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IMPACT TOOLBOX



Portable GIS Toolbox for Image Processing and Land Cover Mapping



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Abstract

Did you ever try to produce a reliable land cover map from Earth Observation data? How many steps are involved and how many different tools do you need? Did you succeed in a reasonable amount of time?

IMPACT toolbox offers a combination of elements of remote sensing, photo interpretation and processing technologies in a portable and stand-alone GIS environment, allowing non ITC users to easily accomplish all necessary pre-processing steps while giving a fast and user-friendly environment for visual editing and map validation.

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This document version 1.0 dated 10/2015 is referring to the **IMPACT toolbox 1.0 beta**.

Please check the last version on <http://forobs.jrc.ec.europa.eu/products/software>

1. Overview

Earth Observation imagery has been identified as a key source of information for mapping and monitoring land cover changes or degradation over time. However, data extraction, layerstacking, radiometric calibration, normalization, mosaicking, automatic classification and segmentation are only some of the pre-processing steps that a user has to undertake to obtain a basic land cover map; at which point, post-processing tasks such as class editing, land cover validation and statistics extraction, are required, with experts using available GIS tools.

The IMPACT (Image Processing) toolbox has been designed to offer a combination of functions for remote sensing, photo interpretation and processing technologies in a portable and stand-alone GIS environment, allowing non specialist users to easily accomplish all necessary pre-processing steps while giving a fast and user-friendly environment for visual editing and map validation. The rationale for this development has been the strong link between the JRC projects to monitoring forests in the tropical belt (TREES; FOROBS; ReCaREDD) and partner forest national services, where capacities to procure, maintain and exploit image processing and GIS packages remains weak.

Based on open sources technologies, IMPACT makes use of GeoExt, OpenLayers and Mapserver for the graphical user interface and raster/vector rendering; EO data processing is carried out by GDAL and Python. No installation or virtual machines are required and therefore the package can be copied onto a portable device for easy execution and data sharing. Internet connection is not essential although might offer access to additional information such as very high resolution WMS layers from Google or other sources.

Raw Landsat and RapidEye satellite imagery can be ingested and converted to top of atmosphere reflectance and then pre-classified using the built-in pixel based classifier; ultimately, single-date or multi-date image segmentation is performed throughout Baatz segmenter [1] from Inpe's TerraLib Operators [2]; generated objects (polygons) are automatically labelled according to class majority derived from the pixel based classification. This last step is essential to offer a preliminary land cover maps (for each input date/epoch), reducing the photo interpreter's verification workload. Additional image processing features, such as clipping, simple indices generation and spectral unmixing are also available.

IMPACT contains modules for visual identification of forest degradation, ground truth collection and spatial statistics all characterized by easy to learn and user friendly interfaces.

2. Introduction

3. Structure

The IMPACT tool is a portable browser-based application for image processing, visualization and mapping running under Microsoft Windows (Xp,Vista,Win7,Win8,Win10). Once downloaded from our website [3] it is sufficient to extract the entire content on your disk (avoiding system folders).

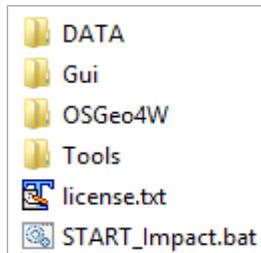


Figure 1 Content of the IMPACT Toolbox

In order to keep a separation between user data, processing tools and graphical user interface, the following structure has been implemented Figure 1:

- DATA: contains user's vector and raster data and has been divided into subfolders reflecting the different processing steps as indicated on Figure 2;
- Gui: contains the graphical user interface, dependencies and map editing functions Figure 3;
- OSGeo4W: contains the engine and all dependencies such as the OSGeo4W distribution with Apache, Python, GDAL, Openlayers, Mapserver, GeoExt, Javascript and HTML.

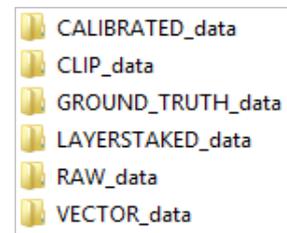


Figure 2 Content of DATA folder

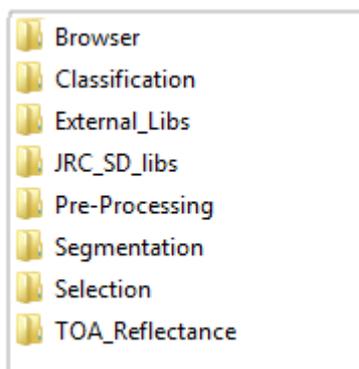


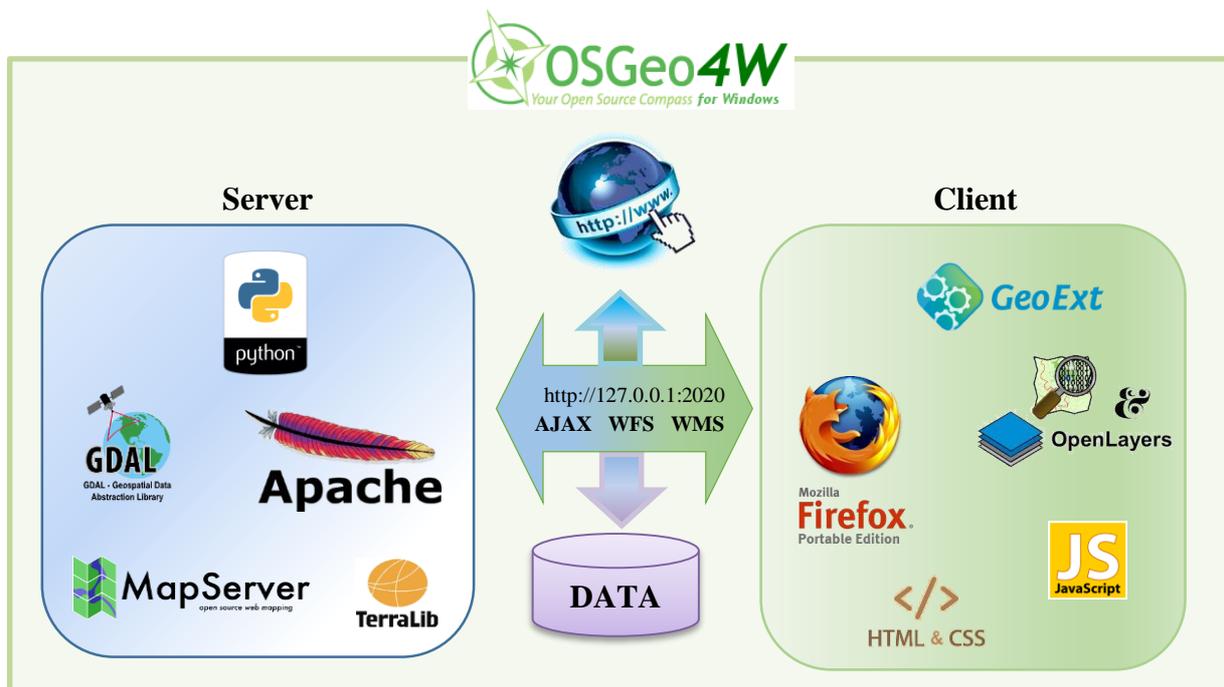
Figure 3 Content of Tools directory

- Tools: contains a dedicated folder for each processing module or external library/package used within the tool such as a portable version of Firefox under "Browser", python scripts for image classification, segmentation, clipping etc.

START_Impact.bat: windows executable files to start the IMPACT tool; on start a new shell with a minimum set of libraries, path and dependencies is loaded ensuring the correct execution of internal utilities. Lastly, an instance of Apache is created listening on port 2020 (be sure is not used by other applications) and the tool is displayed using the provided Firefox portable browser via <http://127.0.0.1:2020>. By closing the shell, Apache is automatically shut down.

This simple file system-based structure gives to the user, the full control of his data guaranteeing, at the same time, the possibility of loading them into external software for further processing/visualization. There are periodical scans of DATA folder (default set every 60 seconds) ensuring an up-to date visualization of available products.

Figure 4 shows the software and programming languages used both on server and client side under the OSGeo4W container. It is worth noting however, that in the windows portable version (1.0b) of the IMPACT toolbox, the server and client are referring to the same pc; although not indispensable, internet connection offers access to high resolution Google Maps background layers.

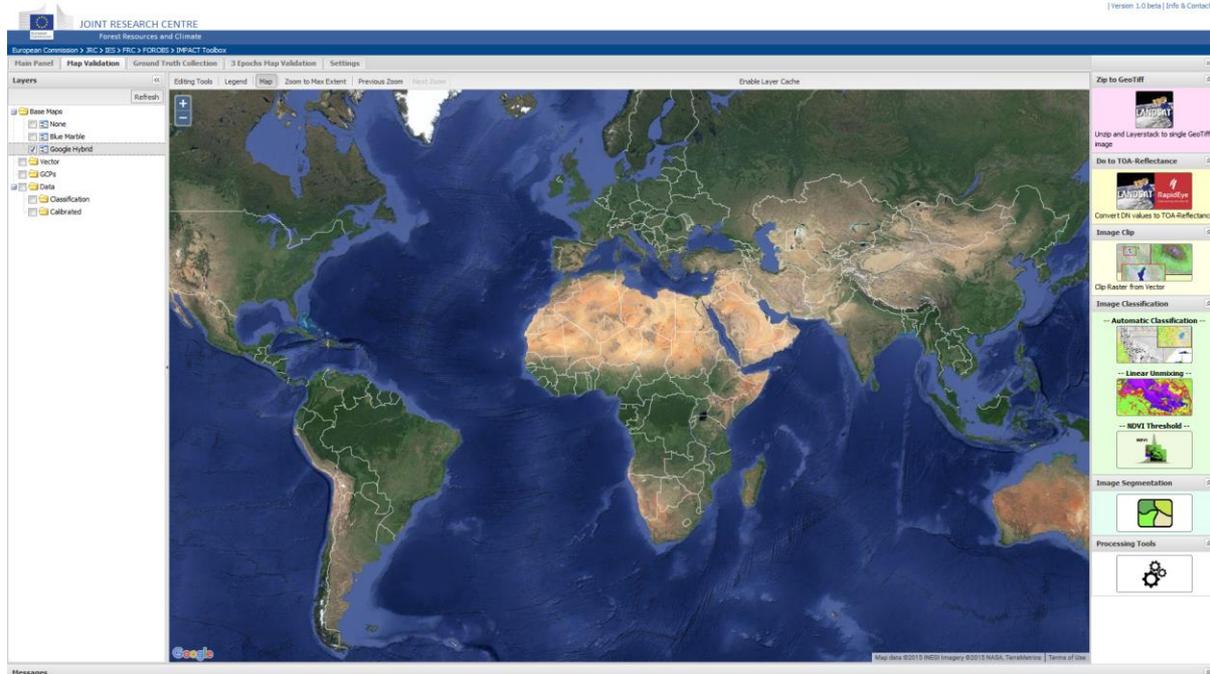


Software	License	www
Apache	Apache License, Version 2.0	http://httpd.apache.org/
Python 2.7	GPL compatible	https://www.python.org/
Mapserver	MIT-style license (X11 License) (http://www.gnu.org/licenses/license-list.html#X11License)	http://www.mapserver.org/
Openlayers 2.13.1	Modified BSD (http://www.gnu.org/licenses/license-list.html#ModifiedBSD)	http://openlayers.org/
ExtJs 4.2.1	GPLv3+ (https://directory.fsf.org/wiki/Ext_JS#tab=Details)	https://www.sencha.com/
GeoExt 2.0.1	BSD-license (http://www.gnu.org/licenses/license-list.html#OriginalBSD)	https://geoext.github.io/geoext2/
Proj4js	-- (https://github.com/proj4js/proj4js/blob/master/LICENSE.md)	http://proj4js.org/
Numpy	BSD 3Clause (https://directory.fsf.org/wiki/NumPy#tab=Details)	http://www.numpy.org/
Pymorph	BSD License Terms	http://packages.python.org/pymorph/
Terra Lib	LGPL-2.1 (http://opensource.org/licenses/LGPL-2.1)	http://www.terralib.org/

Figure 4 Software and programming languages used at server and client side under the OSGeo4W umbrella. Distribution Licenses are reported as well.

4. Main Panel

The Main Panel is the IMPACT’s desktop from where is possible to monitor available raster and vector layers (left panel), visualize them on the map (central panel) and execute processing modules available on the right panel.



The 60 seconds auto refresh (can be adjusted within the “Settings” panel, see dedicated chapter) guarantees a prompt visualization of user datasets and processing outputs; available layers are grouped into the following categories Figure 5:

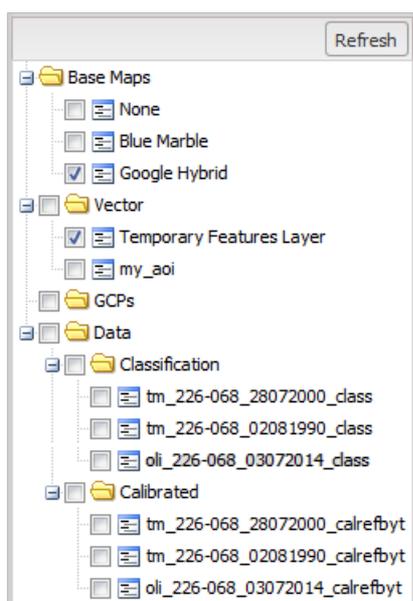


Figure 5 Tree Panel showing layers availability and structure

Base Map: contains three background map options; blank, Blue Marble map and Google Hybrid map, which is the default and automatically selected if internet connection is available.

Vector: any vector layers in *DATA/VECTOR_data/* and subfolders will be visible under this group; it should contain reference data like administrative boundaries, area of interests etc.

