Semi-Automatic Classification Plugin Documentation

Release 5.3.6.1

Luca Congedo

24 giu 2017

Indice

Parte I

Introduction

Developed by Luca Congedo, the **Semi-Automatic Classification Plugin** (*SCP*) is a free open source plugin for QGIS that allows for the semi-automatic classification (also known as supervised classification) of remote sensing images. It provides several tools for the download of free images, the preprocessing, the postprocessing, and the raster calculation (please see *What can I do with the SCP?* (pagina 271)).

The **overall objective** of *SCP* is to provide a set of intertwined tools for raster processing in order to make an automatic workflow and ease the land cover classification, which could be performed also by people whose main field is not remote sensing. The first version of the *SCP* was written by Luca Congedo in 2012 for the ACC Dar Project in order to create a tool for the classification of land cover in an affordable and automatic fashion (read this working paper). Following versions of *SCP* were developed as personal commitment to the remote sensing field and open source software. *SCP* version 5 (codename: Kourou) is developed in the frame of Luca Congedo's PhD in Landscape and Environment at Sapienza University of Rome.

http://www.youtube.com/watch?v=K2mIa66e6h0

This **user manual** provides information about the *Plugin Installation* (pagina 7) of SPC and the *The Interface of SCP* (pagina 29), with detailed information about all the functions. In addition, the *Breve Introduzione al Telerilevamento (Remote Sensing)* (pagina 139) illustrates the basic concepts and definitions which are required for using the *SCP*.

Tutorials di Base (pagina 173) are available for learning the main functions of *SCP* and *Thematic Tutorials* (pagina 211) illustrate specific tools.

You are kindly invited to **contribute to SCP** (see *How to contribute to SCP* (pagina 272)) and join the Facebook group or the Google+ Community. Several thousand people have already joined and posted hundreds of questions and comments. Also, please read the *Frequently Asked Questions* (pagina 255).

For more information and tutorials visit the official site

From GIS to Remote Sensing

Come citare

Congedo Luca (2016). Semi-Automatic Classification Plugin Documentation. DOI: http://dx.doi.org/10.13140/RG.2.2.29474.02242/1

Licenza

Translators:

Language: Author

Parte II

Plugin Installation

The Semi-Automatic Classification Plugin requires the installation of GDAL, OGR, NumPy, SciPy and Matplotlib (already bundled with QGIS).

This chapter describes the installation of the Semi-Automatic Classification Plugin for the supported Operating Systems.

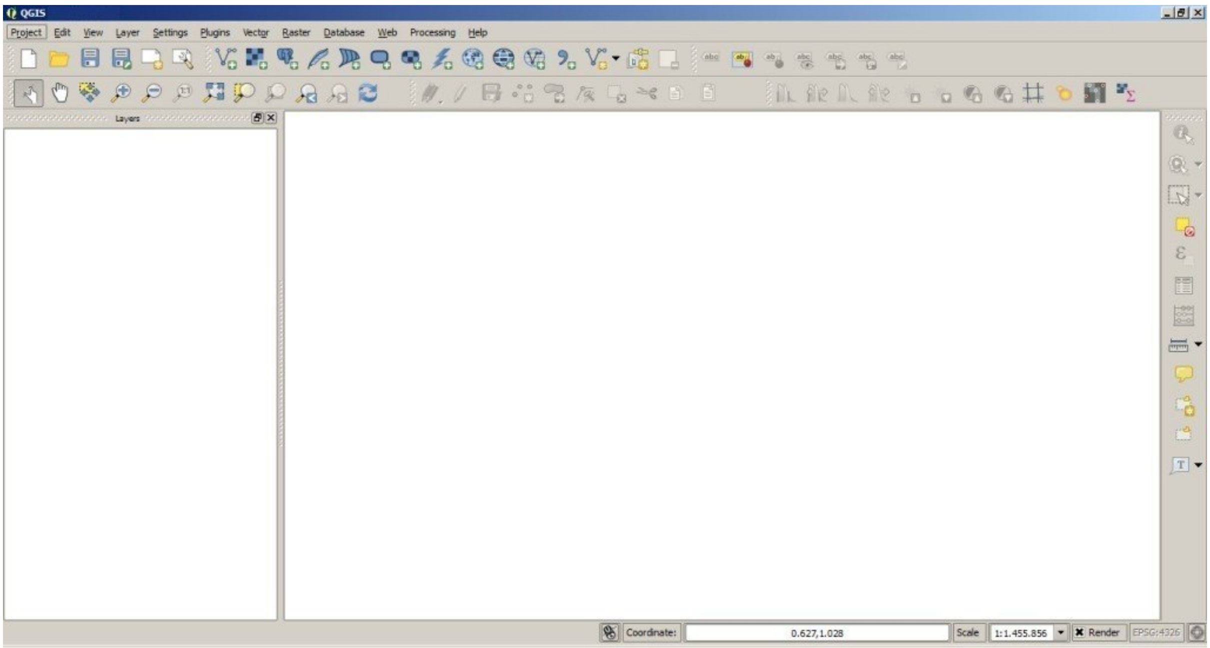
CAPITOLO 1

Installation in Windows 32 bit

Scaricamento e installazione di QGIS

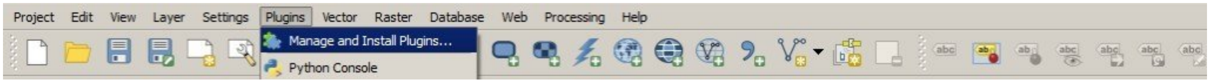
- Download the latest QGIS version 32 bit from here (the direct download of QGIS 2.8 from this link);
- Execute the QGIS installer with administrative rights, accepting the default configuration.

Now, QGIS 2 is installed.



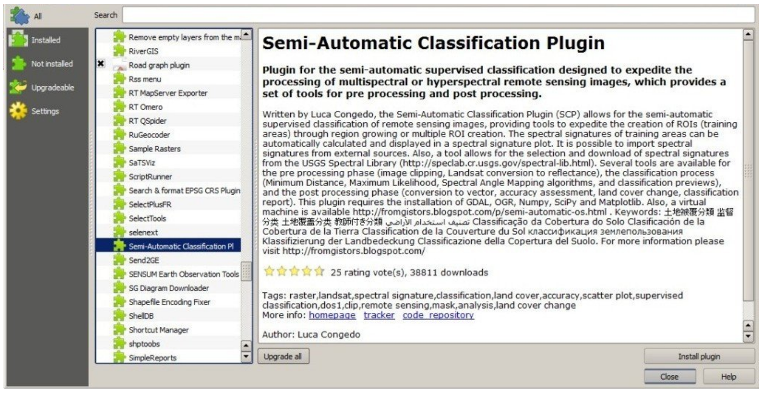
Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;

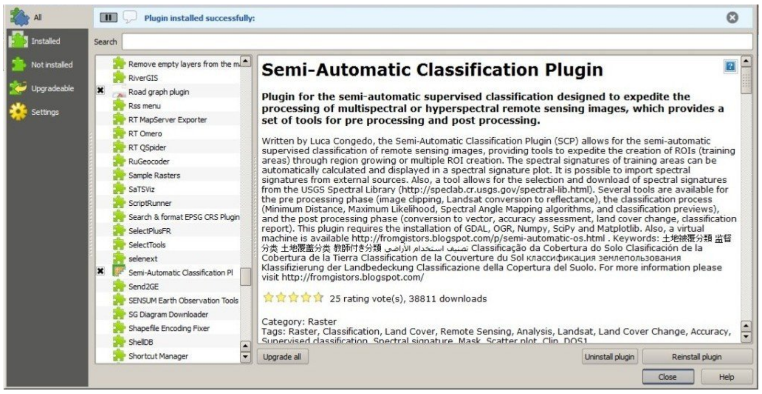


- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

  TIP: in case of issues or an offline installation is required see *Come installare il plugin manualmente?* (pagina 257) and *How to install the plugin from the official SCP repository?* (pagina 257).

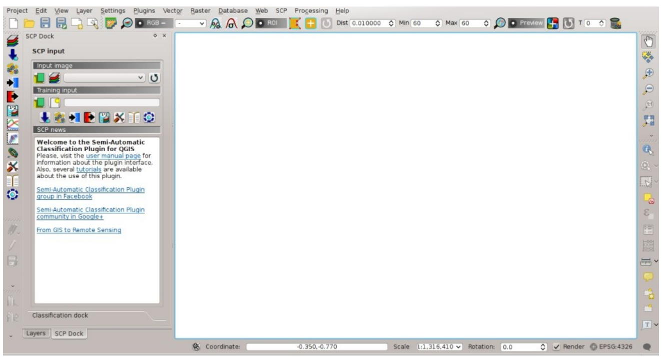


- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);



Configuration of the plugin

Now, the Semi-Automatic Classification Plugin is installed and a dock and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *SCP Tools* (pagina 31) and the dock according to your needs, as in the following image.



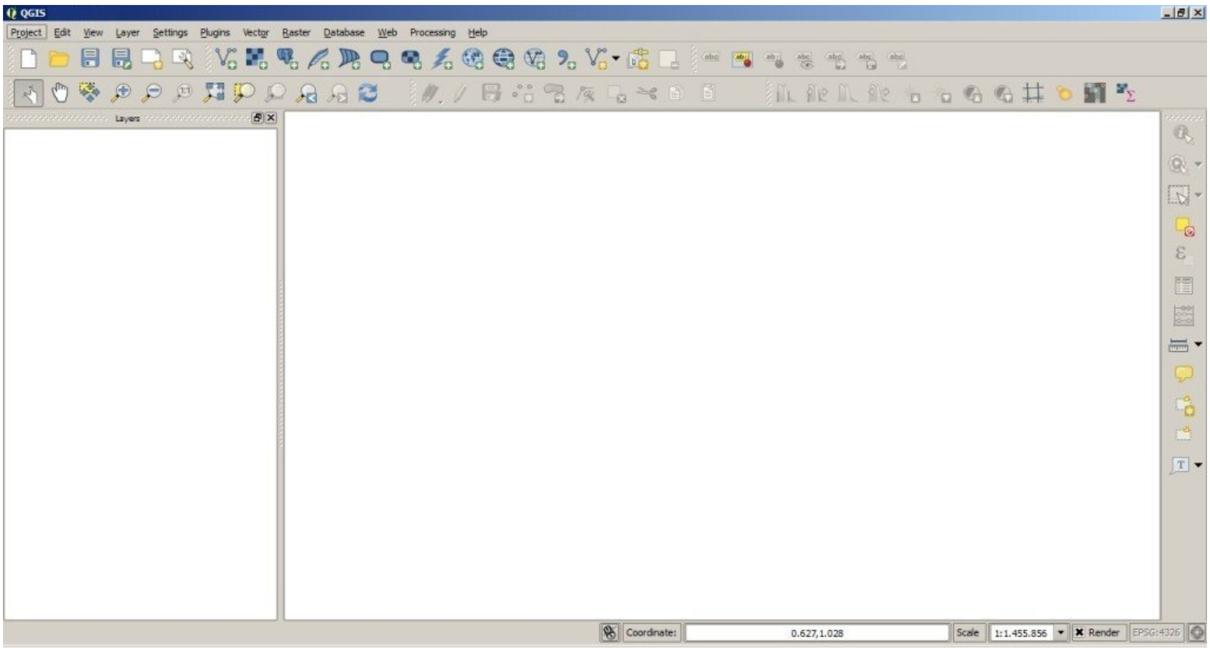
CAPITOLO 2

Installation in Windows 64 bit

Scaricamento e installazione di QGIS

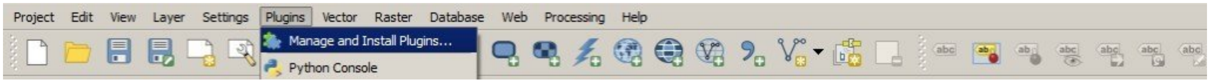
- Download the latest QGIS version 64 bit from here (the direct download of QGIS 2.8 from this link);
- Execute the QGIS installer with administrative rights, accepting the default configuration.

