentation to resort to a suitable fine-resolution object layer at plot or sub-plot scale; (2) the extraction of a large set of radiometric indices (vegetation, soil, water) from HR and VHR data plus VHR texture indices, (3) object-based featuring of both reference areas (for training) and segmented objects; (4) Random Forest (RF) model fitting and classification of the featured object layer. Several implementation details have been also managed to cope with cloudy acquisitions, the small field and landscape fragmentation constraints, as well as the intra-class variability due to the heterogeneity of cropping practices and plot conditions. This includes (1) a suitable multi-temporal gap-filling per time series as performed in [1], (2) the precise co-registration of the multi-sensor dataset and an optimized fine-scale object statistics computation, and (3) a specific training sample generation strategy based on the intersection between the object layer and polygons from the provided reference dataset.

In order to assess the performances of the methodology on several sufficiently contrasted tropical agro-systems, a specific protocol for testing has been conceived and agreed among several JECAM site contributors in the form of a proper cross-site experiment using, to the extent possible, corresponding input datasets to eventually point out strenghts and weaknesses related to site specificities and acquisition conditions. The target Land Cover nomenclature (hierarchical, with four nested level including a Crop vs. Non-Crop level) has been agreed-upon and harmonized at most among the various tropical JECAM sites. Tested sites include landscapes dominated by smallholder farming (Burkina Faso - Koumbia, Madagascar - Antsirabe) as well as more intensive and heterogeneous agricultural territories (Brazil - Sao Paulo, Reunion Island). These experiments proved, on one side, the general applicability and effectiveness of the methodology even at larger scales with respect to JECAM sites, but also allowed to consistently identify room for improvements.

[1] J. Inglada, A. Vincent, M. Arias, B. Tardy, D. Morin, and I. Rodes. Operational High Resolution Land Cover Map Production at the Country Scale Using Satellite Image Time Series. Remote Sensing, 9(1):95, 2017.

[2] MDPI (Ed.). Remote Sensing in Agriculture and Vegetation: High Resolution Image Time Series for Novel Agricultural Applications [Special Issue]. Remote Sensing, 2018. https://www.mdpi.com/journal/remotesensing/special_issues/highresolution_timeseries_agr

[3] V. Lebourgeois, S. Dupuy, E. Vintrou, M. Ameline, S. Butler, and A. Bégué. A Combined Random Forest and OBIA Classification Scheme for Mapping Smallholder Agriculture at Different Nomenclature Levels Using Multisource Data (Simulated Sentinel-2 Time Series, VHRS and DEM). Remote Sensing, 9(3):259, 2017.


VHR SCENE
PLEIADES / SPOT6/7
VHR scene preprocessing
Segmentation
Time series preprocessing
HR Time Series
Sentinel-2 and Landsat-8
Textures
Object-based feature extraction
Digital Elevation and Slope
Model Optimization
Reference Data
K-fold cross validation
Quality Assessment
Classification
Land Cover Maps