GCP: empty for this panel, will contain vector data used in the Ground Truth Collection panel;

Data: contains user’s raster data divided into *Classification* (result of the automatic classification/unmix/indexes threshold processing modules), *Calibrated* with any satellite data or user’s GeoTiff products and *Other* containing file

data without default Impact's suffixes. These data are found in the directory structure under /DATA/CALIBRATED_data/.

The 'context menu' (right click) available above the map panel offers quick access to navigation option such as zoom to max extent, jump to previous/next zoom and feature drawing; the latter, enabled by pressing "Draw Polygon", stores user's features in a temporary layer named "Temporary Features Layer" that can be saved for future usage into a shapefile by right-clicking on the layer itself; default output location: DATA/VECTOR_data/User_Features/); shapefile name should not contain spaces or any non-alphanumeric characters; ".shp" extension is appended by default. "Delete Features" removes highlighted (on mouse over) features with a mouse click.

Is worth noting that a shapefile created in the tool is visible under "Vector" group and can be selected in the raster data clipping;

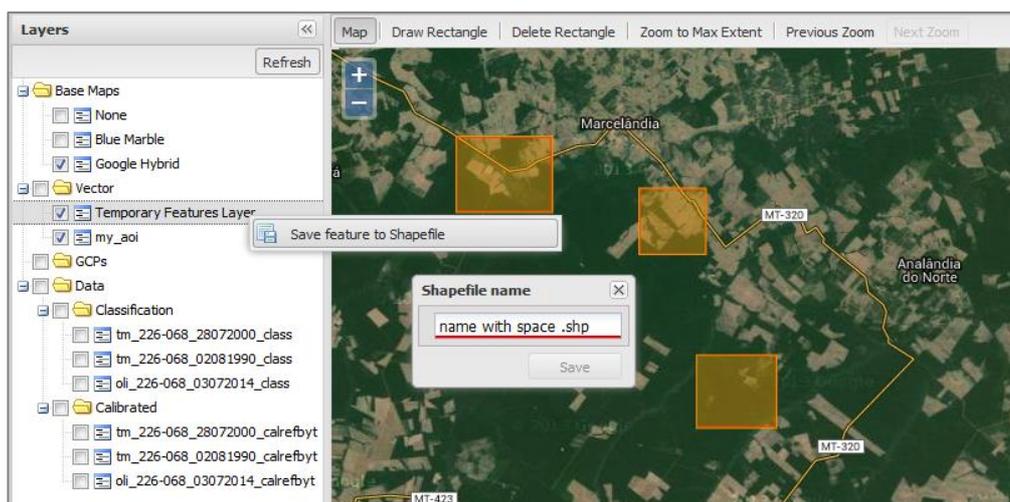


Figure 6 Action Menu with navigation a drawing options. 'Temporary Features Layers' could be saved as shapefile; if name contains non-alphanumeric characters, a red line will appear.

5. Processing Modules

Zip to GeoTiff

	<p>Purpose: Unzipping, Layer stack and Archiving Landsat data</p> <p>Input directory: <i>DATA/RAW_data</i></p> <p>Processing directory: <i>DATA/RAW_data/tmp</i></p> <p>Output directory: <i>DATA/LAYERSTAKED_data</i></p> <p>Output zip backup directory: <i>DATA/RAW_data/Processed</i> (could be deleted if not necessary)</p>
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By executing this module, Landsat TM/ETM+/OLI zipped (.tar.gz or .tar.bz) archives placed in the DATA/RAW_data directory will be processed and converted into a single Geo Tiff file as follows:

Only (R,G,B,NIR,SWIR1,SWIR2)[#] bands are extracted, renamed and layer stacked; thermal and panchromatic bands are zipped and stored within the same folder. The output directory contains the resulting files with the following naming convention:

Multispectral GeoTiff file: [sensor]_[path]_[row]_[ddmmyyyy].tif

Multispectral quick look : [sensor]_[path]_[row]_[ddmmyyyy].gif

Metadata file: [sensor]_[path]_[row]_[ddmmyyyy].met

Zipped files for archive:

[sensor]_[path]_[row]_[ddmmyyyy]_[band{1*,61,62,8,9,10,11,BQA}].tif.gz

Projection and spatial resolution: as derived from the source data.

[#] Landsat 4/5/7 : bands 1,2,3,4,5,7 Landsat 8 : bands 2,3,4,5,6,7

* Landsat 8 pre-blue band 1

DN to TOA Reflectance

By converting the raw digital number (DN) values to top-of-atmosphere (TOA) reflectance data from different sensors/platforms are calibrated to a common radiometric scale, minimizing spectral differences caused by acquisition time, sun elevation, and sun–earth distance.



Purpose: Unzipping, Layer stack and Archiving Landsat data

Input directory: *DATA/LAYERSTAKED_data*

Output directory: *DATA/CALIBRATED_data*

Output **Landsat** suffix : *_calrefbyt.tif*

Output **RapidEye** suffix: *_calrefx10k.tif*

Calibrations coefficients

Landsat 8bit (or 12bit for Oli) DN to TOA correction formula is as follows:

$$\rho_{\lambda} = \pi * L_{\lambda} * d^2 / ESUN_{\lambda} * \cos \theta_{SZ}$$

Where

<p>ρ_{λ} = TOA reflectance for band λ</p> <p>L_{λ} = Radiance for band $\lambda = M_{\lambda} * Q_{cal} + A_{\lambda}$</p> <p>$M_{\lambda}$ = Band-specific multiplicative rescaling factor</p> <p>A_{λ} = Band-specific additive rescaling factor</p>	<p>Q_{cal} = Quantized and calibrated standard product pixel values</p> <p>$d = (1 - 0.01672 * \cos(0.01745 * (0.9856 * (\text{Julian Day Image} - 4))))$</p> <p>$\theta_{SZ}$ = Local solar zenith angle</p> <p>Tm ESUN = [1957.0, 1826.0, 1554.0, 1036.0, 215.0, 80.67]</p> <p>Etm ESUN = [1969.0, 1840.0, 1551.0, 1044.0, 225.70, 82.07]</p> <p>Oli ESUN = [2067.0, 1893.0, 1603.0, 972.6, 245.0, 79.72]</p>
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Multiplicative and additive rescaling factors are extracted from the metadata file. In order to reduce the size of the calibrated data, 32bit Float reflectance values [0-1] are then rescaled to 8bit Byte [0-255] with a linear multiplication factor of 255.

- *RapidEye* data are usually provided as 5 band layer stacked Geo-Tiff files, therefore the module (*Zip to GeoTiff*) is not necessary for this sensor. Users have to put the entire *RapidEye* folder into *DATA/LAYERSTAKED_data*; to convert 16bit Digital Number (DN) to radiance it is necessary to multiply by the radiometric scale factor, as follows:

$$L_{\lambda} = DN_{\lambda} * \text{ScaleFactor}(\lambda)$$

where $\text{ScaleFactor}(\lambda) = 0.01$

The resulting value is the at sensor radiance of that pixel in watts per steradian per square meter ($W/m^2 \text{ sr } \mu\text{m}$). The TOA correction formula for *RapidEye* data is as follows:

$$\rho_{\lambda} = \pi * L_{\lambda} * d^2 / ESUN_{\lambda} * \cos \theta_{SZ}$$

Where

<p>ρ_{λ} = TOA reflectance for band λ</p> <p>L_{λ} = Radiance for band λ</p> <p>θ_{SZ} = Local solar zenith angle</p>	<p>$d = (1 - 0.01672 * \cos(0.01745 * (0.9856 * (\text{Julian Day Image} - 4))))$</p> <p>ESUN = [1997.8, 1863.5, 1560.4, 1395.0, 1124.4]</p>
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32bit Float reflectance values [0-1] are then rescaled to 16bit Unsigned Integer [0-10000] with a linear multiplication factor of 10000. Formulas and parameter are derived from [4].

NOTE: Only once *Image Calibration* has been performed is it possible to visualize available images on the map panel of the IMPACT tool.

Example

DATA/CALIBRATED_data contains a subset of a Landsat 8 imagery over Brazil to be used as training dataset (oli_226-068_03072014 original ID = "LC82260682014184LGN00")

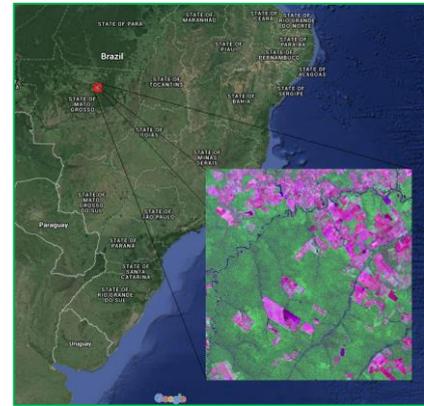
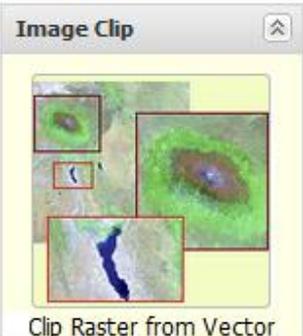


Image Clip

Image clipping can represent a crucial step to reduce processing time and data volume. The user has the possibility to clip any GeoTiff file from the input *CALIBRATED_data* directory using predefined vector layer(s) containing one or more features each. Vector projection will be on the fly converted to match the raster one. Clipping can be done only after data calibration.

	<p>Purpose: clip GeoTiff</p> <p>Input directory for vector data: <i>DATA/VECTOR_data/</i></p> <p>Input vector data: user selection</p> <p>Output directory: <i>DATA/CALIBRATED_data/</i></p> <p>Optional output: <i>DATA/CLIP_data/</i></p> <p>Output prefix: Clip_[vector name or feature ID]_[img_name].tif</p>
-------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

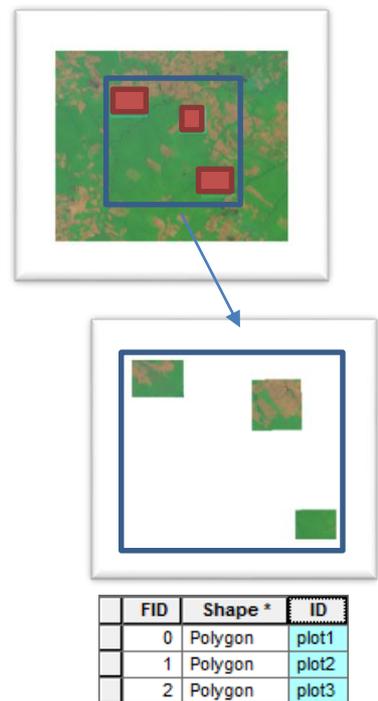
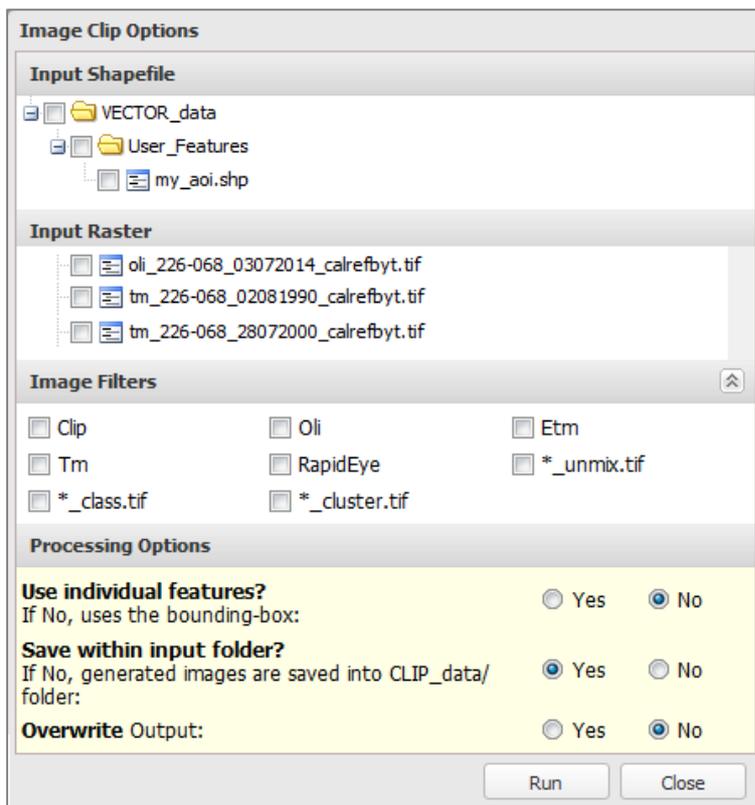


Figure 7 Image Clip options: input shapefile selection on top, available raster in the middle and processing options at the bottom of the interface.

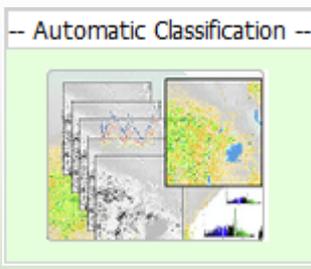
EXAMPLE

VECTOR_data directory contains a test vector file (*my_aoi.shp*) having 3 features (red shapes) with ID="plot1-3". The above settings will process the available image *oli_195-056_08042015.tif* from *DATA/CALIBRATED_data* saving clip results (bounding box only, blue line) into its own subfolder as *Clip_my_aoi_oli_226-068_03072014.tif*.

In case "Use individual features" is flagged as 'Yes', the 'ID' will be used as prefix for the 3 out filenames e.g. *Clip_plot{1-3}_oli_226-068_03072014.tif*

If 'ID' filed is not available, it will be generated on the fly using a sequential number.