Now, QGIS 2 is installed.



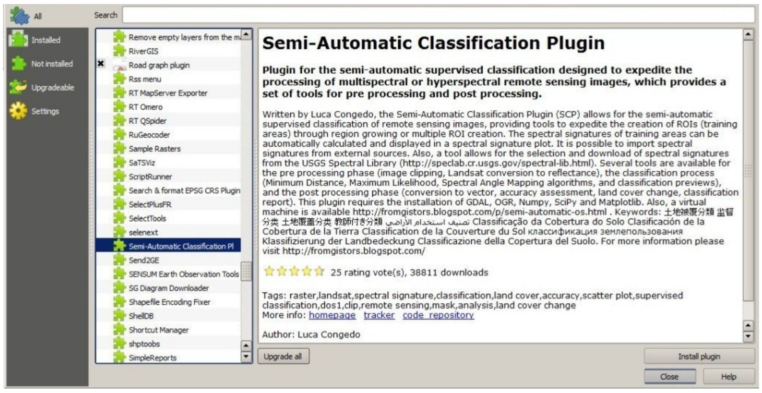
Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;

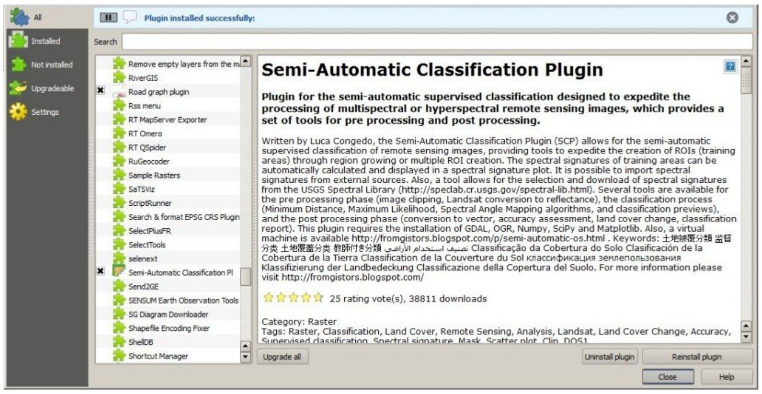


- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

  TIP: in case of issues or an offline installation is required see *Come installare il plugin manualmente?* (pagina 257) and *How to install the plugin from the official SCP repository?* (pagina 257).



- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);



Configuration of the plugin

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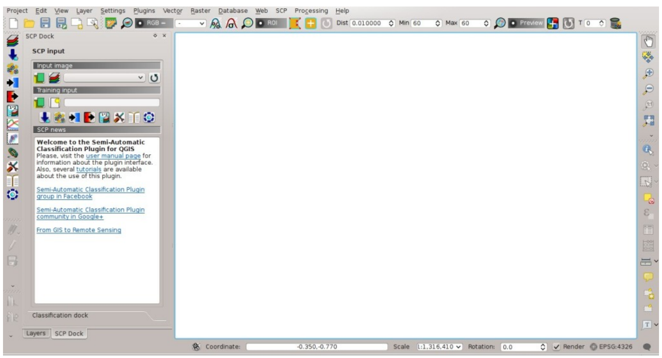
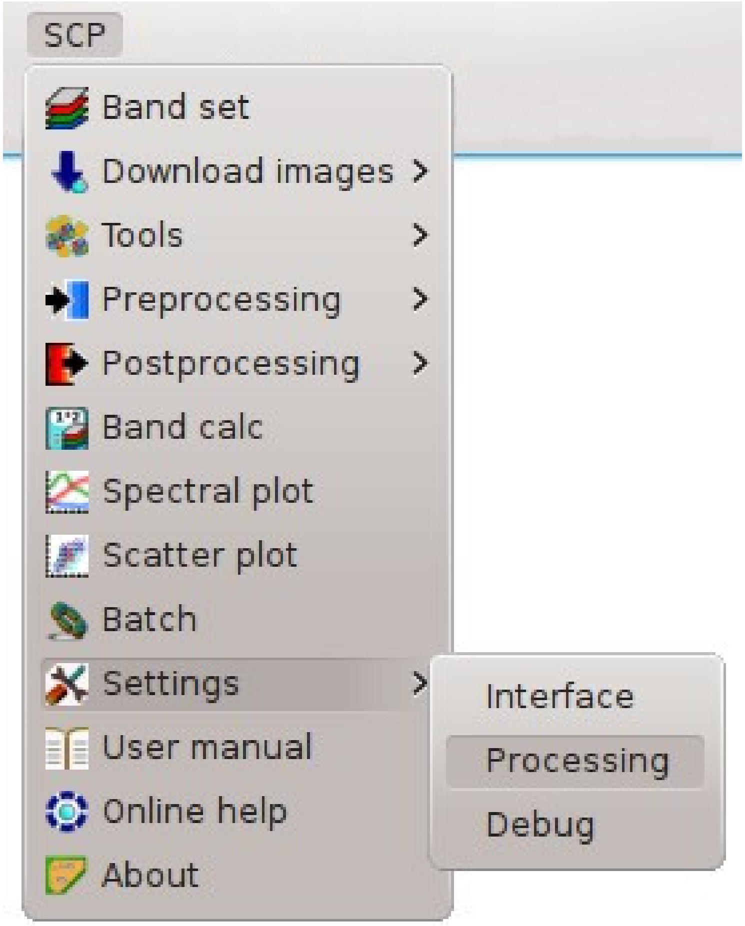
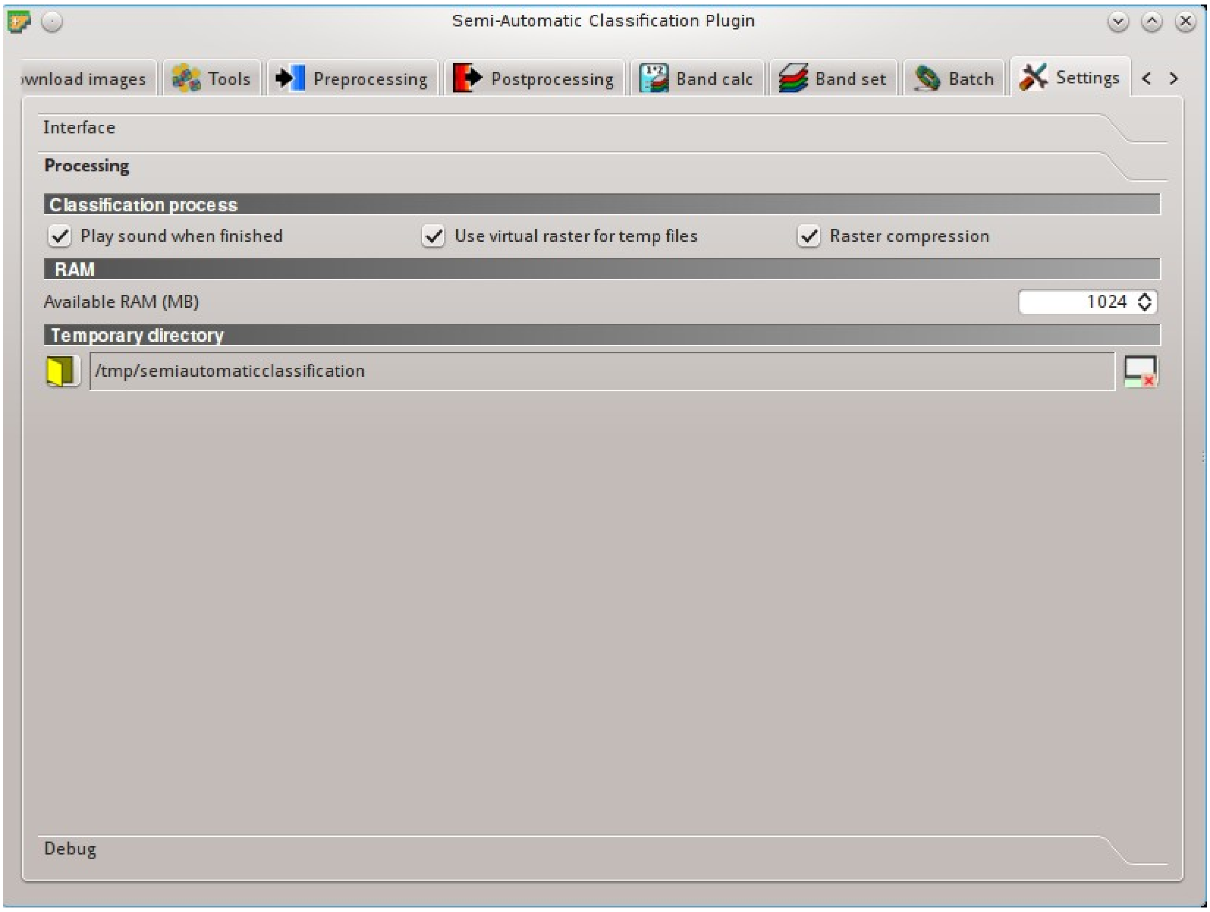


The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu* (pagina 29) select `Settings > Processing`.



In the *Settings* (pagina 116), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.


Semi-Automatic Classification Plugin
ownload images
Tools
Preprocessing
Postprocessing
Band calc
Band set
Batch
Settings
Interface
Processing
Classification process
Play sound when finished
Use virtual raster for temp files
Raster compression
RAM
Available RAM (MB)
1024
Temporary directory
/tmp/semiautomaticclassification
Debug

CAPITOLO 3

Installation in Ubuntu Linux

Scaricamento e installazione di QGIS

- Apri un terminale e digita:

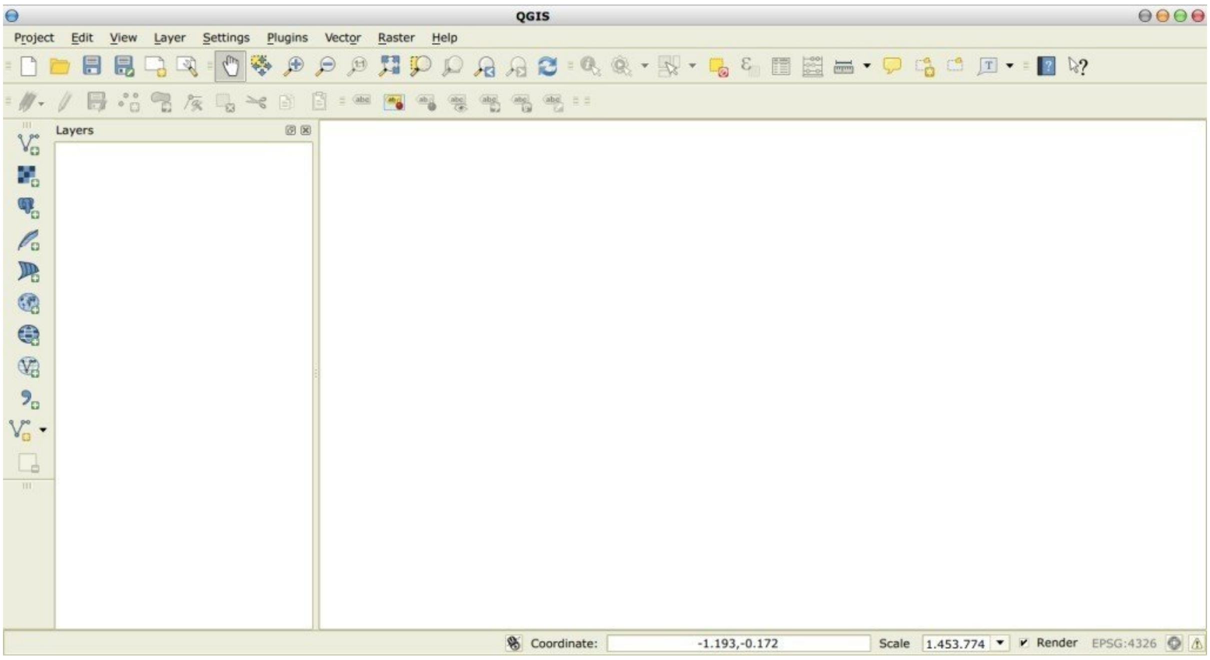
```
sudo apt-get update
```

- Prego Inserire la user password;
- Type in a terminal:

```
sudo apt-get install qgis python-matplotlib python-scipy
```