Image Classification



Purpose: automatic pixel based classification

Input directory: *DATA/CALIBRATED _data/*

Output directory: *DATA/CALIBRATED _data/*

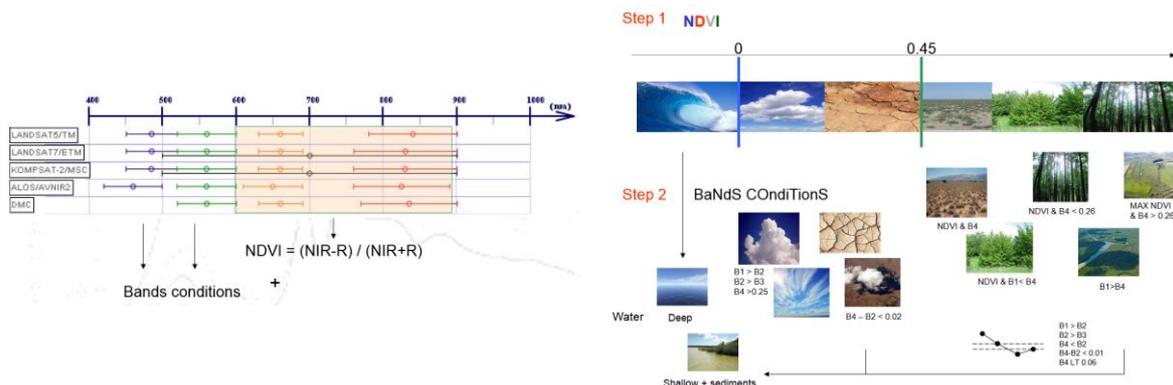
Output suffix: *_class.tif*, 1 band with palette color table

Pixel values and colors: as on Table 1

The aim of this tool is to offer a fully automatic pixel-based classification product to be used in further processing steps like segmentation and land cover mapping. The Single Date Classification (SDC) algorithm as described and implemented in [5], is based on pre-defined knowledge-based “fuzzy” rules aiming to convert the TOA reflectance input bands into discrete thematic classes (Table 1)

In brief, the classification chain is based on 2 steps:

- 1) NDVI partition into 3 broad categories as follow : $[-1,0]$ = water; $]0,0.45]$ = soil; $[0.45,1]$ = vegetation;
- 2) ad-hoc bands conditions (e.g. $NIR > RED > 0.5$) to split each category in sub-classes and eventually, promote pixels to other categories as it might happen e.g. for turbid water when having NDVI values > 0 (falling into soil range) .



The current implementation performs best when using B,G,R,NIR,SWIR1-2 bands (Landsat TM/ETM+/OLI, Sentinel 2 and landsat-like imagery) however sensor like RapidEye, DMC, ALOS/AVNIR2, SPOT4/5 and Komsat, are fully supported although yielding reduced accuracy in water/dark soil discrimination due to the missing SWIR bands as indicated on Figure 8 and Figure 9.

Similar SDC algorithm robustness and scalability among the aforementioned sensor have been confirmed by [6] and [7]; however, SDC's accuracy is not easily quantifiable since the algorithm delivers broad thematic categories derived from spectral properties observed during a precise time in the vegetation cycle; is therefore possible to classify leaf-off deciduous forest as grass or soil. [5] better explains how to combine and analyze SDCs time series in order to produce more accurate land cover maps.

It is worth noting the SDC is capable of retrieving sun azimuth from the correspondent metadata in order to apply post classification 3D models and morphological filters (opening and closing) for better clouds/shadow masking and "salt and pepper" reduction. As on Table 1, cloudy pixels (ID 1 and 2) and potential shadow pixels (ID = 10,35,40,41,42) are initially treated using the morphological 'closing' filter of 500m; afterward, cloudy pixels are projected in the sun azimuth and possible overlaps are automatically recoded as Shadow/Low Illumination (ID=42).

Please note that on off-nadir acquisition sensor like RapidEye, the relative position of clouds and their shadows don't match the provided sun azimuth angle. The apparent cloud shift distance, in relation to its true position, depends on the off-nadir angle and on the cloud height. Whereas the satellite off-nadir angle is well known, the height of imaged clouds is unknown [8]. For this later reason the clouds and shadow masking as provided by SDC might not be optimal for RapidEye imagery. Ideally the user could replace the 'real' sun azimuth with the apparent one within the .xml metadata.

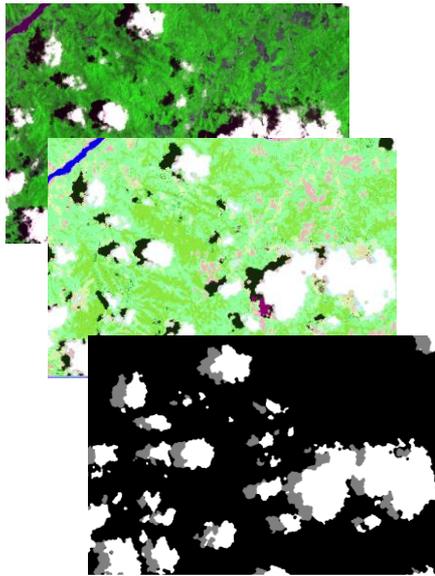


Figure 8 Reference Landsat Image on the back; classified layer with clouds (white) and shadows (black and violet) in the middle; buffered cloud and shadow mask on top.

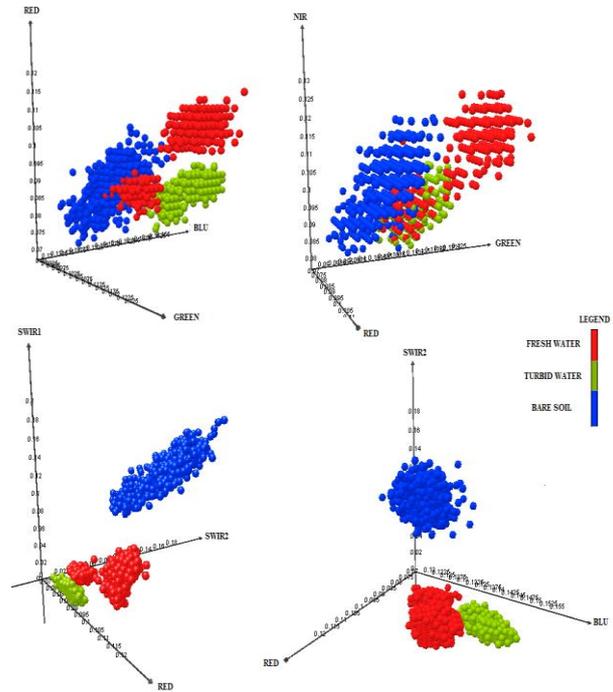


Figure 9 Top line 3D plots show bad discrimination between bare soil and water using B,G,R,NIR bands; better discrimination is possible using SWIR12 bands as on bottom line;

A pop-up interface will easy data selection (single or multiple files) and settings such as filters, overwrite or evergreen forest normalization. This latter option is performing the so called “dark object subtraction”, an image normalization process towards predefined median forest valued improving classification accuracy. See dedicated chapter for more details.

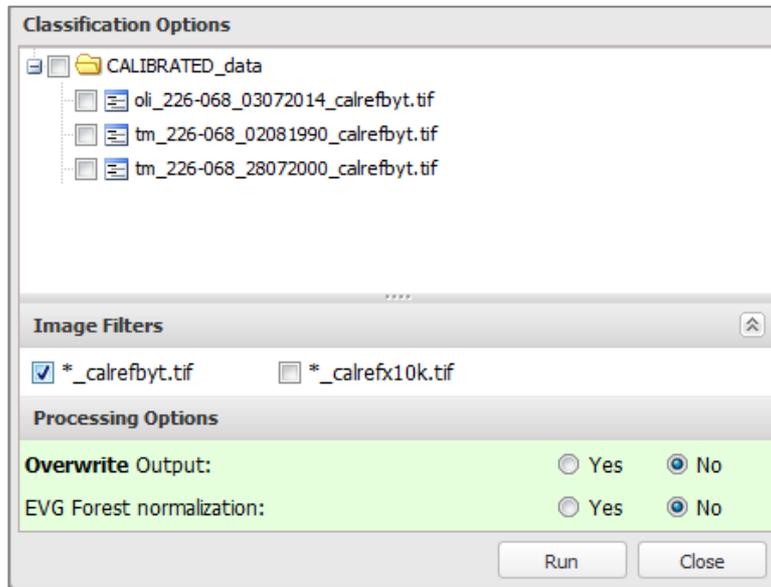


Figure 10 Classification interface

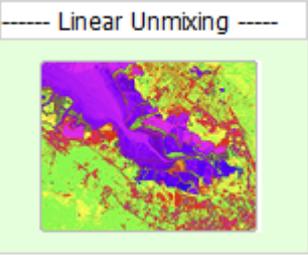
SDC output legend is showed on Table 1. SDC is not aiming to offer detailed and reliable land cover map since is relying on spectral properties observed during a precise time in the vegetation cycle; however, during the leaf-on acquisitions is more likely to have a good match between the proposed class description and actual land cover type.

ID	Class description	Color	ID	Class description	Color
0	No data	Black	14	Shrub / open forest	Light Green
1	Cloud - core	White	16	Shrub / open forest	Yellow-Green
2	Cloud - edge	Light Blue	21	Shrub / Grass	Yellow
3	Snow - ice	Cyan	22	Grass	Light Green
5/6/7	Deep Water	Blue	30/31	Soil	Olive Green
8	Turbid Water	Light Blue	34	Soil	Pink
9	Bright veg. Humid Grass/Shrub	Bright Green	35	Dark soil	Purple
10	Dark dense veg	Dark Green	40	Shadow on vegetation	Dark Green
11/12	Dark dense veg	Green	41	Shadow on bare soil	Magenta
13	Shrub dense	Medium Green	42	Shadow / Low illumination	Grey

Table 1 Thematic classes ID, color and the associated description as observed at the date of the image acquisition.

NOTE: in case of processing failure (low memory), setting a higher value of the “Memory_Buffer” variable within the /Tools/JRC_SD_libs/PiNo_classifier.py file could solve the issue.

Linear Spectral Unmixing



Purpose: Linear Spectral Unmixing

Input directory: *DATA/CALIBRATED _data/*

Output directory: *DATA/CALIBRATED _data/*

Output suffix: *_unmix.tif*, rgb image with palette color table

Pixel values: rescaled [0-255] percentage of each component (corresponding to R: Soil, G: Vegetation, B: Water)

The Linear Spectral Unmixing (LSU) is a tool to decompose the pixels into the abundance of its components, reducing the image dimensionality while still preserving most information required for post processing and mapping activity. The proposed model, inspired by [9], [10], makes use of predefined endmembers for estimating soil, vegetation and water fraction images. Prior to the LSU, is possible to perform the “Evergreen Forest Normalization” to minimize spectral difference across images acquired at different time and space. The adopted endmembers have the following values expressed in TOA-Reflectance [0-1] for bands [B,G,R,NIR,SWIR1,SWIR2]:

Soil = [0.14, 0.16, 0.22, 0.39, 0.45, 0.27]

Vegetation = [0.086,0.062,0.043,0.247,0.109,0.039]

Water = [0.07, 0.039, 0.023, 0.031, 0.011, 0.007]

When processing RapidEye data, only B,G,R,NIR bands are used and further adjustment could be done to better fit sensor properties and using Red-Edge band as well.

The following LSU formula has been implemented in python (*RUN_image_unmixing.py*):

$$\text{Unmix} = I \times (E^+)^T$$

where:

Unmix = 3x1 matrix of endmembers fractions computed using the Unconstrained LSU

I = input image (6 bands) reshaped into a 2D array concatenating a) pixels from each band into a 1D vector and b) concatenating all vector bands

E = 3x1 array of endmembers [Soil, Vegetation, Water];

$(E^+)^T$ = transpose of the pseudo inverse of E

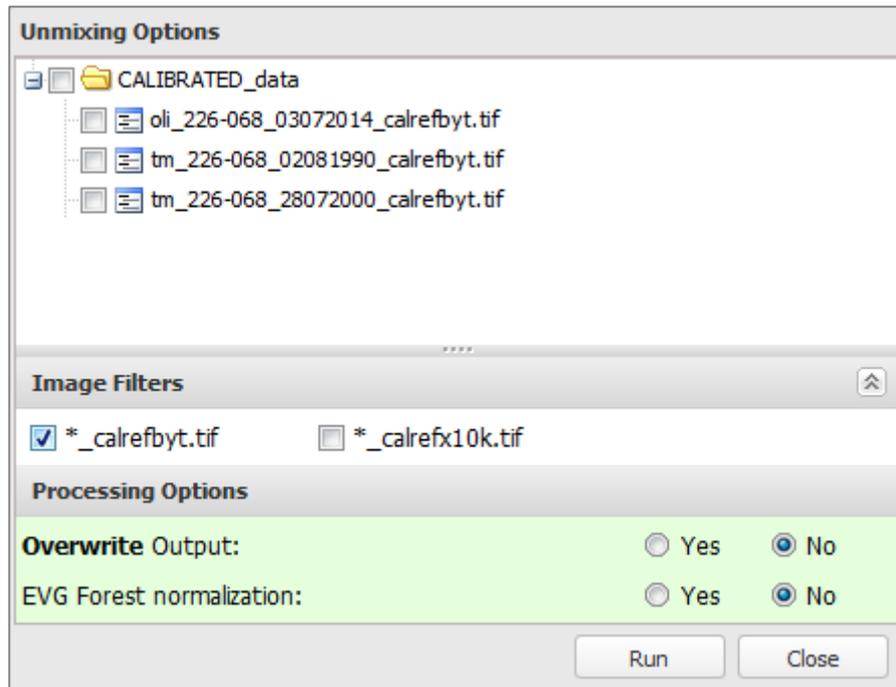


Figure 11 Unmixing interface for data and parameters selection

Input directory for LSU data: *DATA/CALIBRATED_data/*

Output directory: *DATA/CALIBRATED_data/*

Classification output suffix:

- *_unmix.tif* , RGB format corresponding to Soil, Veget and Water

In order to limit the output size while preserving the core of the unmixed distribution (between 0 and 1) continuous floating point values have been rescaled and casted to Byte [0-255] using the following criteria:

$$]-inf, 0] \rightarrow [0,100] \quad]0,1] \rightarrow]100,200] \quad]1,+inf] \rightarrow]200,255]$$

As proposed [11] the use of spectral unmixed data in the segmentation phase might generate better result than using calibrated data.