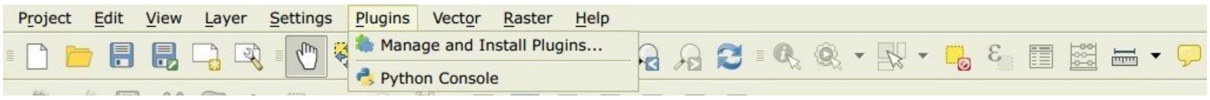
- Press Enter and wait until the software is downloaded and installed.

Now, QGIS 2 is installed.



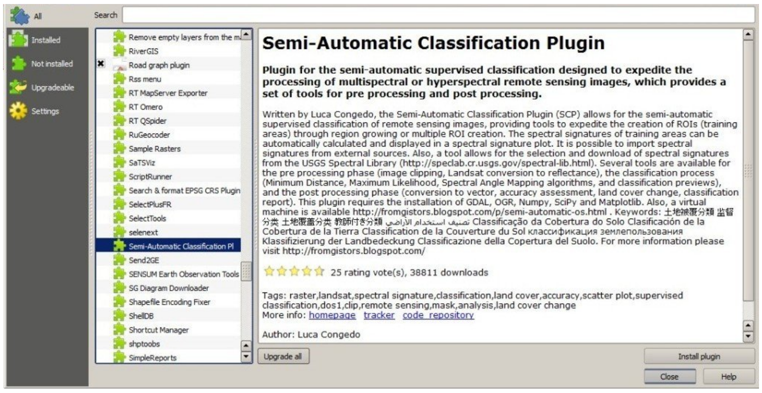
Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;

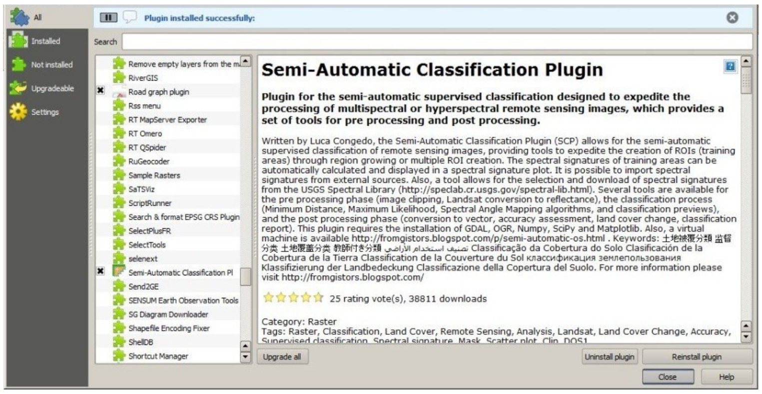


- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

  TIP: in case of issues or an offline installation is required see *Come installare il plugin manualmente?* (pagina 257) and *How to install the plugin from the official SCP repository?* (pagina 257).

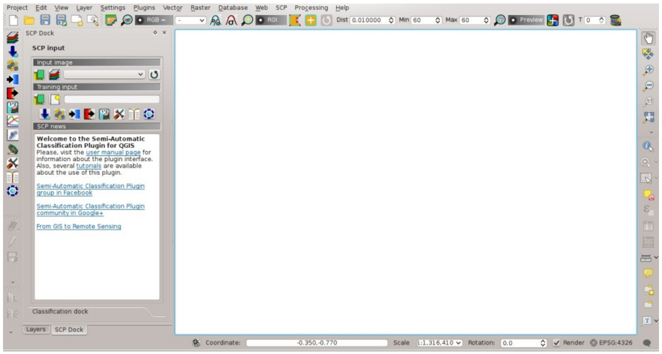


- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);

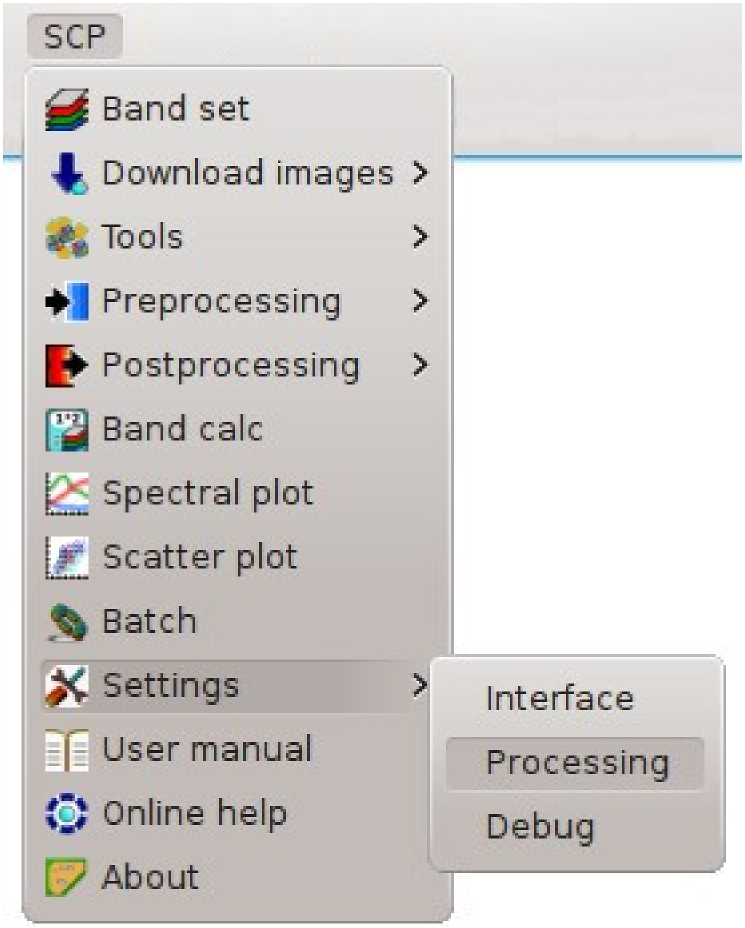


Configuration of the plugin

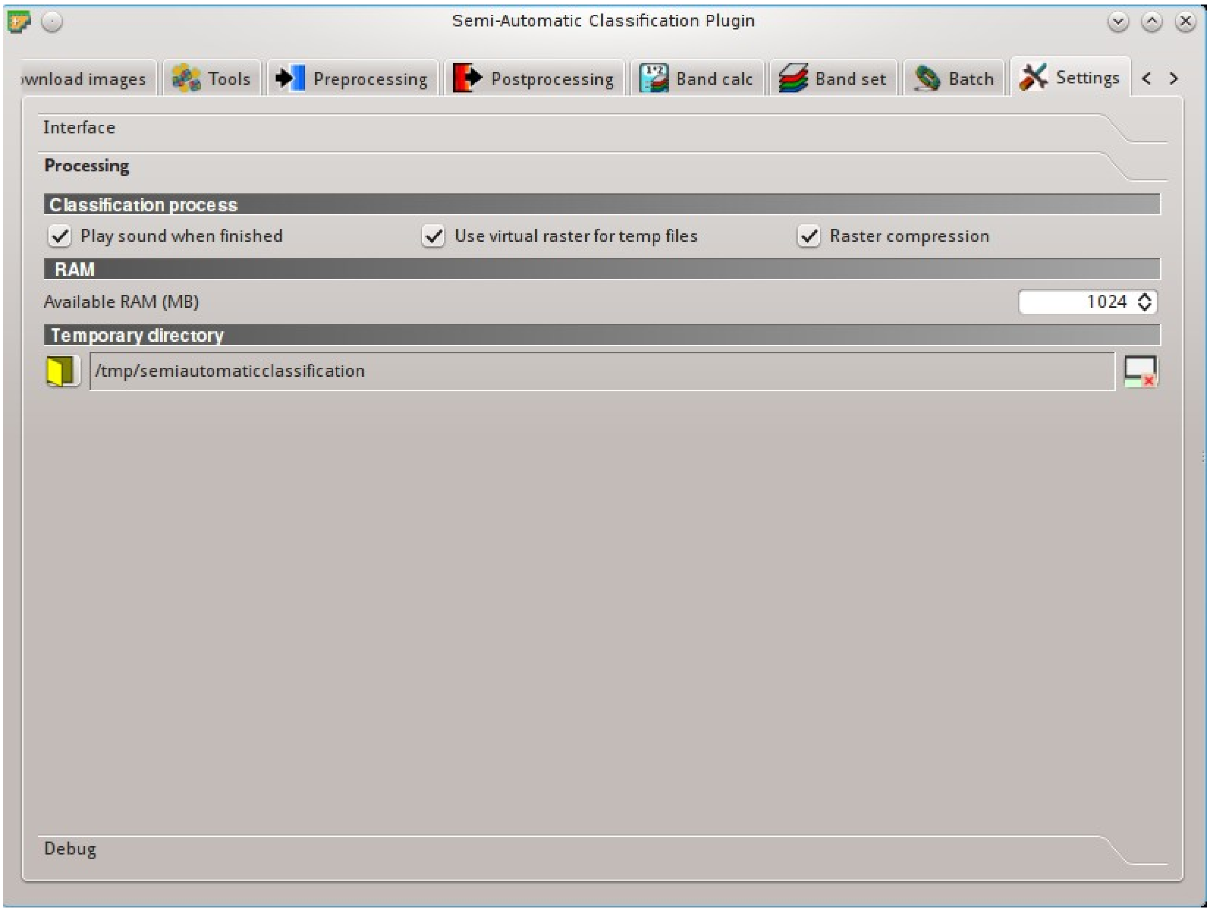
Now, the Semi-Automatic Classification Plugin is installed and a dock and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *SCP Tools* (pagina 31) and the dock according to your needs, as in the following image.



The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu* (pagina 29) select  `Settings > Processing`.



In the *Settings* (pagina 116), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.