NOTE: in case of processing failure (low memory), setting a higher value of the “Memory_Buffer” variable within the */Tools/JRC_SD_libs/RUN_image_unmixing.py* file could solve the issue.

ND(V,W,S)I Threshold



Purpose: image clustering based on normalized index

Input directory: *DATA/CALIBRATED _data/*

Output directory: *DATA/CALIBRATED _data/*

Output suffix: *_cluster.tif*, 1band image with palette color table

Pixel values: cluster value [0-50]

The thresholding tool gives the possibility of dividing input images into a predefined number of clusters [0-50] by making use of an index created on the fly by selecting different band combinations. Although the formula

$$Index = \frac{(Band1 - Band2)}{(Band1 + Band 2)}$$

remains the same, the generated index can assume a variety of meaning by selecting a different band combination as reported on Table 2:

INDEX	Band 1	Band 2	Suitable for:
NDVI Normalized Difference Vegetation Index	NIR	RED	dense vegetation canopy will tend to positive values (say 0.3 to 0.8) while water, clouds and snow fields will be characterized by negative values of this index
(M)NDWI Modified Normalized Difference Water Index	GREEN	SWIR1	positive data values are typically open water areas; while the negative values are typically non-water features
NDS_{now}I Normalized Difference Snow Index	GREEN	NIR	dark tones represent land without snow; values > 0.4 typically indicate the presence of snow. Allows the effective discrimination between snow cover and clouds;
NDS_{oil}I / NDBI Normalized Difference Soil Index / Normalized Difference Built-Up Index	SWIR1	NIR	highlights urban areas and bare soils
NDMI Normalized Difference Moisture Index	NIR	SWIR1	evaluates the different content of humidity from the landscape elements, especially for soils, rocks and vegetation (excellent indicator for dryness)
NDBR Normalized Difference Burning Ratio	NIR	SWIR2	highlights areas that have burned and to index the severity of a burn
GREEN-RED index	GREEN	RED	highlights new opening in dense forest
NOTE: literature might report the above mentioned indexes created using a different bands combination			

Table 2: Non exhaustive list of possible indexes to be used for image thresholding and clustering.

The partition (clustering) of the index is done dividing its histogram into a number of equal-width bins in the given range (number of clusters defined by the user); calculated bins are then used to determine the cluster Id [0-50] and associated Color ramp [blue-red-green].

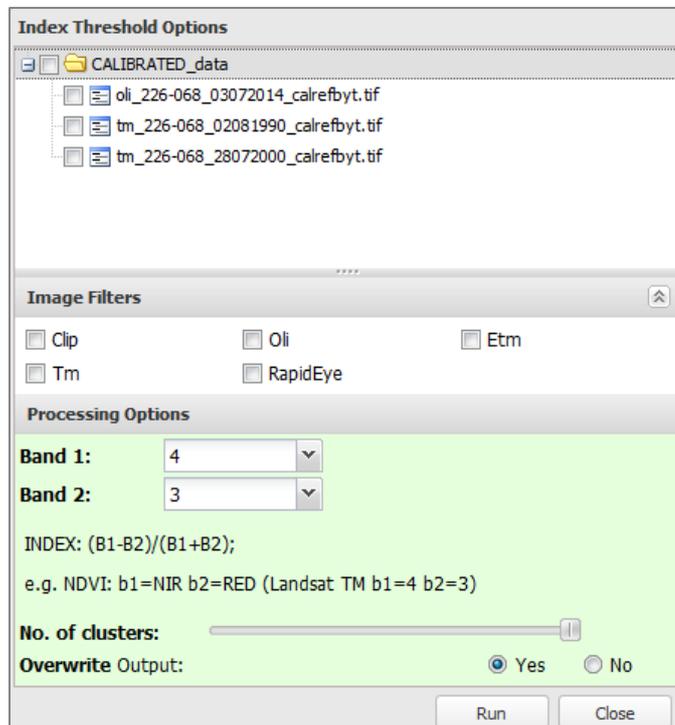
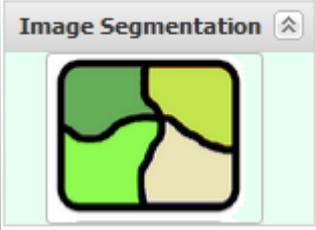


Figure 12 Index Thresholding interface

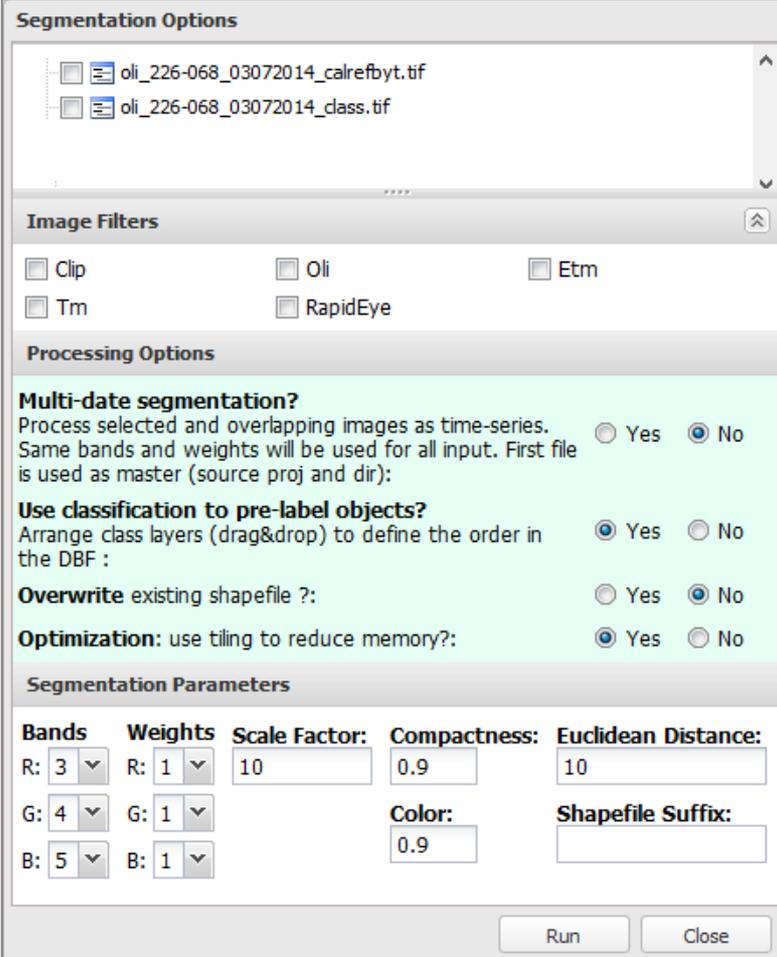
Image Segmentation



Purpose: image segmentation
Input directory: *DATA/CALIBRATED_data/*
Output directory: *DATA/CALIBRATED_data/*
Output Type: vector file (ERSI format)
Output suffix: .shp

Image segmentation is the process of partitioning a digital image into multiple segments on the base spectral, geometrical or computed properties (texture) together with user defined parameter describing the size, shape and similarity versus adjacent segments. Baatz algorithm [1] is available as an open-source package from INPE's TerraLib operators [2].

Hereafter the graphical users interface designed to facilitate data and parameters selection.



Segmentation Options

oli_226-068_03072014_calrefbyt.tif
oli_226-068_03072014_class.tif

Image Filters

Clip Oli Etm
 Tm RapidEye

Processing Options

Multi-date segmentation?
Process selected and overlapping images as time-series. Same bands and weights will be used for all input. First file is used as master (source proj and dir): Yes No

Use classification to pre-label objects?
Arrange class layers (drag&drop) to define the order in the DBF : Yes No

Overwrite existing shapefile ?: Yes No

Optimization: use tiling to reduce memory?: Yes No

Segmentation Parameters

Bands	Weights	Scale Factor:	Compactness:	Euclidean Distance:
R: 3	R: 1	10	0.9	10
G: 4	G: 1		Color:	Shapefile Suffix:
B: 5	B: 1		0.9	

Run Close

Figure 13 Image Segmentation interface

Segmentation Options:

- Multi-date segmentation:
 - “No”: selected images are treated individually and the correspondent vector file (ESRI Shapefile format) is saved within the image directory; please ensure that segmentation parameters are applicable to all selected images, bands selection above any other.
 - “Yes”: selected images are layer stacked (only selected bands) into a single one using the selected bands and weight. Please ensure the geographical overlap. First file is use to extract output location and reference projection

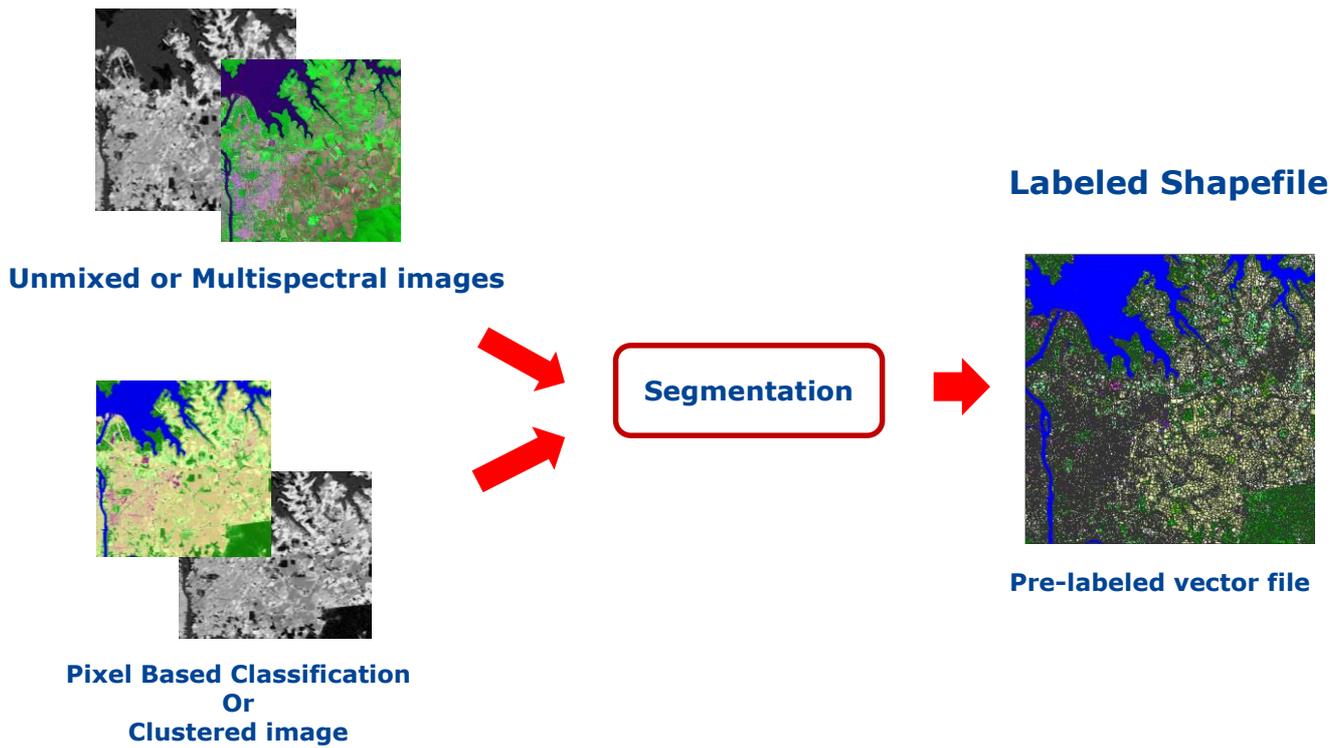
- Use classification to pre-label objects: “_class.tif” and “_cluster.tif” files could be used to pre-label objects according to occurrence rules (currently the ‘mode’) and lookup-table (described here after) either in single or multi-date mode. In the latter case, the .dbf file will reflect the top-down order in which files are organized in the tree-panel saving (after the ID field) as many fields as the input images as on Table 3. It is possible to drag-and-drop a layer to the right position / chronological order if needed (see also Figure 20)

- Overwrite: set to “Yes” to automatically delete output files (if any)

- Optimization: if “Yes”, input images are processed using a tiling approach reducing the total amount of memory; however, the final segmentation might reflect the tiling patterns (please refer to the Note at the end of this chapter for additional information)

ID	T1_cluster	T1_class	T2_cluster	T2_class
0	21	9	22	14
1	21	9	22	14
2

Table 3 Example of DBF file containing 2 classified epochs: T1_cluster represents the mode value of the single date classification in object = ID at Time 1, T1_class its translation into the in-use land cover legend at T1; similar for T2.



Proposed lookup table (SDC2Class) as implemented in Tools/JRC_SD_libs/Simonets_PROC_libs.py:

Single Date Class	Land Cover Legend*
1,2,3	15
5,6,7,8	13
9	9
10,11,12	1
13	7
14,16	9
21,22	12
30,31,32,34	14
40	1
41,42	11
99	0

Table 4 Lookup table showing the recoding strategy adopted. *Land cover legend is described on “Map Validation” chapter.