Semi-Automatic Classification Plugin
ownload images
Tools
Preprocessing
Postprocessing
Band calc
Band set
Batch
Settings
Interface
Processing
Classification process
Play sound when finished
Use virtual raster for temp files
Raster compression
RAM
Available RAM (MB)
1024
Temporary directory
/tmp/semiautomaticclassification
Debug

CAPITOLO 4

Installation in Debian Linux

Scaricamento e installazione di QGIS

- Apri un terminale e digita:

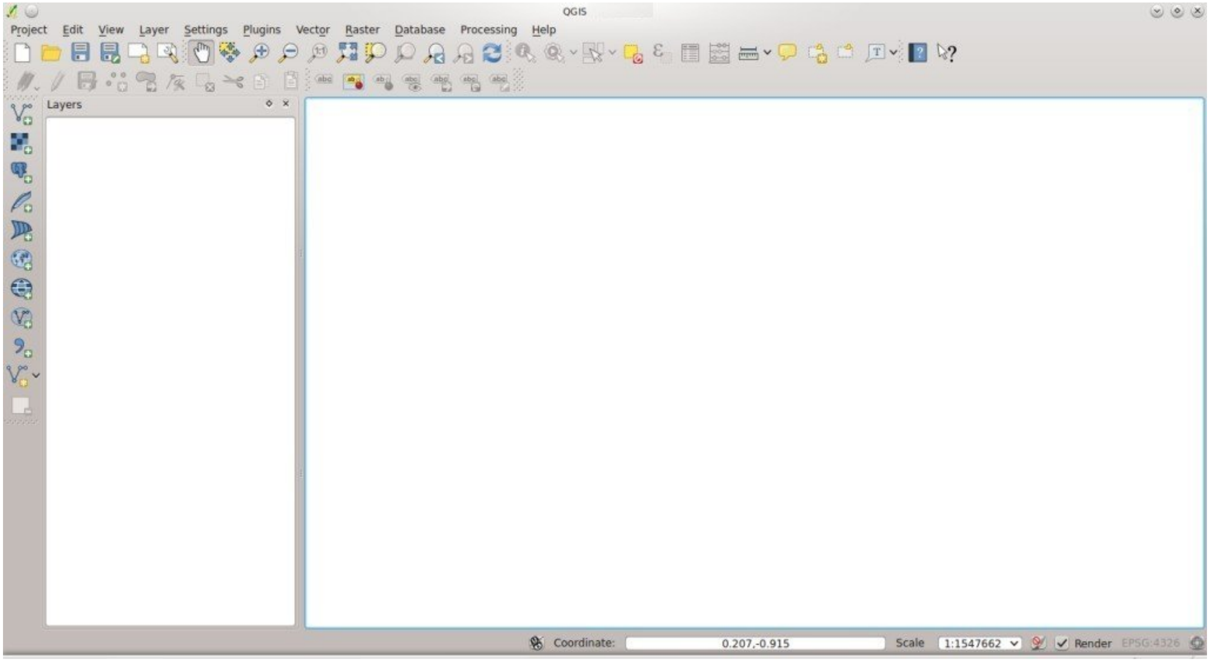
```
sudo apt-get update
```

- Prego Inserire la user password;
- Type in a terminal:

```
sudo apt-get install qgis python-matplotlib python-scipy
```

- Press Enter and wait until the software is downloaded and installed.

Now, QGIS 2 is installed.

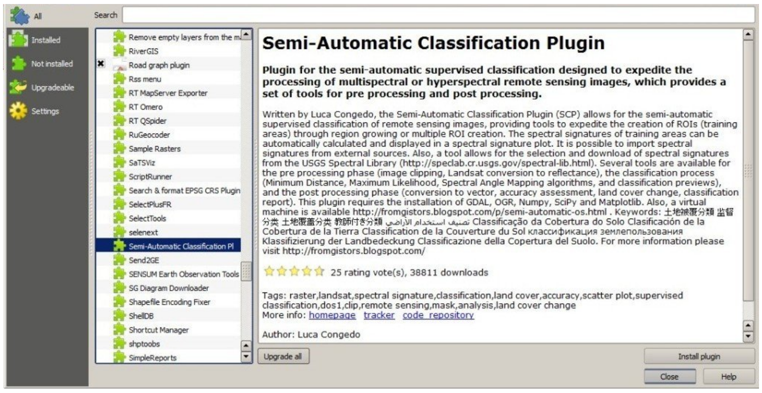


Semi-Automatic Classification Plugin installation

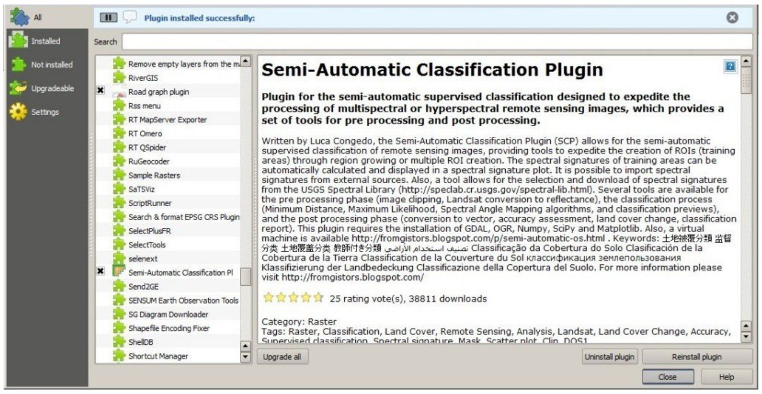
- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;

- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

  TIP: in case of issues or an offline installation is required see *Come installare il plugin manualmente?* (pagina 257) and *How to install the plugin from the official SCP repository?* (pagina 257).

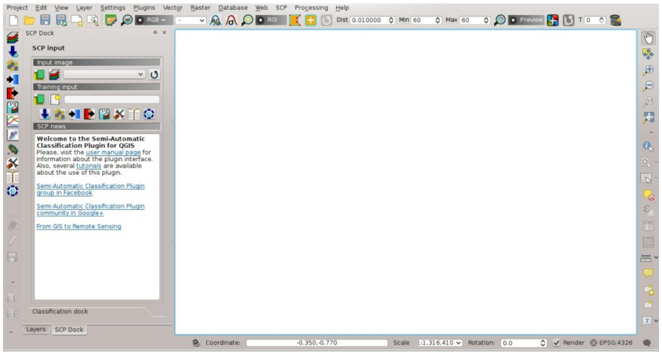


- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);

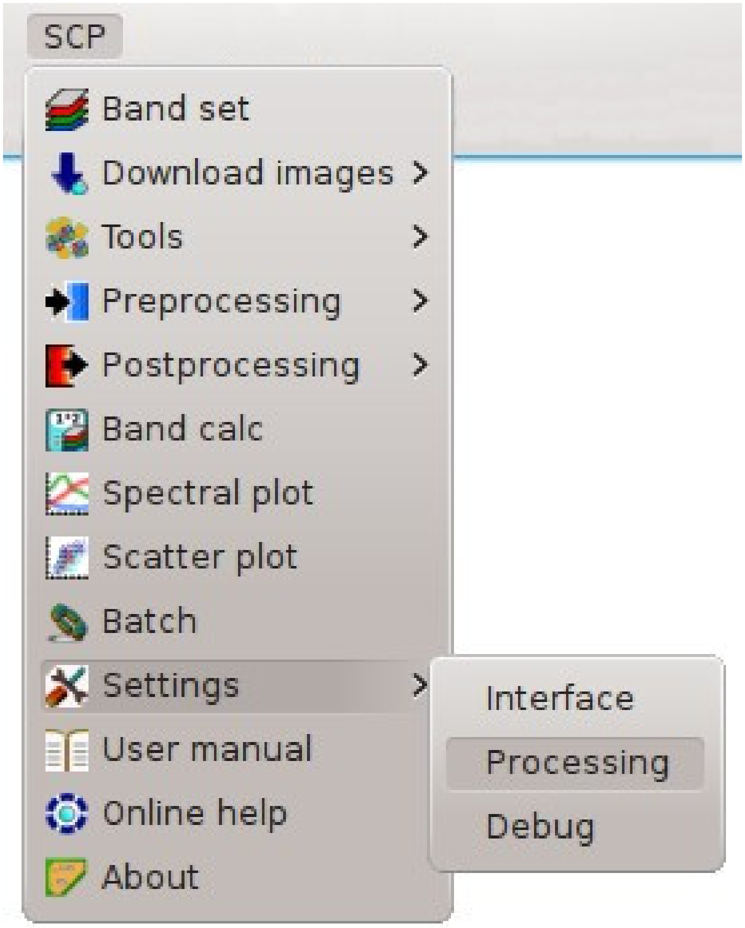


Configuration of the plugin

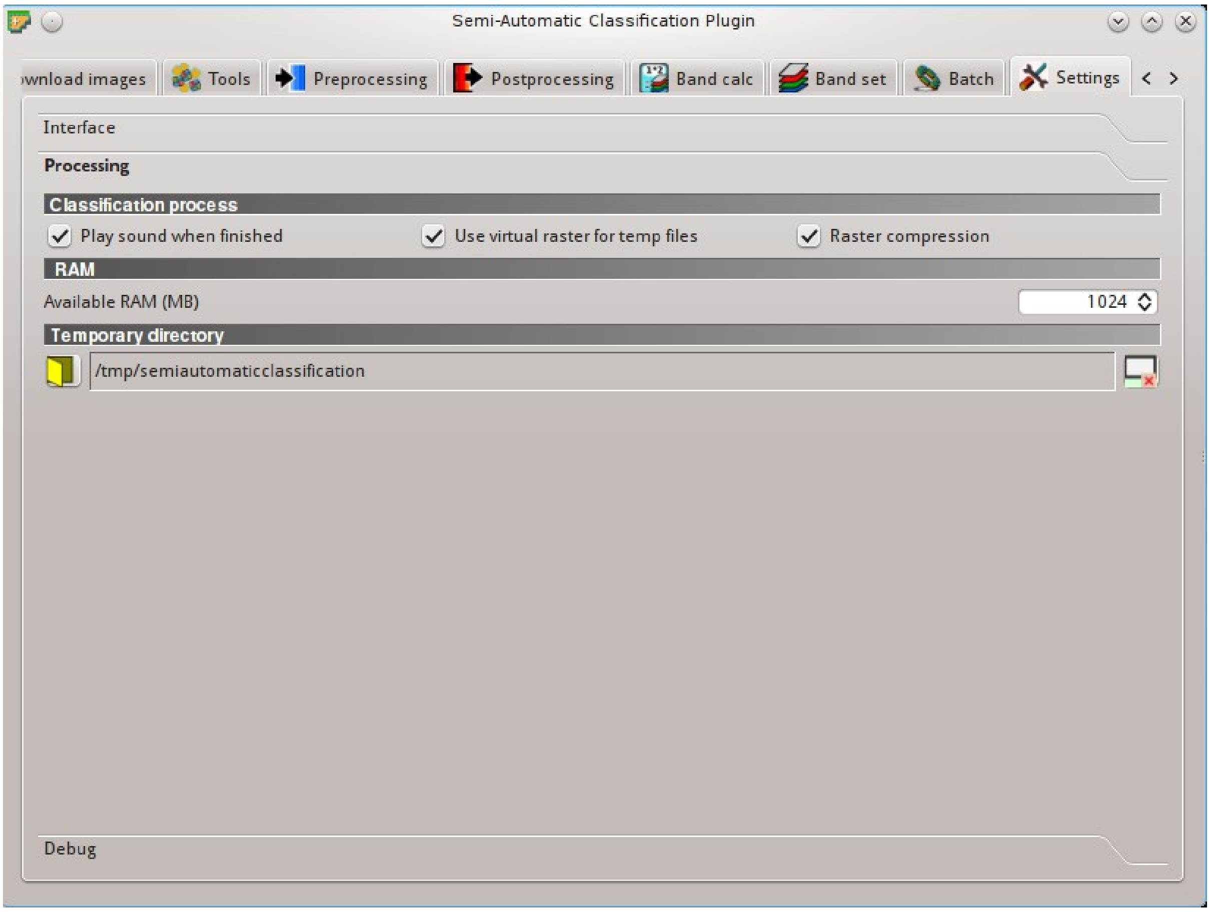
Now, the Semi-Automatic Classification Plugin is installed and a dock and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *SCP Tools* (pagina 31) and the dock according to your needs, as in the following image.



The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu* (pagina 29) select `Settings > Processing`.



In the *Settings* (pagina 116), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.


Semi-Automatic Classification Plugin
wnload images
Tools
Preprocessing
Postprocessing
Band calc
Band set
Batch
Settings
Interface
Processing
Classification process
Play sound when finished
Use virtual raster for temp files
Raster compression
RAM
Available RAM (MB)
1024
Temporary directory
/tmp/semiautomaticclassification
Debug

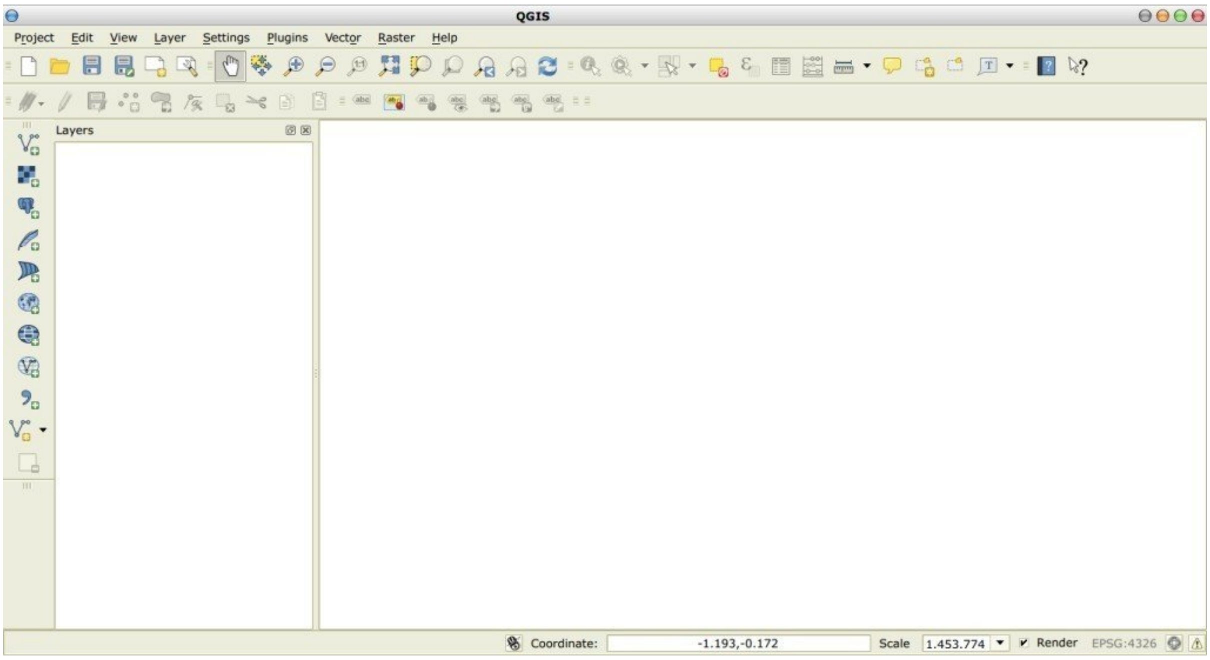
CAPITOLO 5

Installation in Mac OS

Scaricamento e installazione di QGIS

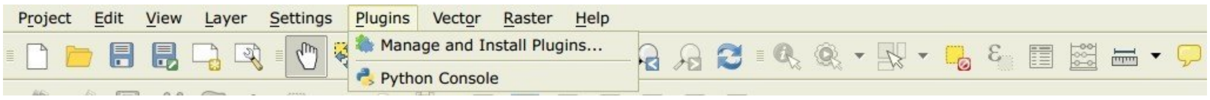
- Scarica ed installa la piùrecente versione di QGIS e GDAL da qui http://www.kyngchaos.com/software/qgis .
- In addition, download and install the python modules Numpy, Scipy, and Matplotlib from this link .

Now, QGIS 2 is installed.



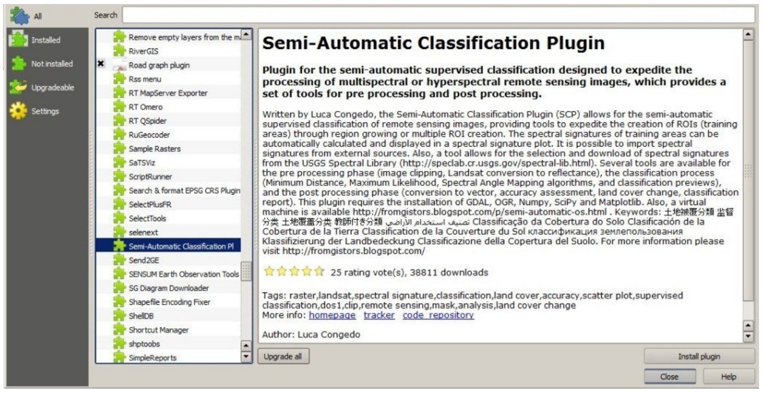
Semi-Automatic Classification Plugin installation

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;

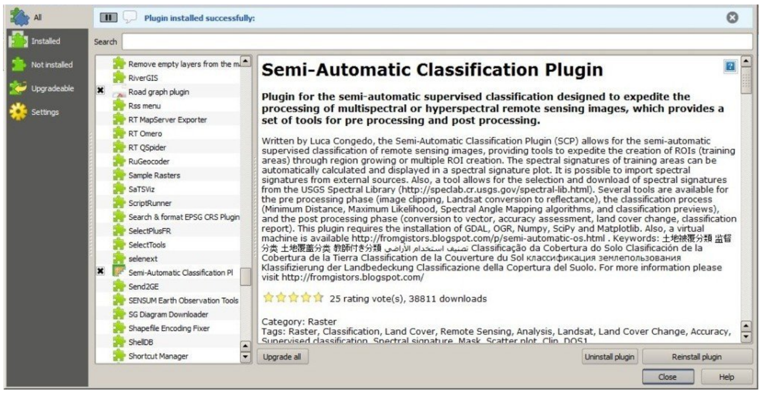


- From the menu `All`, select the Semi-Automatic Classification Plugin and click the button `Install plugin`;

  TIP: in case of issues or an offline installation is required see *Come installare il plugin manualmente?* (pagina 257) and *How to install the plugin from the official SCP repository?* (pagina 257).

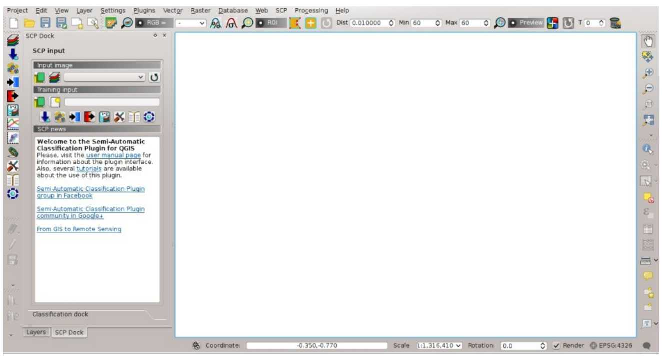


- The SCP should be automatically activated; however, be sure that the Semi-Automatic Classification Plugin is checked in the menu `Installed` (the restart of QGIS could be necessary to complete the SCP installation);