Segmentation Parameters:

- Bands and weights: raster bands and associated weight to be used
- Scale factor: this factor controls the spectral heterogeneity of the image objects and is therefore correlated with their average size; smaller it is, more objects you will get
- Color: Baatz spectral component [0.0, 1.0]
- Compactness: Baatz morphological component [0.0, 1.0]
- Euclidean distance: used only if the memory “optimization” flag is enabled; represents the minimum Euclidean Distance (expressed in DN values) to be used while merging segments crossing two adjacent tiles; higher values will allow aggregation of heterogeneous objects; lower values will keep the straight edges of the tiles.
- Suffix: user define string (only alphanumeric) to be add to the output filename

NOTE:

- Please ensure that the selected band numbers are available within the raster/s (generic “Baatz Failure” error message will be raised)
- The multi-date segmentation creates an ancillary file within the directory of the first selected image (master) containing the name of the processed images and the order of the *_class.tif* within the .DBF file
- Objects pre-labeling requires a classified raster *_class.tif* (e.g. the result of the automatic classification) from which to extract statistical information from (e.g. the “mode”) together with a lookup table to convert it into the adopted land cover/use legend. Clustered images *_cluster.tif* or user-defined classified raster/maps are accepted but will only be used to fill the “T(n)_cluster” attribute since the conversion from cluster ID to Land cover/use cannot be defined a priori. Currently is possible to overcome this limitation by changing the python class MYmode2D and SDC2Class within the *Simonets_PROC_libs.py* file
- Big TIFF files are not supported

Segmentation results could be visualized using the Map Validation Panel

Annex1 reports several tests conducted using a different parameters.

5.1 Processing Modules: Evergreen Forest Normalization

Evergreen forest areas could be considered as a pseudo invariant features in the radiometric normalization of remote sensed imagery. Median forest value, extracted using the provided evergreen forest mask at 250mt (/Tools/Classification/Global_EVG_map_ll.tif) are then compare to reference medians and adjusted as follows:

$$\varphi_{adjusted}(\lambda) = \varphi_{original}(\lambda) - \tilde{x}_{forest}(\lambda) + x_{ref}(\lambda)$$

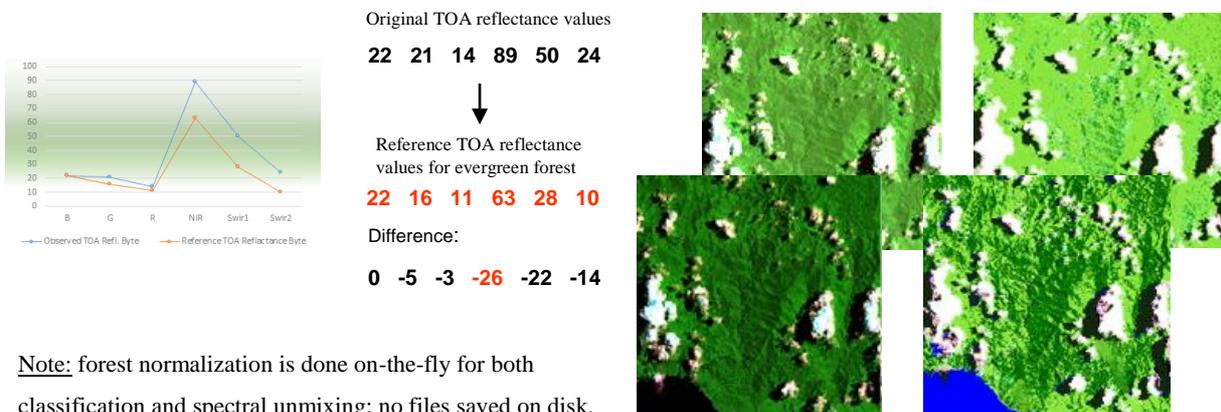
where:

$\tilde{x}_{forest} \lambda$ = median value for band λ of evergreen forest as derived from the image;

$x_{ref}(\lambda)$ = reference evergreen forest values for band λ as derived from representative areas collected across all continents;

B,G,R,NIR,SWIR1,SWIR2 = [0.086,0.062,0.043,0.247,0.109,0.039] or [22,16,11,63,28,10] expressed in byte (TOA Reflectance_[0-1] * 255) as proposed in [12];

Further developments will ensure that forest normalization will be applied only if input image has a significant amount of evergreen forests (i.e. more than 1000 pixels) and will give the possibility of changing the reference median values in the Settings panel.



Reference evergreen forest map has been created using the Global Forest Change product [13] (Tree cover >65% in 2013) intersect with Globcover 2009 product [14] classes 40,65,70,160.

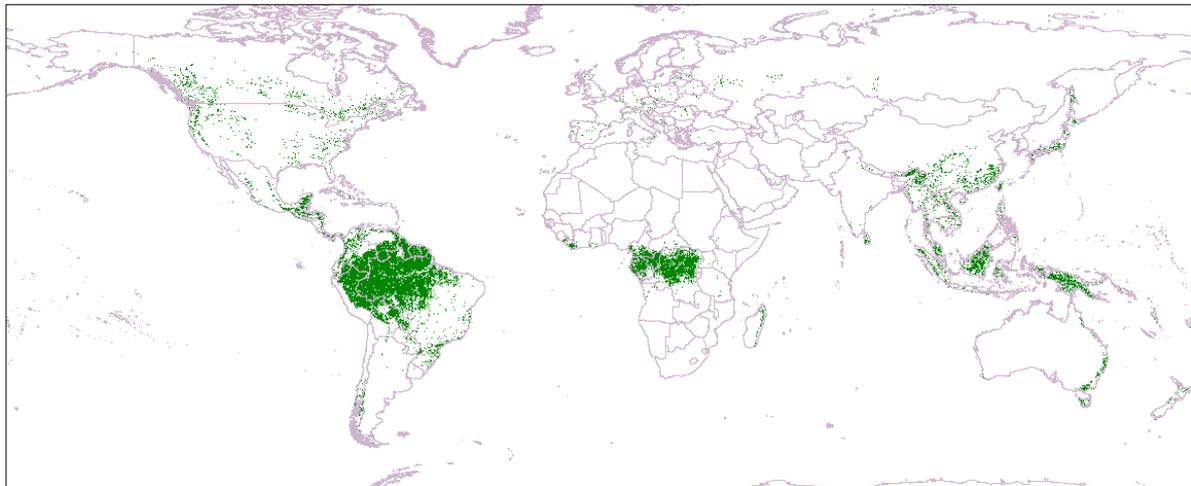


Figure 14 Evergreen forest mask as derived from the Global Forest Change Product and Globcover 2009 intersection

6. Map Validation Panel

Within the Map Validation panel is possible to visualize and edit vector files such as the result of the segmentation step in order to check and assess the quality of land cover maps. By clicking on the “Editing Tools” any available vector file (*.shp) within the /DATA/CALIBRATED_data/ folder could be loaded together with any raster that come along; files are then visible on the layer tree under the correspondent category; please refer to “Settings” chapter to better understand input requirements.

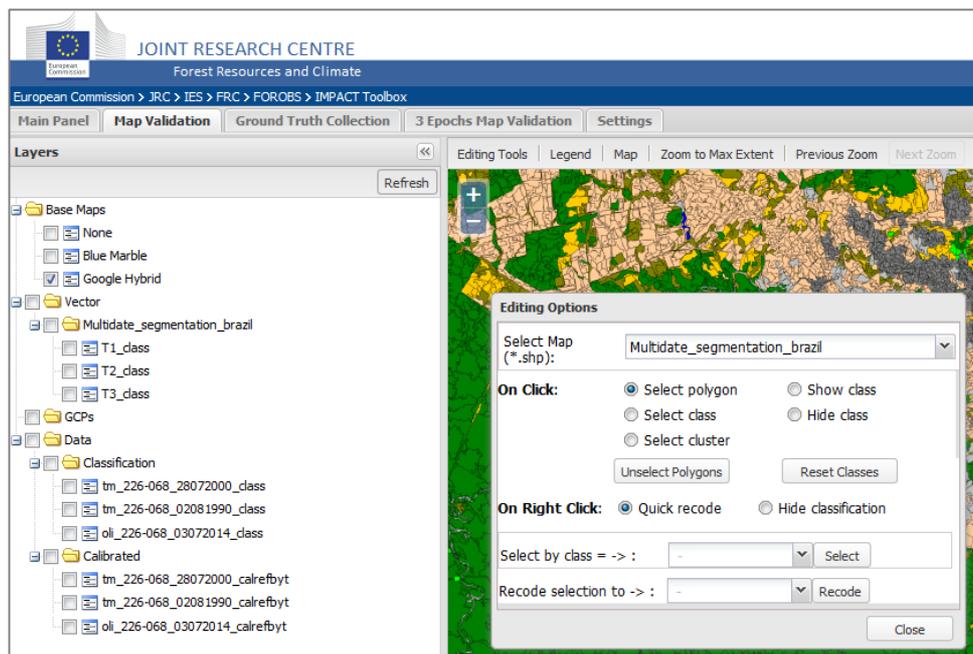
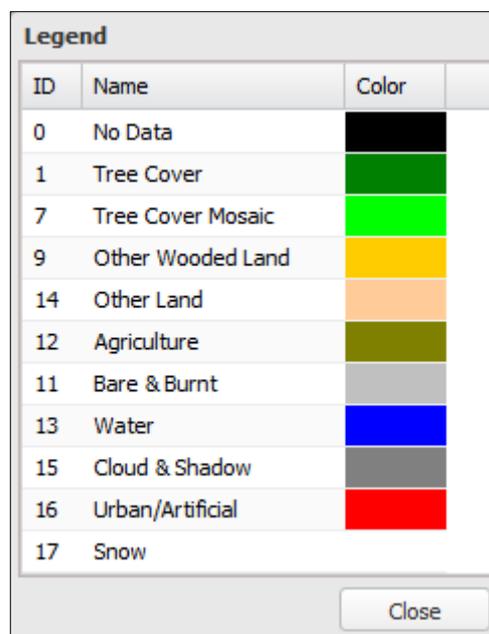


Figure 15 Map Validation and Editing Options panels

The background map will automatically fit the vector spatial extent and the skeleton is visualized in black; by right-clicking on the vector item is possible to remove it from the map, change visualization parameters and visualize existing layers contained into the .dbf file (e.g. “T1_class”, “T2_class”, “T3_class”)

Land Cover/ Land Use classes are visualized with different colors according to the information extracted from the .dbf file (e.g. “T1_class” column); colors, class ID and description are showed in the Legend popup and could be customized by the user in the Settings panel (see Settings chapter for more details) ;



ID	Name	Color
0	No Data	Black
1	Tree Cover	Green
7	Tree Cover Mosaic	Bright Green
9	Other Wooded Land	Yellow
14	Other Land	Light Orange
12	Agriculture	Olive Green
11	Bare & Burnt	Grey
13	Water	Blue
15	Cloud & Shadow	Dark Grey
16	Urban/Artificial	Red
17	Snow	White

Figure 16 Default Land Cover / Land Use Legend

Editing Mode

By right clicking on one vector attribute (e.g. ‘T1_class’) a ‘context menu’ allows layout customization and editing mode.

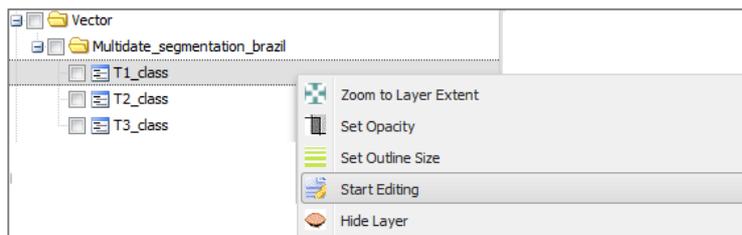


Figure 17 Context menu appearing by right clicking an attribute layer

Common navigation/visualization instructions:

- Double left click : zoom in;
- Double right click : zoom out;
- Scrolling wheel : zoom in/out;
- Shift + mouse selection : zoom the desired area of interest;
- Right click will temporary hide any classification layers in order to display either user's raster or the background layer;

While in editing mode:

- Navigation to other tabs is disabled;
- Selected layer becomes red and is not possible to edit or delete other layers;
- Is possible to hide/select/recode classes or objects using the "Editing Option" panel;
- Recoding is only applied to objects within the current map extent;
- After single or multi (CTRL+ Left click) polygon selection, a fast recoding popup legend is also available by pressing the right mouse; is possible to disable this option by selecting 'Hide classification' on right click in the "Editing Option" panel;
- While showing or hiding a class, any class re-assignment (different from the masked one) will not be visible until the "*Unselect Class*" button is pressed; although this behavior might be interpreted like a bug, it has been revealed useful for a) set a preliminary filter/mask on a class and b) add or remove object from/to other classes while keeping them masked if not belonging to the filtered class.

NOTE:

- Vector and raster files are visualized as WMS; it might be plausible to face a decreasing of performances while using vector files with more that 10K features; if so, it might be desirable to disable the skeleton of vector file under "*Vector*" branch in the tree-panel avoiding double visualization in case a classification layer (e.g. T1_class) has been loaded as well
- Raster created within the tool are optimized to be visualized through Mapserver; if coming from processing done outside the IMPACT we are encouraging running the following commands and keep the associated .xml file together with the .tif file:

```
gdal_translate -co COMPRESS=LZW -co TILED=YES -ot Byte -scale -co BIGTIFF=YES IN OUT
gdaladdo OUT 2 4 8 16 32 64 128 256 512 1024 2048 4096
gdalinfo -stats OUT
```

- When Map Validation panel is active, the automatic scan and refresh of DATA folder is disabled.

7. Ground Truth Collection Panel

The Ground Truth collection panel has been developed with the aim of easily collect and save ground reference information (related to either Land Cover/Land Use or Degradation) into a pre-defined vector file generated following a sampling or wall-to wall strategy. Despite its design looks similar to the Map Validation panel, the way of rendering vector data (WFS) and file structure is slightly different: input vector data from /DATA/GROUND_TRUTH_data/ directory must contain the following fields (in any order):

Mandatory		Optional			
ID	T1_class	Name	Cause1	Cause2	Comment

If those attributes are not available, while entering the “editing mode“, the .dbf file will be populate accordingly.

Optional fields are designed to store additional information to each polygon such as, in this particular version of the tool, degradation causes, scale etc. Please refer to “Settings Panel” to better understand how to customize those values according to your needs.