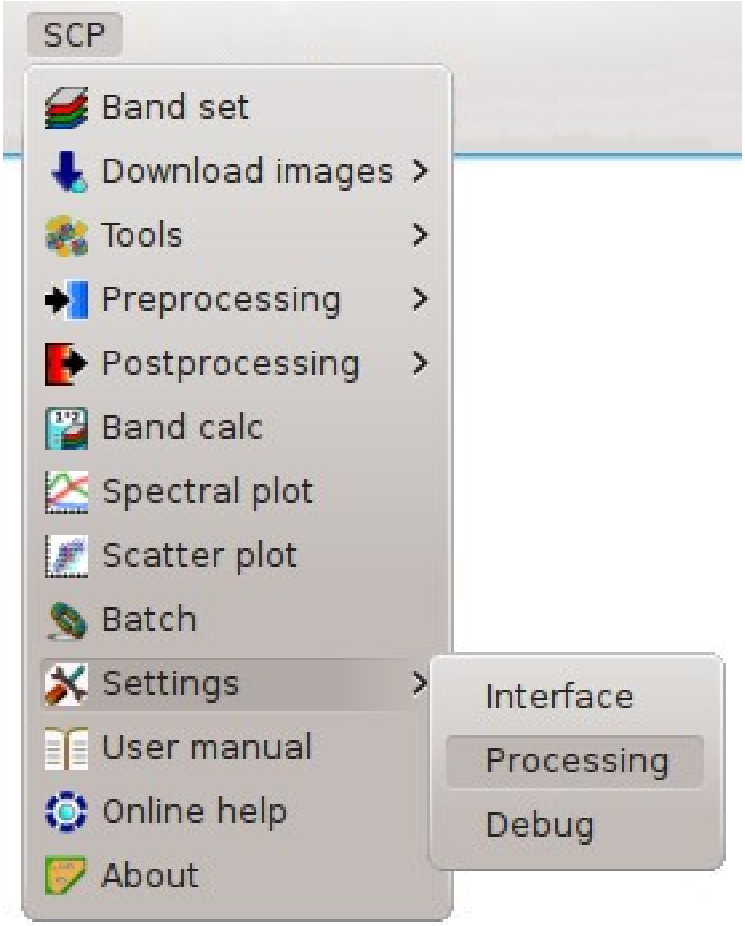


Configuration of the plugin

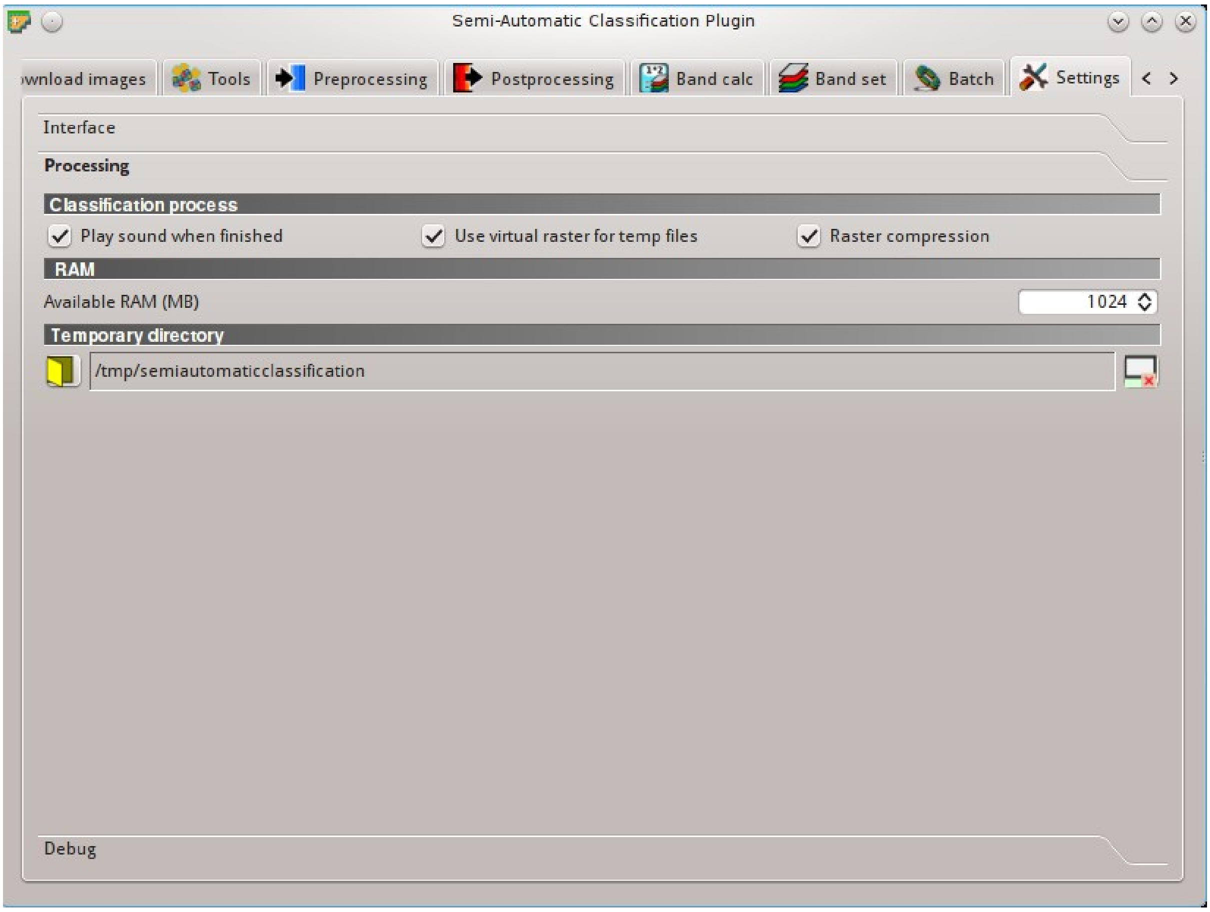
Now, the Semi-Automatic Classification Plugin is installed and a dock and a toolbar should be added to QGIS. Also, a SCP menu is available in the Menu Bar of QGIS. It is possible to move the *SCP Tools* (pagina 31) and the dock according to your needs, as in the following image.



The configuration of available RAM is recommended in order to reduce the processing time. From the *SCP menu* (pagina 29) select  `Settings > Processing`.



In the *Settings* (pagina 116), set the `Available RAM (MB)` to a value that should be half of the system RAM. For instance, if your system has 2GB of RAM, set the value to 1024MB.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Raster compression
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Available RAM (MB)
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Temporary directory
/tmp/semiautomaticclassification
Debug

Parte III

The Interface of SCP

CAPITOLO 6

SCP menu

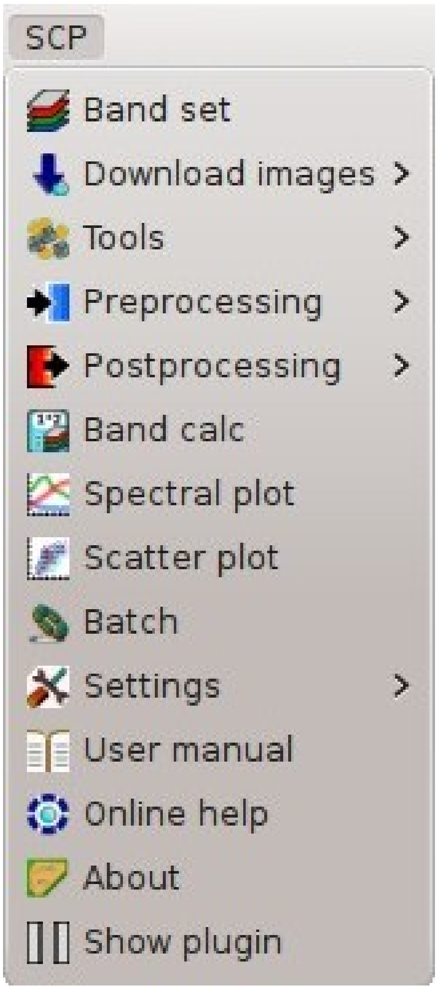


Fig. 6.1: *SCP menu*

The *SCP menu* allows for the selection of the main functions of the *Finestra Interfaccia Principale* (pagina 49), the *Spectral Signature Plot* (pagina 123), and the *Scatter Plot* (pagina 129).

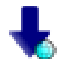
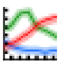
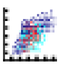
- *Band set* (pagina 110);
- *Download images* (pagina 51);
- *Tools* (pagina 65);
- *Preprocessamento* (pagina 77);
- *Postprocessamento* (pagina 91);
- *Band calc* (pagina 104);
- *Spectral Signature Plot* (pagina 123);
- *Scatter Plot* (pagina 129);
- *Batch* (pagina 114);
- *Settings* (pagina 116);
- *User manual*: open the online user manual in a web browser;
- *Online help*: open the Online help in a web browser; also, a Facebook group and a Google+ Community are available for sharing information and asking for help about SCP;
- *Show plugin*: show all the SCP toolbars and dock if previously hidden;

CAPITOLO 7

SCP Tools

Fig. 7.1: *SCP Tools*

The toolbar *SCP Tools* allows for the selection of the main functions of the *Finestra Interfaccia Principale* (pagina 49), the *Spectral Signature Plot* (pagina 123), and the *Scatter Plot* (pagina 129).

-  *Band set* (pagina 110);
-  *Download images* (pagina 51);
-  *Tools* (pagina 65);
-  *Preprocessamento* (pagina 77);
-  *Postprocessamento* (pagina 91);
-  *Band calc* (pagina 104);
-  *Spectral Signature Plot* (pagina 123);
-  *Scatter Plot* (pagina 129);
-  *Batch* (pagina 114);
-  *Settings* (pagina 116);
-  *User manual*: open the online user manual in a web browser;

- *Online help*: open the Online help in a web browser; also, a Facebook group and a Google+ Community are available for sharing information and asking for help about SCP;

CAPITOLO 8

Working toolbar

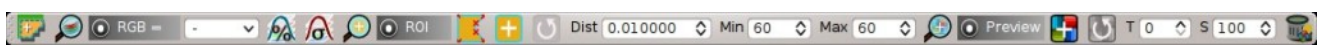


Fig. 8.1: *Working toolbar*

The *Working toolbar* allows for displaying the *Input image* (pagina 38), creating *temporary ROIs* and *classification previews*.

The functions are described in detail in the following paragraphs, using these conventions:

 = Input date

`[I]` = Input text

 = List

 = Input number

 = Optional

 = Configuration stored in the active project of QGIS

 = Configuration stored in QGIS registry

 = Slider

 = Table

Image control

-  : show the *Finestra Interfaccia Principale* (pagina 49);
-  : zoom the map to the extent of *Input image* (pagina 38);

- *RGB=* : use the button to show/hide the *Input image* (pagina 38) in the map; from the list select a *Colore Composito* (pagina 147) that is applied to the *Input image* (pagina 38); new color composites can be entered typing the band numbers separated by `-` or `;` or `,` (e.g. RGB = 4-3-2 or RGB = 4;3;2 or RGB = 4,3,2);
- : display the input image stretching the minimum and maximum values according to cumulative count of current map extent;
- : display the input image stretching the minimum and maximum values according to standard deviation of current map extent;

Temporary ROI

A *temporary ROI* is a temporary polygon displayed in the map, which can be saved permanently in the *Training input* (pagina 40). A *temporary ROI* can be drawn manually or using a *Region Growing Algorithm* (pagina 151).

- : zoom the map to the extent of *temporary ROI*;
- *ROI*: use the button to show/hide the *temporary ROI* and the *Training input* in the map;
- : activate the pointer to create a *temporary ROI* by drawing a polygon in the map; left click on the map to define the ROI vertices and right click to define the last vertex closing the polygon; press the keyboard button `CTRL` to add a multipart polygon; press the keyboard buttons `CTRL + Z` for removing the last multipart polygon;
- : activate the pointer to create a *temporary ROI* using the region growing algorithm; left click on the map for creating the ROI; right click on the map for displaying the spectral signature of a pixel of the *Input image* (pagina 38) in the *Spectral Signature Plot* (pagina 123); press the keyboard button `CTRL` to add a multipart polygon (new parts are not created if overlapping to other parts); press the keyboard buttons `CTRL + Z` for removing the last multipart polygon;
- : create a *temporary ROI* using the region growing algorithm at the same seed pixel as the previous one; it is useful after changing the *region growing parameters*;

***Region growing parameters*: the following parameters are required for the ROI creation using a region growing algorithm o**

  - *Dist* : set the interval which defines the maximum spectral distance between the seed pixel and the surrounding pixels (in radiometry unit);
  - *Min* : set the minimum area of a ROI (in pixel unit); this setting overrides the `Range radius` until the minimum ROI size is reached; if `Rapid ROI on band` is checked, then ROI will have at least the size defined `Min ROI size`; if `Rapid ROI on band` is unchecked, then ROI could have a size smaller than `Min ROI size`;
  - *Max* : set the maximum width of a ROI (i.e. the side length of a square, centred at the seed pixel, which inscribes the ROI) in pixel unit;

Classification preview

Classification preview allows for displaying temporary classifications (i.e. classification previews). Classification previews are useful for testing the algorithm in a small area of the *Input image* (pagina 38), before classifying the entire image which can be time consuming (see *Classification output* (pagina 46)).

Classification preview is performed according to the parameters defined in *Classification algorithm* (pagina 44).

In addition to the classification raster, an *Algorithm raster* (pagina 158) can be displayed, which is useful for assessing the distance of a pixel classified as `class X` from the corresponding spectral signature *X*. In *Classification previews*, black pixels are distant from the corresponding spectral signature (i.e. probably a new ROI, or spectral signature, should be collected in that area) and white pixels are closer to the corresponding spectral signature (i.e. probably the spectral signature identifies correctly those pixels).

After the creation of a new preview, old previews are placed in QGIS Layers inside a layer group named `Class_temp_group` (custom name can be defined in *Temporary group name* (pagina 118)) and are deleted when the QGIS session is closed.

> **WARNING**: Classification previews are automatically deleted from disk when the QGIS session is closed; a QGIS message (that can be ignored) could ask for the path of missing layers when opening a previously saved project.

- : zoom the map to the extent of the last *Classification preview* (pagina 35);
- *Preview*: use the button to show/hide the last *Classification preview* (pagina 35) in the map;
- : activate the pointer for the creation of a *Classification preview* (pagina 35); left click the map to start the classification process and display the classification preview; right click to start the classification process and show the *Algorithm raster* (pagina 158) of the preview;
- : create a new *Classification preview* (pagina 35) centred at the same pixel as the previous one;
- *T* 1: change dynamically the classification preview transparency, which is useful for comparing the classification to other layers;
- *S* 1 : size of the preview in pixel unit (i.e. the side length of a square, centred at the clicked pixel);
- : remove from QGIS the *classification previews* that are archived in the *Class_temp_group*;

CAPITOLO 9

SCP dock

The *SCP dock* allows for the definition of inputs, the creation of ROIs (Regions Of Interest) and spectral signatures, and the classification of an input image.

The *Input image* (pagina 38), to be classified, can be a multi-band raster or a set of single bands defined in the *Band set* (pagina 110).

The *Training input* (pagina 40), created with *SCP*, stores the ROI polygons and spectral signatures used for the land cover classification of the *Input image* (pagina 38).