A vector file (My_Sampling.shp) is available within the input directory and could be loaded using the “Editing Tools” button. As showed on Figure 18, it might contain objects following regular pattern (grid), circles from a sampling approach, irregular polygons and, although not recommended for large areas, objects derived from wall-to-wall image segmentation.

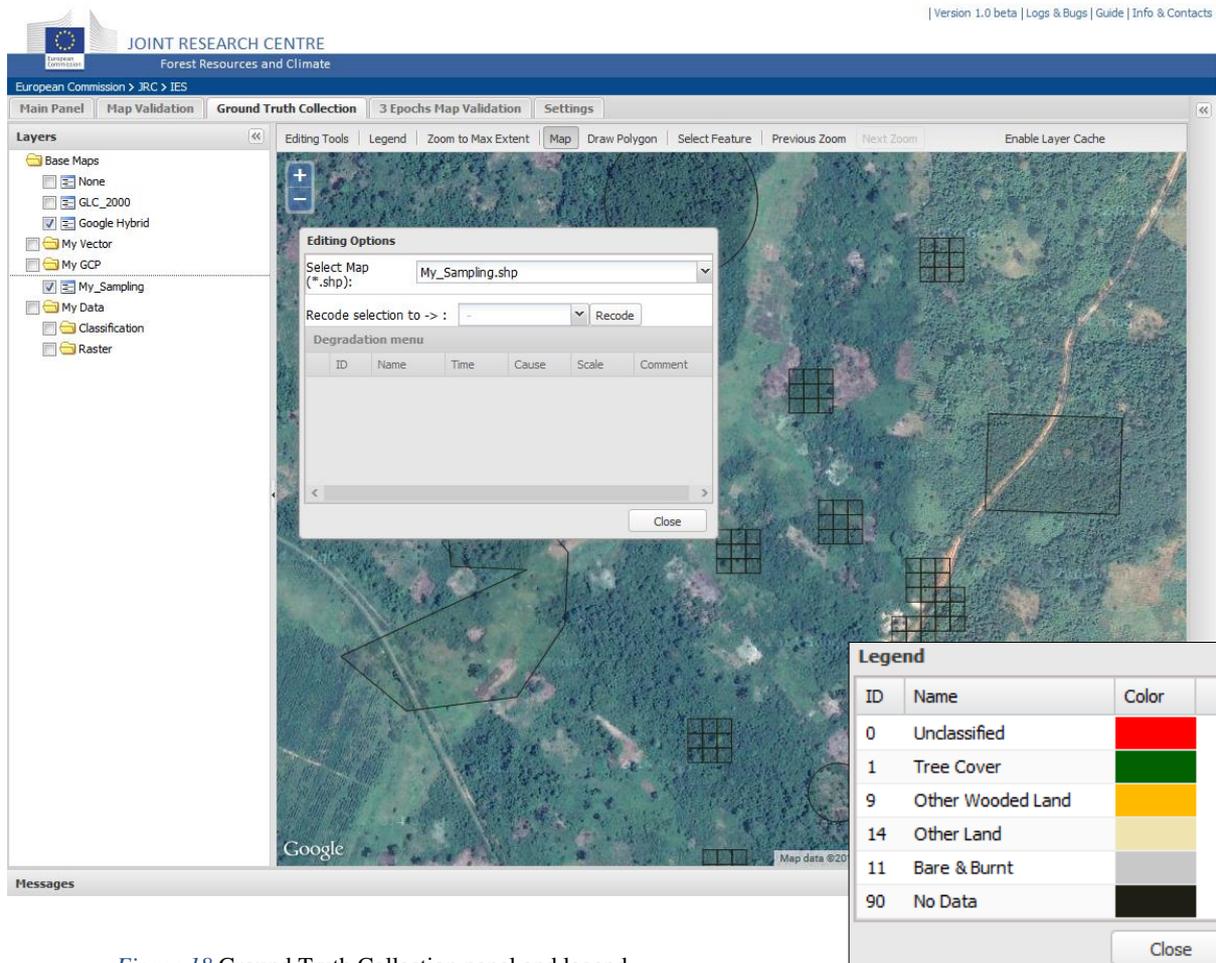


Figure 18 Ground Truth Collection panel and legend

After being loaded, the vector layer will appear under the Ground Control Points “GCP” branch on the left side tree-panel and the Degradation menu in the Editing Option panel will remain disable until the Editing mode starts (right click on My_Sampling → Start Editing). As for the Map Validation Panel, the editing mode is indicated by changing to red the name of the layer; right click will now show the ground truth legend (see “Settings Panel” for further customization) for a quick class assignment. Navigation and visualization options are similar as well.

If the .dbf file contains the above mentioned optional fields, the Degradation menu will be enable when one or multiple objects (CTRL+ Left Click) are selected: by clicking on the line is possible to add

- the name of the validator
- the causes and additional comments

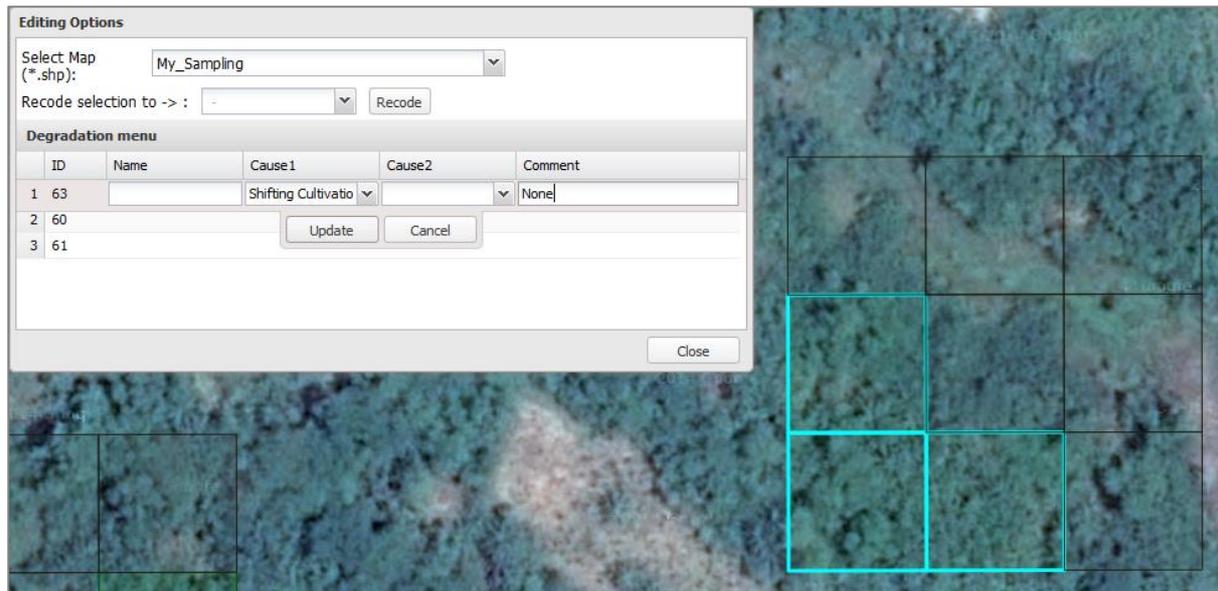


Figure 19 Editing Options: degradation info to be linked to selected objects in addition to land cover class

NOTE:

When the Ground Truth Collection panel is active, the automatic scan and refresh of DATA folder is disabled.

8. 3 Epochs Map Validation Panel

This panel has been designed with the aim of integrating and distributing an open source version of the *JRC Land Cover Change Validation Tool* [15] originally developed in Interactive Data Language (IDL) for the Global Forest Resource Assessment (FRA) Remote Sensing Survey, a FAO land cover/land use mapping initiative under which JRC had cover a key role in data selection, processing and tools development. While keeping multi date map visualization (up to tree) and standard editing features, it offers the innovative selection and recoding strategy based on *clusters* and *classes* alternatively. This hybrid editing technique has been designed and successfully used in [16] for forest cover mapping in Russia and is currently in use at JRC for land cover/land use change detection and mapping over protected areas in Africa within the MESA and BIOPAMA project.

For the sake of clarity within the IMPACT tool a *cluster* represents a set of objects with common spectral properties (category) as generated by the automatic SDC tool while a *class* is the land cover/land use class associate to each object by the interpreter; is worth noting that one *cluster* might include objects with different *class* and vice-versa.

Data preparation

A vector file resulting from a multi date image segmentation (see Image Segmentation chapter for more details), must have the following structure:

ID	T1_cluster	T1_class	T2_cluster	T2_class	T3_cluster	T3_class
0	2	15	2	15	2	15

- T1,T2 and T3: epochs and associated display from left to right;
- *_cluster* represents the mode of the single date classification category; could not be modified
- *_class* initially filled using the translation schema as proposed on Table 4, it will contain land cover/land use classes assigned by the interpreter;

While selecting input multispectral images and classifications from the Segmentation interface, pleas ensure the correct chronological order of the *_class* file by re-arranging the top-down order using the layer drag-and-drop option as on Figure 20.

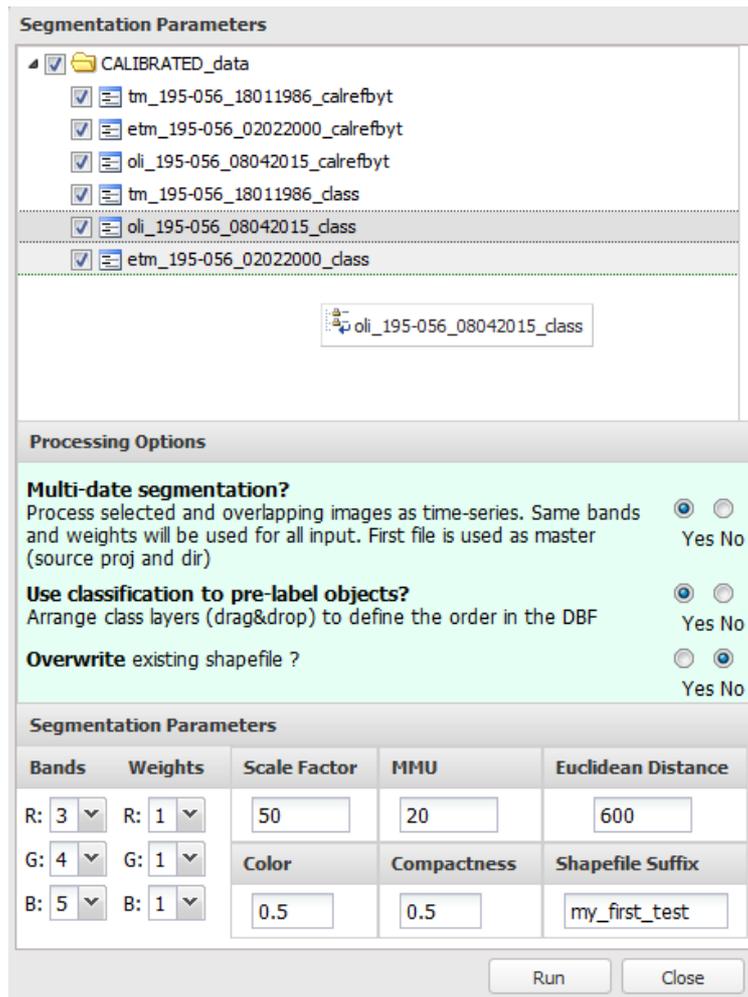


Figure 20 Segmentation Parameters interface: while moving layer *oli_195-056_08042015_class* to the end of the list, a green line is showing the correct drop position.

If needed, an ancillary text file containing the list and order of the images used, is available in the same output directory; for the proposed segmentation test it contains the following lines:

```
Master Image: W:/DATA/CALIBRATED_data/tm_195-056_18011986_calrefbyt.tif
Other image: W:/DATA/CALIBRATED_data/etm_195-056_02022000_calrefbyt.tif
Other image: W:/DATA/CALIBRATED_data/oli_195-056_08042015_calrefbyt.tif
Classification order in DBF :
Classification: W:/DATA/CALIBRATED_data/tm_195-056_18011986_class.tif
Classification: W:/DATA/CALIBRATED_data/etm_195-056_02022000_class.tif
Classification: W:/DATA/CALIBRATED_data /oli_195-056_08042015_class.tif
```

Validation panel

The validation panel consists of 6 geographically linked maps showing the land cover for the tree acquisition epochs on top and the related satellite images on bottom. By pressing the Option button is possible to select a vector file from the drop-down menu (a test file is available under `\DATA\CALIBRATED_data\`) and available images could be loaded interactively for each display; in case the image name contains the “_1990_”, “_2000_” or “_2010_” keyword, will be only visible within the correspondent epoch.

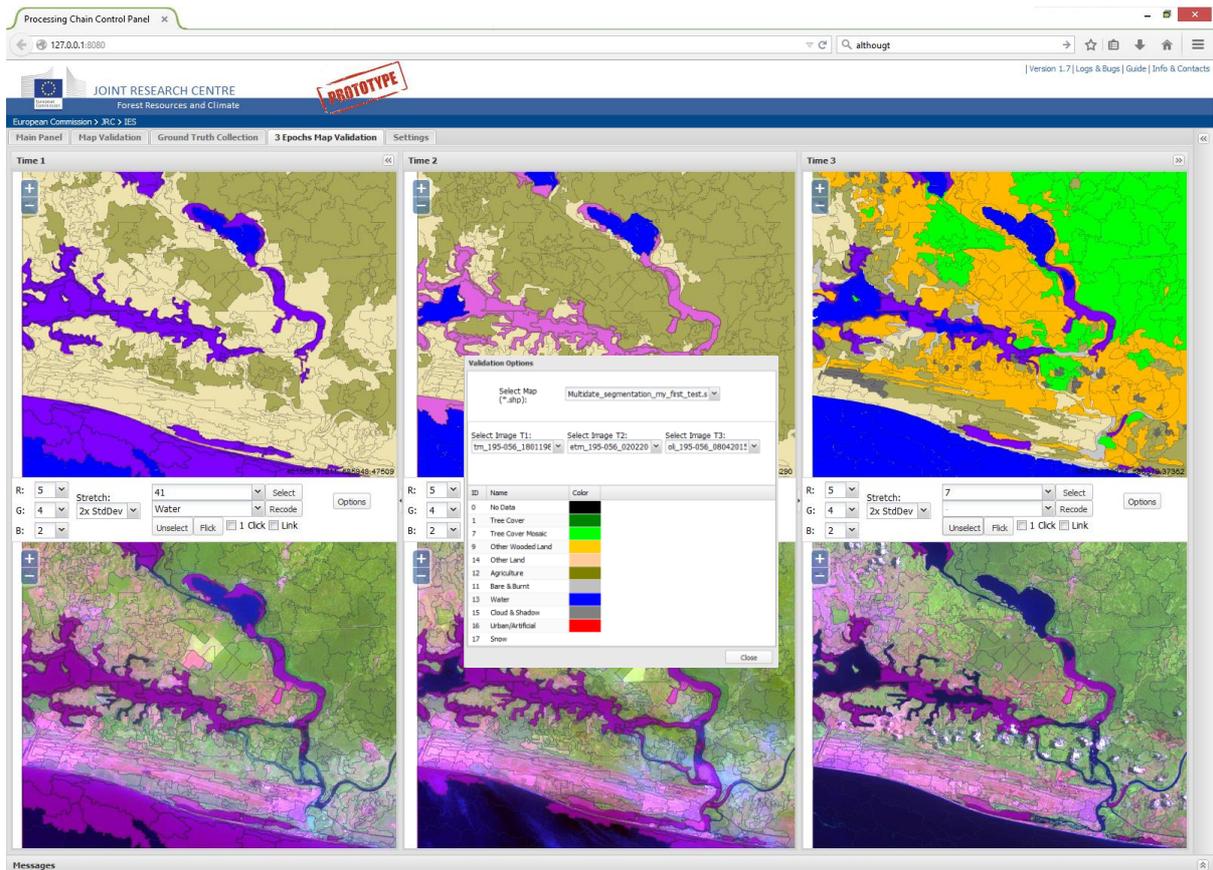


Figure 21 3 Epochs Map Validation panel: land cover/land use maps on top and satellite imagery on the bottom for the tree different acquisition times (left to right); selected clusters are visualized in violet.

By changing the raster visualization option is possible to select the most suitable band combination and stretch among a predefined selection such as ‘Scale 0-255’, ‘Min-Max’ and ‘1x/2x Standard Deviation’.

Editing mode

Within this panel the editing mode is always enable; by a left-clicking on either a map or an image is possible to select and recode a cluster (default behavior) within each epochs (columns) independently; selected cluster becomes violet and its ID is visible in the drop-down menu, see Figure 22.

Selection either by cluster or class, could be done using the drop-down menu as well. If the “Link” checkbox has been ticked, selected cluster/class is highlighted on all other maps as well. This feature allows fast recoding of huge amount of objects by selecting, over the tree epochs, the cluster that best represent a specific land cover on the ground. Since the cluster IDs and the preliminary land cover classes, derived

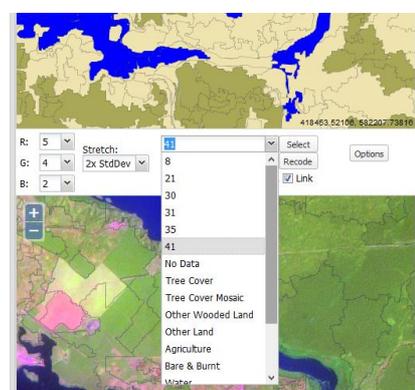


Figure 22 Drop-down menu containing Clusters (numbers) and Classes (names).

from the SDC, might not be the same across the tree images due to seasonal differences, atmospheric conditions or natural/anthropogenic changes we would like to remark that often the best match between a cluster/class and ground cover might come from a different epoch. On Figure 23 is observable how the river on Time 2 is not properly classified; however, is possible to either inherit the water layer form Time 3 (by linking display, selecting the water class on Time 3 and recoding selected objects on Time 2) or recoding the grey cluster/class on Time 2 into water.

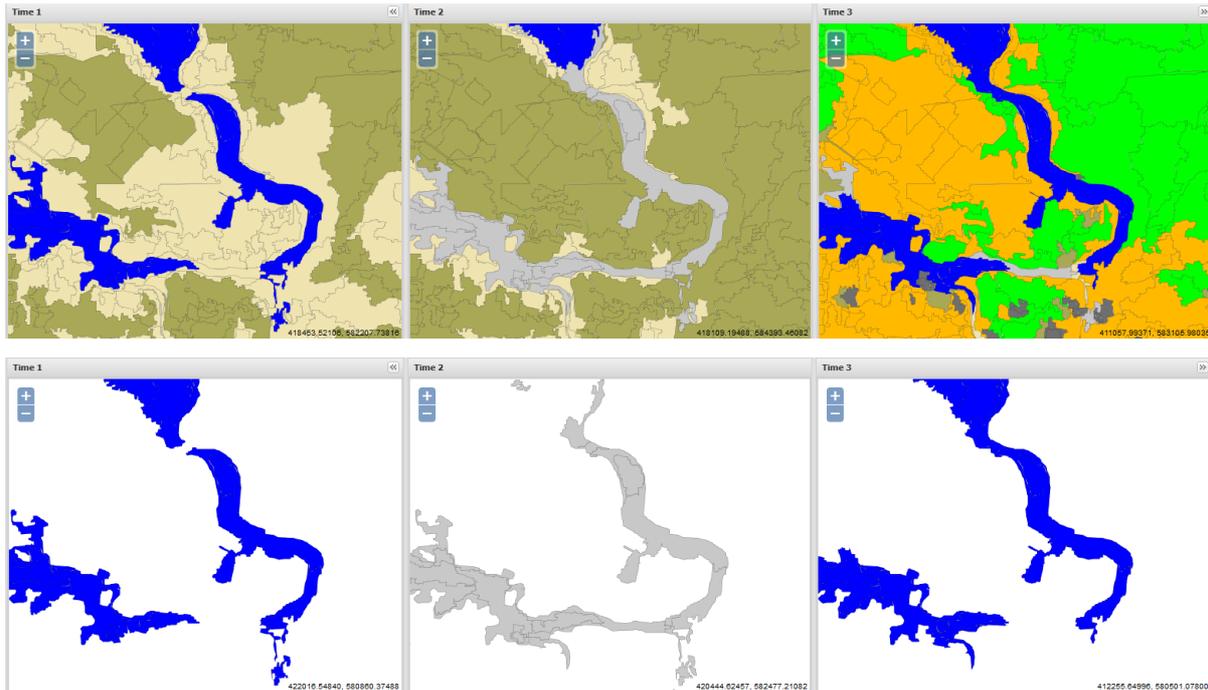


Figure 23 Rivers are not well classified on Time2 but is still possible to inherit water class from other maps or use Time 2 cluster/class combination to easily refine the classification.

Often a cluster contains objects that, although spectrally similar, might belong to different land cover/land use; here the need of handling them individually: the “1 Click’ option allows single or multiple (CTRL + Left click) objects recoding and could be used together with the map “Link” option.

Limitations

Projection: within this panel is only possible to edit vector and raster files having the same geographical extent and reference system either in UTM or Geographic Lat-Lon projection.

9. Settings Panel

The *Settings Panel* offers an easy way to customize the behavior and layout of the tool. Settings are grouped into different tabs as follow:

Tool Options:

if not interested in using the ‘3 Epoch Validation’ and/or “Ground Truth Collection” panels, is possible to disable them for a lighter execution of the tool. Refresh time indicates how often the content of the left side layer-tree has to be updated so as new products are

automatically visible; values below 60 seconds might overload the all system in presence of lots of files. Please note that only the ‘Main Panel’ has the “auto refresh” option.

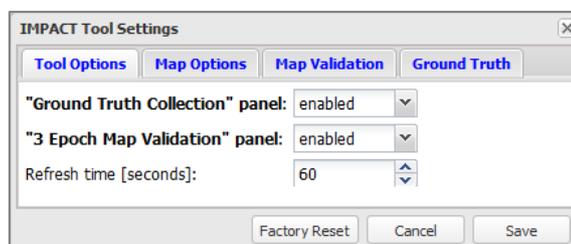


Figure 24 IMPACT Tool Settings Panel: Tool Options

Map Options:

setting a default map extent, position and zoom level while loading can be done via this panel.

Rendering raster and vector using the “single” tile mode might take a bit longer but avoids receiving several pieces (tiles) of the image to be then recomposed by the client with a possible tiny delay.

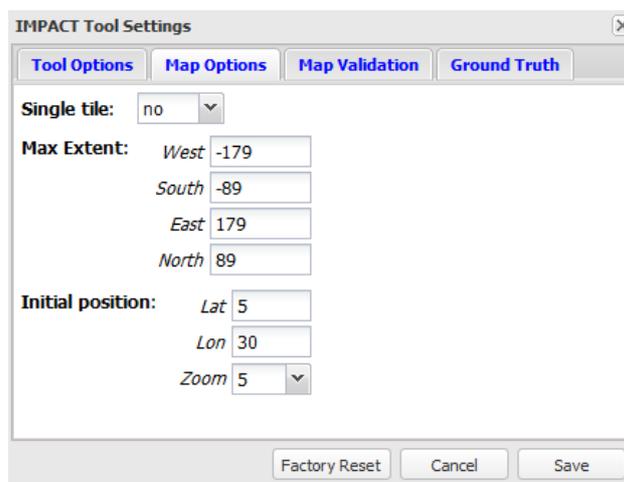


Figure 25 IMPACT Tool Settings Panel: Map Options

Map Validation: contains parameters use in “Map Validation” and “3 Epochs Map Validation” panels such as the name of the attributes (columns in .dbf) and the legend codes and associated colors. By clicking on them is possible to rename/add/remove a class and assign a new color.

Ground Truth: similar to the above mentioned settings but a has a dedicated Legend (id, class name and color) and requires extra attributes to save degradation information.

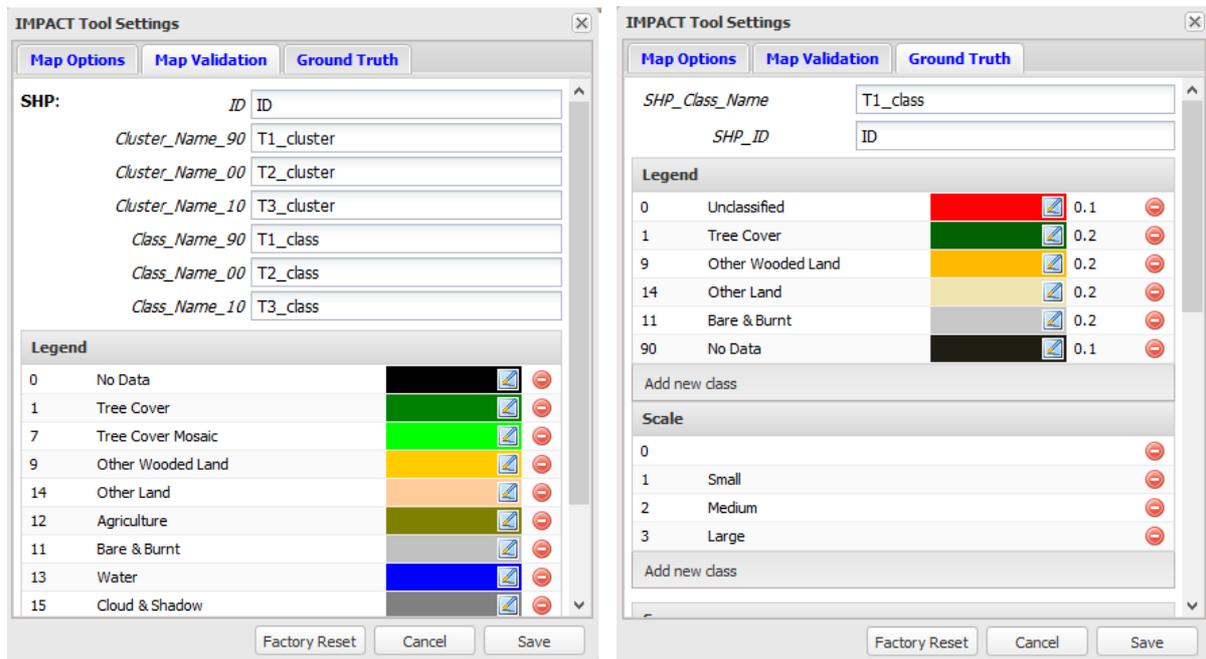


Figure 26 IMPACT Tool Settings Panel: Map Validation options and legend on the left; Ground Truth legend and additional degradation fields on the right

After saving, a *configuration.json* file will appear in the /Gui/ directory. A ‘Factory Reset’ button is available to restore default parameters.

10. IMPACT: well-known issues

- Impact main directory has to be saved into a disk location not containing spaces or non-alphanumeric characters; is preferable to avoid windows system folder
- Ensure no other network services are running on port 2020 (Tomcat, Apache)
- Image processing (classification, segmentation) requiring more than 4Gb of memory might fail prematurely and without handling the exception
- Opening raster or vector file with external software (Erdas, Envi, ArcMap, Qgis) while processing might cause unexpected failure.
- Overwriting raster or vector file while visible on map might cause inconsistencies due to ‘cache’ effects; panning / zooming the map is sufficient to reload the correct data from disk.