ROIs are polygons used for the definition of the spectral characteristics of land cover classes. *SCP* allows for the creation of *temporary ROI polygons* using a region growing algorithm or drawn manually. Using the region growing algorithm the image is segmented around a pixel seed including spectrally homogeneous pixels. *Temporary ROI polygons* can be saved in the *Training input* (pagina 40) along with the spectral signatures of the ROI. It is worth pointing out that classification is always based on spectral signatures.

In *SCP*, land cover classes (and ROIs) are defined with a system of *Classes* (*Class ID*) and *Macroclasses* (*Macroclass ID*) (see *Classi e Macroclassi* (pagina 153)) that are used for the classification process; each *Macroclass ID* is related to a *Macroclass Information* (e.g. macroclass name) and each *Class ID* is related to a *Class Information* (e.g. class name), but only *Macroclass ID* and *Class ID* are used for the classification process.

Training input is composed of a vector part (i.e. a shapefile) and a spectral signature part which are independent. The attribute table of the vector contains four fields as in the following table.

Training input fields

Description	Field name	Field type
Macroclass ID	MC_ID	int
Macroclass Information	MC_info	string
Class ID	C_ID	int
Class Information	C_info	string

Spectral signatures of classes are calculated from the ROIs and saved in the *Training input* (pagina 40). In addition, spectral signatures can be imported from other sources (see *Import signatures* (pagina 67)).

The use of the *Macroclass ID* or *Class ID* for classifications is defined with the option *Use MC ID or C ID* in the *Classification algorithm* (pagina 44). It is worth highlighting that when using *Macroclass ID* all the spectral signatures are evaluated separately and each pixel is classified with the corresponding *MC ID* (i.e. there is no combination of signatures before the classification).

La **classification** può essere eseguita per l'intera immagine (*Classification output* (pagina 46)) o per una parte di essa, creando una *Classification preview* (pagina 35).

The functions are described in detail in the following paragraphs, using these conventions:

= Input date

= Input text

= List

= Input number

= Optional

= Configuration stored in the active project of QGIS

= Configuration stored in QGIS registry

= Slider

= Table

SCP input it

Input image

This section allows for the selection of the image to be classified. Raster files must be already loaded in QGIS.

Input image can be a multi-band raster or a set of single bands defined in the *Band set* (pagina 110). If a multi-band raster is selected, raster bands are listed in the *Band set* (pagina 110).

- : open one or more raster files and add them *Band set* (pagina 110);
- : open the *Band set* (pagina 110);
- *Input image* : select the input image from a list of multi-spectral images loaded in QGIS; if the *Band set* (pagina 110) is defined, then this list will contain the item << *band set* >>;

Fig. 9.1: *SCP input*

- : refresh layer list;

Training input

The training input is a file `.scp` created in *SCP* (i.e. a zip file containing a shapefile and an xml file) used for storing ROIs and spectral signatures.

> **Warning**: Signature list files saved with previous versions of *SCP* are not compatible with SPC 5; however you can import a ROI shapefile using the tool *Import shapefile* (pagina 67).

ROIs and spectral signatures are displayed in the *ROI Signature list* (pagina 41). ROIs and spectral signatures can be imported from other sources (see *Import signatures* (pagina 67)) and exported (see *Export signatures* (pagina 70)). ROIs are displayed in QGIS as vector file (in order to prevent data loss, you should not edit this layer using QGIS functions).

- : open a training input file; ROIs and spectral signatures are loaded in *ROI Signature list* (pagina 41); the vector part of the training input is loaded in QGIS;
- : create an empty training input file (`.scp`); the vector part of the training input is loaded in QGIS; also a backup file is created (a file `.scp.backup` in the same directory as the file `.scp`) when the training input file is saved;
- *Training input* : it displays the path to the training input file;
- : open the *Download images* (pagina 51);
- : open the *Tools* (pagina 65);
- : open the *Preprocessamento* (pagina 77);
- : open the *Postprocessamento* (pagina 91);
- : open the *Band calc* (pagina 104);
- : open the *Settings* (pagina 116);
- : open the online user manual in a web browser;
- : open the Online help in a web browser; also, a Facebook group and a Google+ Community are available for sharing information and asking for help about *SCP*;

SCP news

This section displays news about the *SCP* and related services. News are downloaded on startup (internet connection required). It can be enabled or disabled in the settings *Dock* (pagina 118).

Dock di classificazione

The *Classification dock* is designed to manage the **spectral signatures**, and **classify** the *Input image* (pagina 38).

ROI Signature list

Fig. 9.2: *ROI Signature list*

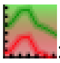
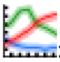
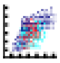
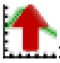
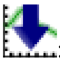
The *ROI Signature list* displays the ROI polygons and spectral signatures contained in the *Training input* (pagina 40). If an item is a ROI polygon, double click the item to zoom to that ROI in the map. Items in the table can be highlighted with the mouse left click.

Changes in the *ROI Signature list* are applied to the file *Training input* (pagina 40) only when the QGIS project is saved. ROIs can be edited, deleted and merged from this table.

> **WARNING**: In order to avoid data loss, do not edit the vector *Training input* using the QGIS tools. Use only the tools of *SCP* for managing the *Training input*.

-  ***ROI Signature list*:**
  - *S*: selection checkbox; only the spectral signatures checked in this list are used for the classification process;
  - ***Type*: type of the item:**
    - *R* = only ROI polygon;
    - *S* = only spectral signature;
    - *B* = both ROI and spectral signature;
  - *MC ID*: ROI Macroclass ID [int]; it can be edited with a single click; *MC Info* is displayed in *Macroclasses* (pagina 43); if the ID of a spectral signature is set 0, then pixels belonging to this signature are labelled as unclassified;
  - *C ID*: ROI Class ID [int]; it can be edited with a single click;

   - *C Info*: ROI Class Information [text]; it can be edited with a single click;
   - *Color*: C ID color; double click to select a color for the class that is used in the classification; if the ID of a spectral signature is set 0, then pixels belonging to this signature are labelled as unclassified;

- : delete highlighted ROIs and signatures;
- : merge highlighted spectral signatures or ROIs obtaining a new signature calculated as the average of signature values for each band (covariance matrix is excluded);
- : calculate spectral signatures of highlighted ROIs;
- : show the ROI spectral signature in the *Spectral Signature Plot* (pagina 123); spectral signature is calculated from the *Input image* (pagina 38);
-  : open the *Scatter Plot* (pagina 129);
- : open the tab *Export signatures* (pagina 70);
- : open the tab *Import signatures* (pagina 67);

Creazione ROI

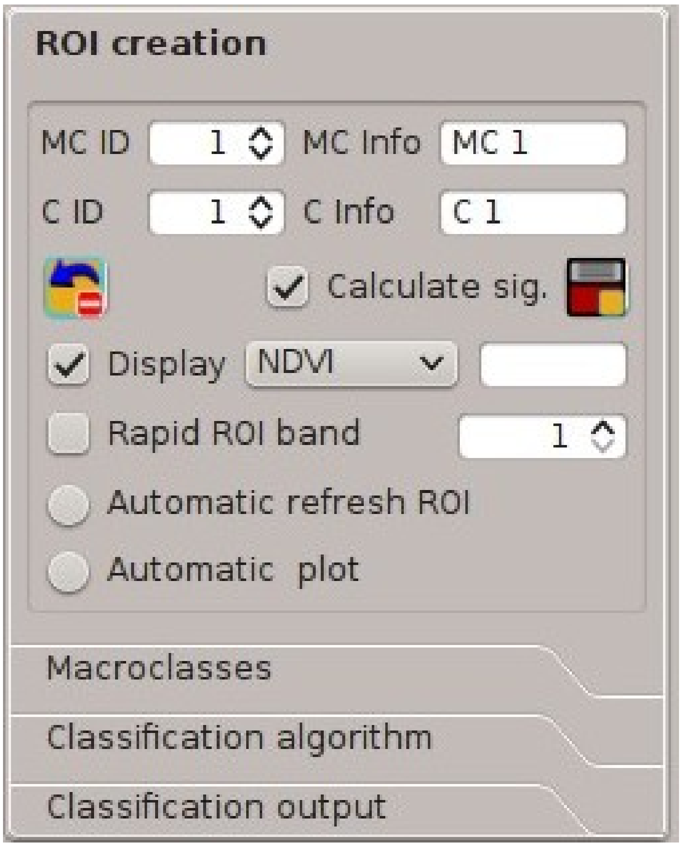


Fig. 9.3: *ROI creation*

ROI creation is complementary to the *Working toolbar* (pagina 33) and it allows for saving ROIs to the *Training input* (pagina 40) defining classes and macroclasses. A *Band set* (pagina 110) must be defined before the ROI creation, and ROI polygons must be inside the area of the *Band set*.

- *MC ID* : ROI Macroclass ID [int]; the corresponding *MC Info* is loaded if already defined in *Macroclasses* (pagina 43);
- *MC Info* : ROI Macroclass information [text]; style and information for macroclasses are defined in *Macroclasses* (pagina 43);
- *C ID* : ROI Class ID [int];
- *C Info* : ROI Class information [text];
- : delete the last saved ROI from the *Training input* (pagina 40);
- *Calculate sig.* : if checked, while saving a ROI, the spectral signature thereof is calculated (from *Input image* (pagina 38) pixels under ROI polygon) and saved to *Training input* (pagina 40) (calculation time depends on the band number of *Input image* (pagina 38));
- : save the temporary ROI to the *Training input* (pagina 40) using the defined classes and macroclasses; ROI is displayed in the *ROI Signature list* (pagina 41);
- ***Display*** **: if the ROI creation pointer is active (see *Working toolbar* (pagina 33)), the pixel value of select**

  - NDVI (Normalized Difference Vegetation Index); NDVI requires the near-infrared and red bands;
  - EVI (Enhanced Vegetation Index); EVI requires the blue, near-infrared and red bands converted to reflectance; wavelengths must be defined in the *Band set* (pagina 110);
  - Custom; use the custom expression defined in the following line *Expression*;

- *Expression* : set a custom expression; expression is based on the *Band set*; bands are defined as *bandset#b + band number* (e.g. `bandset#b1` for the first band of the *Band set*); for example NDVI for a Landsat image would be (`bandset#b4` - `bandset#b3`) / (`bandset#b4` + `bandset#b3`);
- *Rapid ROI band* : if checked, temporary ROI is created with region growing using only one *Input image* (pagina 38) band (i.e.region growing is rapider); the band is defined by the *Band set* number; if unchecked, ROI is the result of the intersection between ROIs calculated on every band (i.e. region growing is slower, but ROI is spectrally homogeneous in every band);
- *Automatic refresh ROI*: calculate automatically a new temporary ROI while *Region growing parameters* in the *Working toolbar* (pagina 33) are being changed;
- *Automatic plot*: calculate automatically the temporary ROI spectral signature and display it in the *Spectral Signature Plot* (pagina 123) (`MC Info` of this spectral signature is set `tempo_ROI`);

Macroclasses

Macroclasses allows for the definition of **Macroclass names and colors** (used to display the results of *Classification preview* (pagina 35) and *Classification output* (pagina 46)). According to *Classification algorithm* (pagina 44), classifications performed using *C ID* have the colors defined for classes in the *ROI Signature list* (pagina 41); classifications performed using *MC ID* have the colors defined in the *Macroclasses* (pagina 43).