11. IMPACT: future developments ...

General:

Unix and Windows portability;

Processing:

- Customization of the pre-labeling phase during image segmentation to better match single date classification schema with the user define land cover classes;
- Image normalization and linear spectral unmixing based on user AOI selection with the possibility of saving it as vector file;
- Change detection base on two or more images
- RapidEye classification improvements
- Include processing modules for Spot and Sentinel 2 data as well.

Map Validation:

- Undo map editing ;
- Possibility to copy classification (entirely or partially) from one layer (epoch) to another;
- Changes extraction between different land cover maps

3 Epochs Map Validation:

- Undo map editing ;
- Overpass the limitation of using 3 dates with a flexible and highly customizable interface;
- Adding the possibility of subtracting clusters from different maps to improve the selection process;

Ground Truth Collection:

- Confusion matrix and accuracy estimation by comparing ground truths with land cover maps.
- Automatic generation of sample point / fishnet

12. Version

This document version 1.0 dated 10/2015 is referring to the IMPACT toolbox 1.0beta.

Please check the last version on <http://forobs.jrc.ec.europa.eu/products/software>

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- Laboratório de Monitoramento Ambiental, EMBRAPA Florestas, Brazil
- Institutions and related partners involved in RECAREDD, MESA, PACSBIO
- The Water Resources Unit, JRC, IT

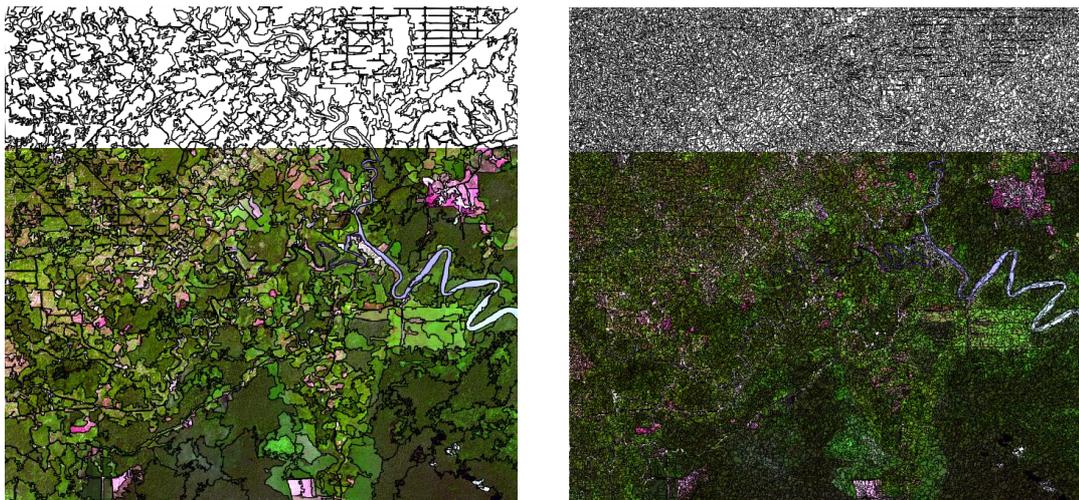
Annex 1: Image segmentation

Suggesting a default set of parameters to be used for image segmentation is not often possible; image size, resolution, data type (byte, integer, float) and nonetheless, the landscape fragmentation may vary significantly from biome to biome; however, this chapter gives an overview of the main parameter involved and the different results obtained by using different acquisition sensors.

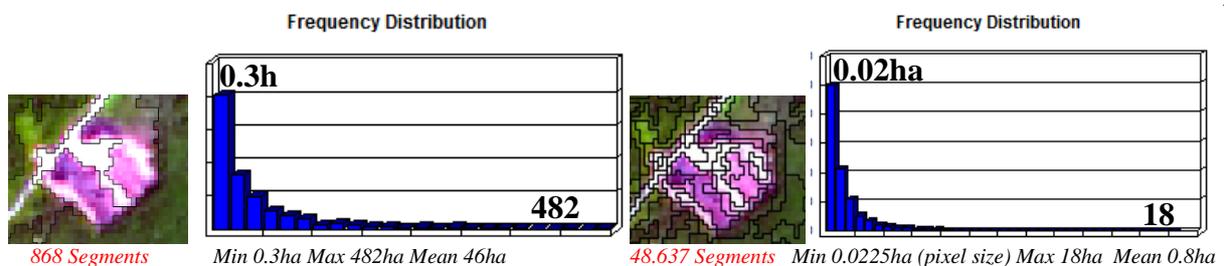
Segmentation Parameters				
Bands	Weights	Scale Factor	MMU	Euclidean Distance
R: 3	R: 1	10	1	1
G: 4	G: 1	Color	Compactness	Shapefile Suffix
B: 5	B: 1	0.5	0.5	

- **Scale Factor:** “key” parameter, controls size and heterogeneity of the objects

SF 80  SF 10



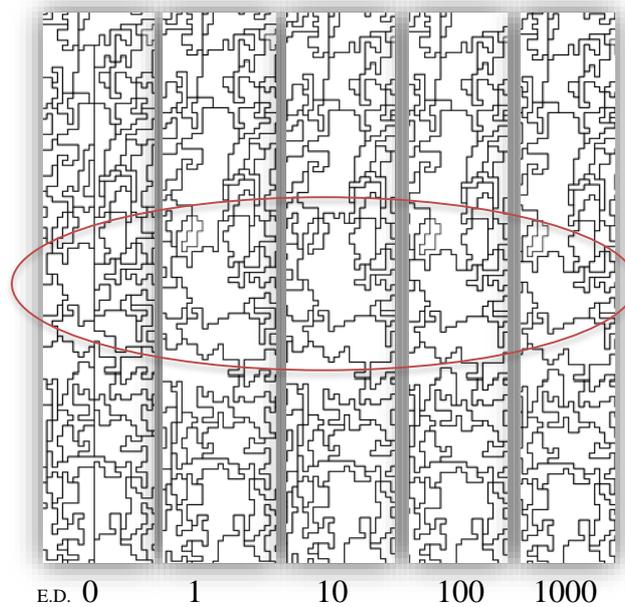
Landsat image (pan-sharpening 15m 16bit) subset 20x20km



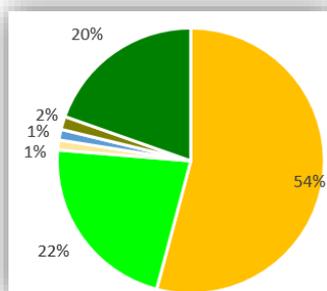
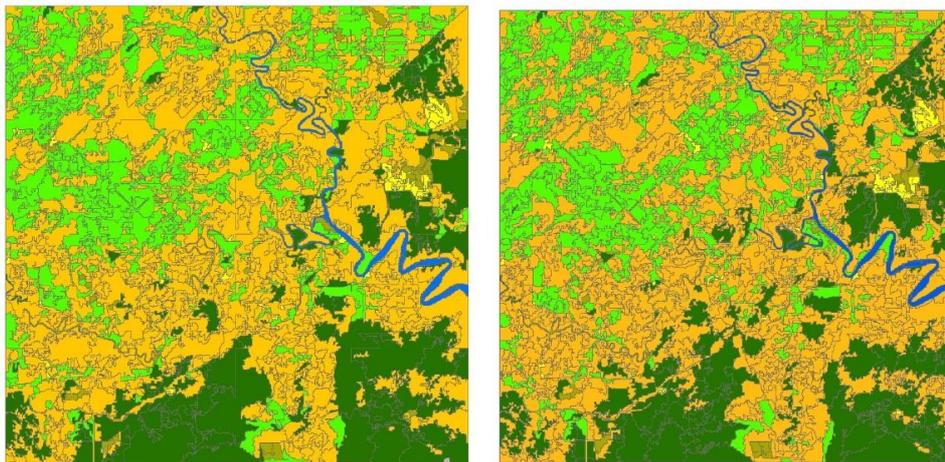
18

- **Bands and Weights:** selection of bands and relative weight to be used for image segmentation
Attention: bands selection order doesn't influence the final results.

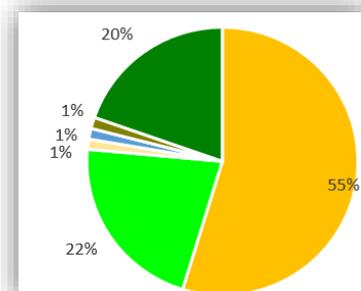
- **Memory Optimization:** while enabling this flag, input image is automatically divided into several tiles before the segmentation takes place; once complete, all tiles are stitched together and objects running along the cut lines are merged according to the **Euclidean Distance** parameter: high values allow merging heterogeneous objects while 0 will keep the cutting line (Euclidean Distance is calculate in pixel DN). Although the cutting edge might be visible when visualizing the skeleton alone, it becomes less visible on classified objects.

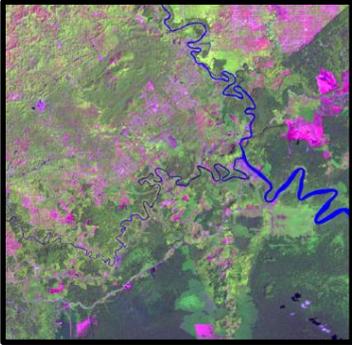
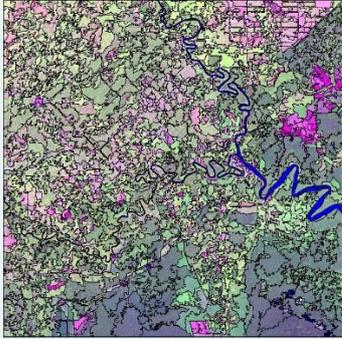
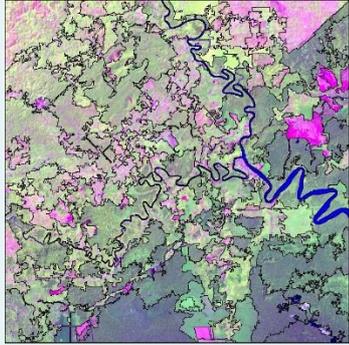
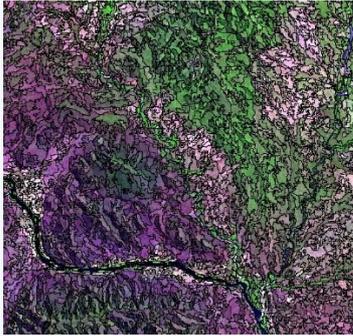
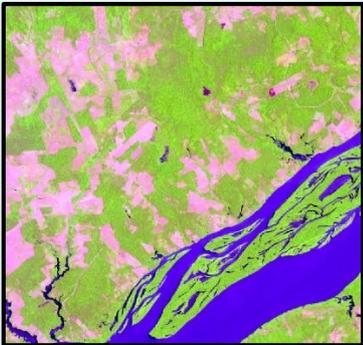


Segmentation with tiling (left) vs no tiling (right)

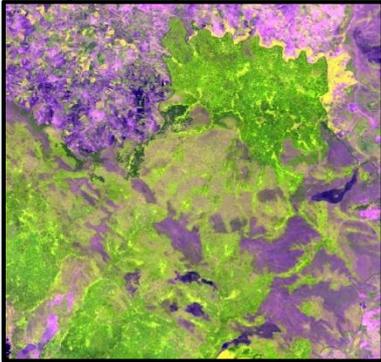


Class	<i>Ha tiles</i>	<i>Ha no tiles</i>
OWL	21629	21888
TCM	8872	8672
OL	483	484
W	518	519
Agri	639	544
TC	7828	7870



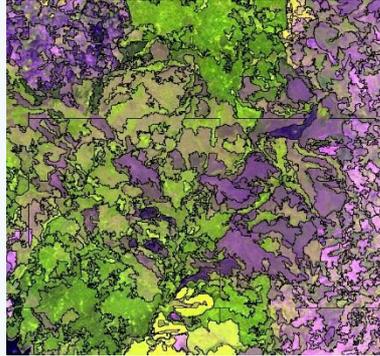
Sensor	Detailed Scale Factor	Scale Factor Suggested
<p>Landsat 30m</p>  <p>--- 20km ---</p>	<p>20-25</p> 	<p>60-80</p> 
<p>Spot5take5 10m</p>  <p>--- 10km ---</p>	<p>50</p> 	<p>100</p> 
<p>Sentinel 10m Copyright ESA</p>  <p>--- 15km ---</p>	<p>50</p> 	<p>100</p> 

RapidEye 5m

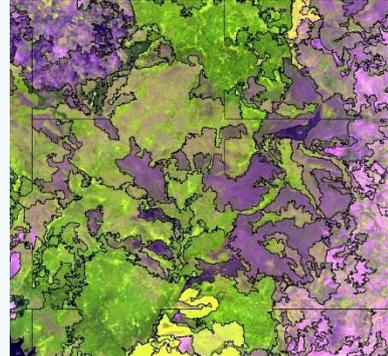


--- 6km ---

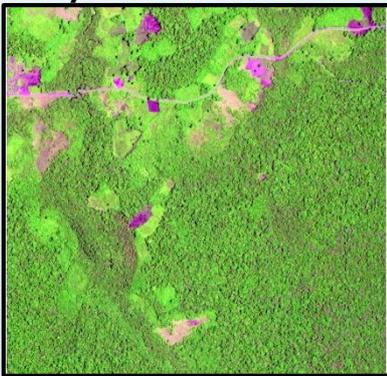
400-500



800-1000

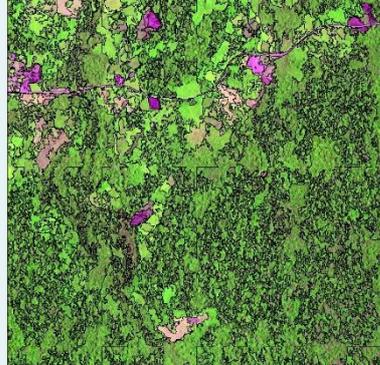


Skybox 2m



--- 3km ---

100



200



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