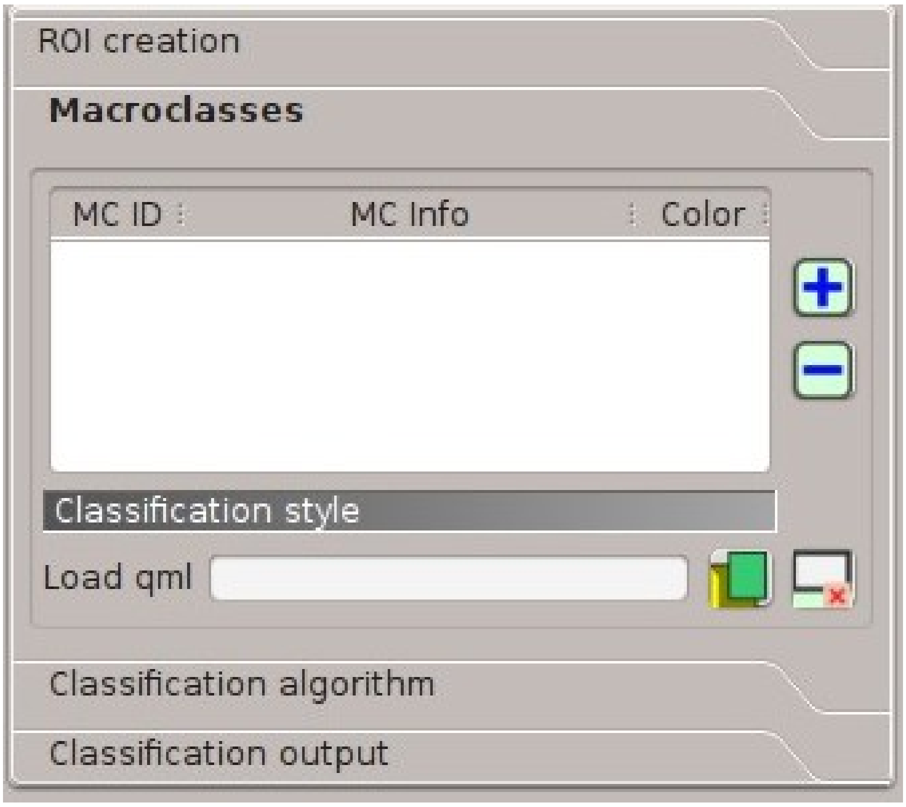
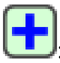
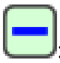


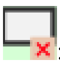
Fig. 9.4: *Macroclasses*

MC IDs are automatically added to this table when a new ROI is saved to the *ROI Signature list* (pagina 41) (if the *MC ID* is not already in the list). Settings are stored in *Training input* (pagina 40).

-  ***Macroclasses***  **:**
  - *MC ID*: Macroclass ID [int]; it can be edited with a single click;
  - *MC Info*: Macroclass Information [text]; it can be edited with a single click;
  - *Color*: MC ID color; double click to select a color for the class that is used in the classification;
- : add a new row to the table;
- : delete the highlighted rows from the table;

Classification style

In addition, a previously saved *classification style* (QGIS .qml file) can be loaded and used for classification style.

- *Load qml*  : select a .qml file overriding the colors defined for *C ID* or *MC ID*;
- : reset style to default (i.e. use the colors defined for *C ID* or *MC ID*);

Classification algorithm

The *Classification algorithm* includes several functions for the classification process used also during the *Classification preview* (pagina 35).

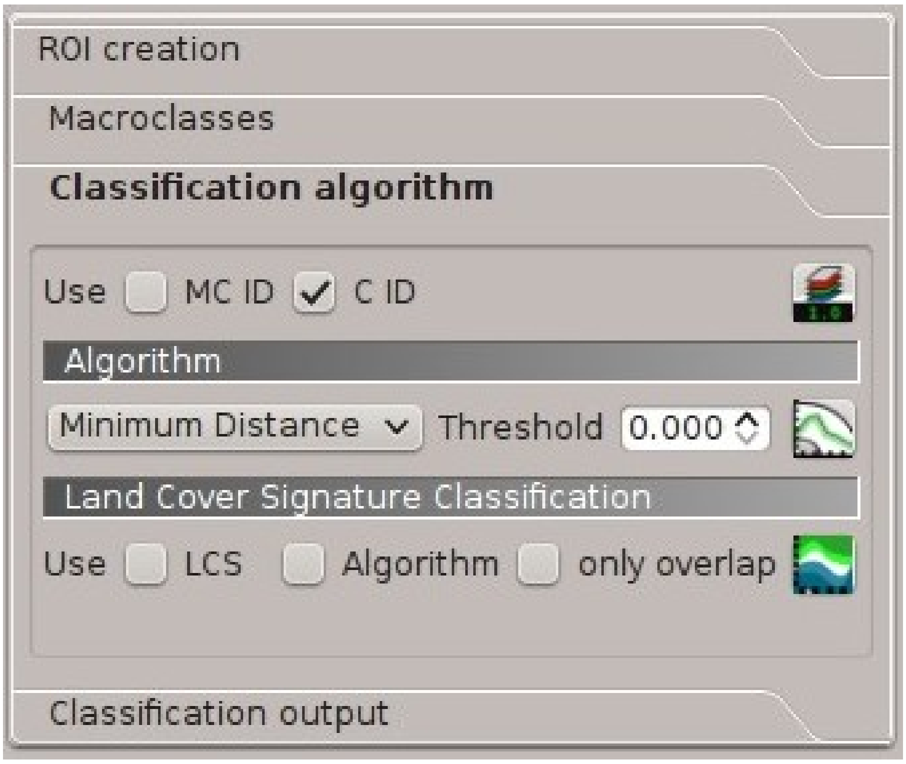


Fig. 9.5: *Classification algorithm*

- *Use* *MC ID* *C ID* : if *MC ID* is checked, the classification is performed using the Macroclass ID (code *MC ID* of the signature); if *C ID* is checked, the classification is performed using the Class ID (code *C ID* of the signature);
- : open the *Algorithm band weight* (pagina 71) for the definition of band weights;

Algorithm

Classification is performed using the selected algorithm.

- : available *Classification Algorithms* (pagina 154) are:
  - *Minimum Distance* (pagina 154);
  - *Maximum Likelihood* (pagina 154);
  - *Spectral Angle Mapping* (pagina 155);
- ***Threshold*** **: it allows for the definition of a classification threshold (applied to all the spectral signatures); fo**
    - for Minimum Distance, pixels are unclassified if distance is greater than threshold value;
    - for Maximum Likelihood, pixels are unclassified if probability is less than threshold value (max 100);
    - for Spectral Angle Mapping, pixels are unclassified if spectral angle distance is greater than threshold value (max 90);
- : open the *Signature threshold* (pagina 72) for the definition of signature thresholds;

Land Cover Signature Classification

Land Cover Signature Classification (pagina 156) is a classification that can be used as alternative or in combination with the *Algorithm* (pagina 45) (see *LCS threshold* (pagina 73)). Pixels belonging to two or more different classes (or macroclasses) are classified as *Class overlap* with raster value = -1000.

- *Use* *LCS* *Algorithm* *only overlap*: if *LCS* is checked, the *Land Cover Signature Classification* is used; if *Algorithm* is checked, the selected *Algorithm* (pagina 45) is used for unclassified pixels of the *Land Cover Signature Classification*; if *only overlap* is checked, the selected *Algorithm* (pagina 45) is used only for class overlapping pixels of the *Land Cover Signature Classification*; unclassified pixels of the *Land Cover Signature Classification* are left unclassified;
- : open the *LCS threshold* (pagina 73);

Classification output

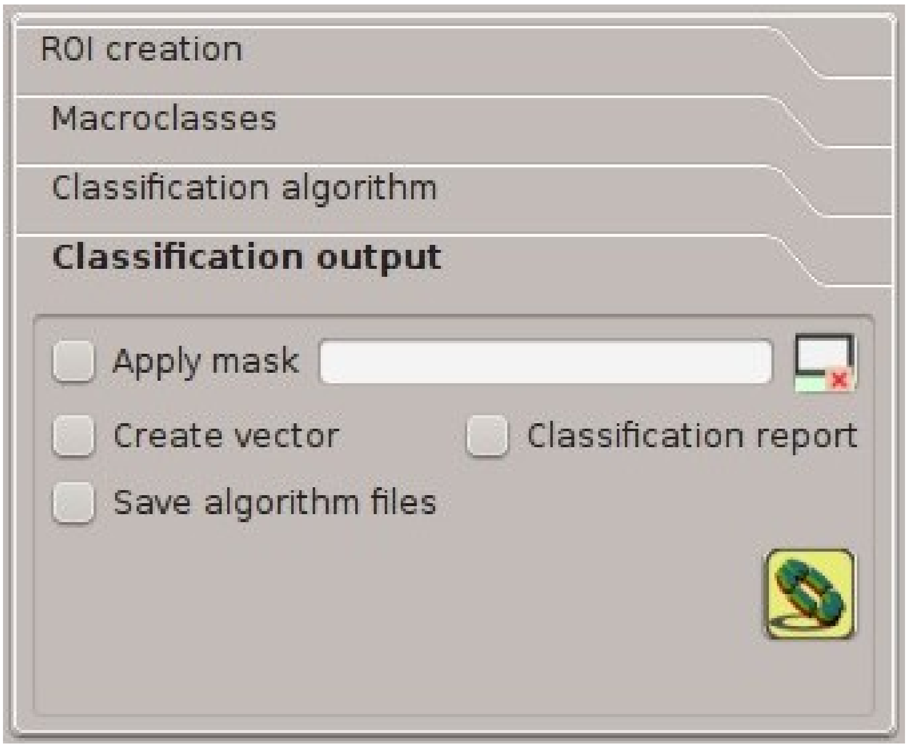


Fig. 9.6: *Classification output*

Classification output allows for the classification of the *Input image* (pagina 38) according to the parameters defined in *Classification algorithm* (pagina 44).

Classification raster is a file `.tif` (a QGIS style file `.qml` is saved along with the classification); also other outputs can be optionally calculated. Outputs are loaded in QGIS after the calculation.

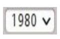
- *Apply mask* : if checked, a shapefile can be selected for masking the classification output (i.e. the area outside the shapefile is not classified);
- : reset the mask shapefile;

- *Create vector* : if checked, in addition to the classification raster, a classification shapefile is saved in the same directory and with the same name as the *Classification output*; conversion to vector can also be performed at a later time (see *Classification to vector* (pagina 96));
- *Classification report* : if checked, a report about the land cover classification is calculated and saved as a .csv file in the same directory and with the same name (with the suffix `_report`) as the *Classification output*; report can also be performed at a later time (see *Classification report* (pagina 94));
- *Save algorithm files* : if checked, the *Algorithm raster* (pagina 158) is saved, in addition to the classification raster, in the same directory as the *Classification output*; a raster for each spectral signature used as input (with the suffix `_sig_MC ID_C ID`) and a general algorithm raster (with the suffix `_alg_raster`) are created;
- : choose the output destination and start the image classification;

CAPITOLO 10

Finestra Interfaccia Principale

The Main Interface Window is composed of several tabs and subtabs. The functions are described in detail in the following paragraphs, using these conventions:



= Input date

= Input text

 = List

= Input number

 = Optional

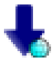
 = Configuration stored in the active project of QGIS

 = Configuration stored in QGIS registry

 = Slider

 = Table

Download images

The tab  *Download images* includes the tools for searching and downloading free remote sensing images. An internet connection is required.

Landsat download

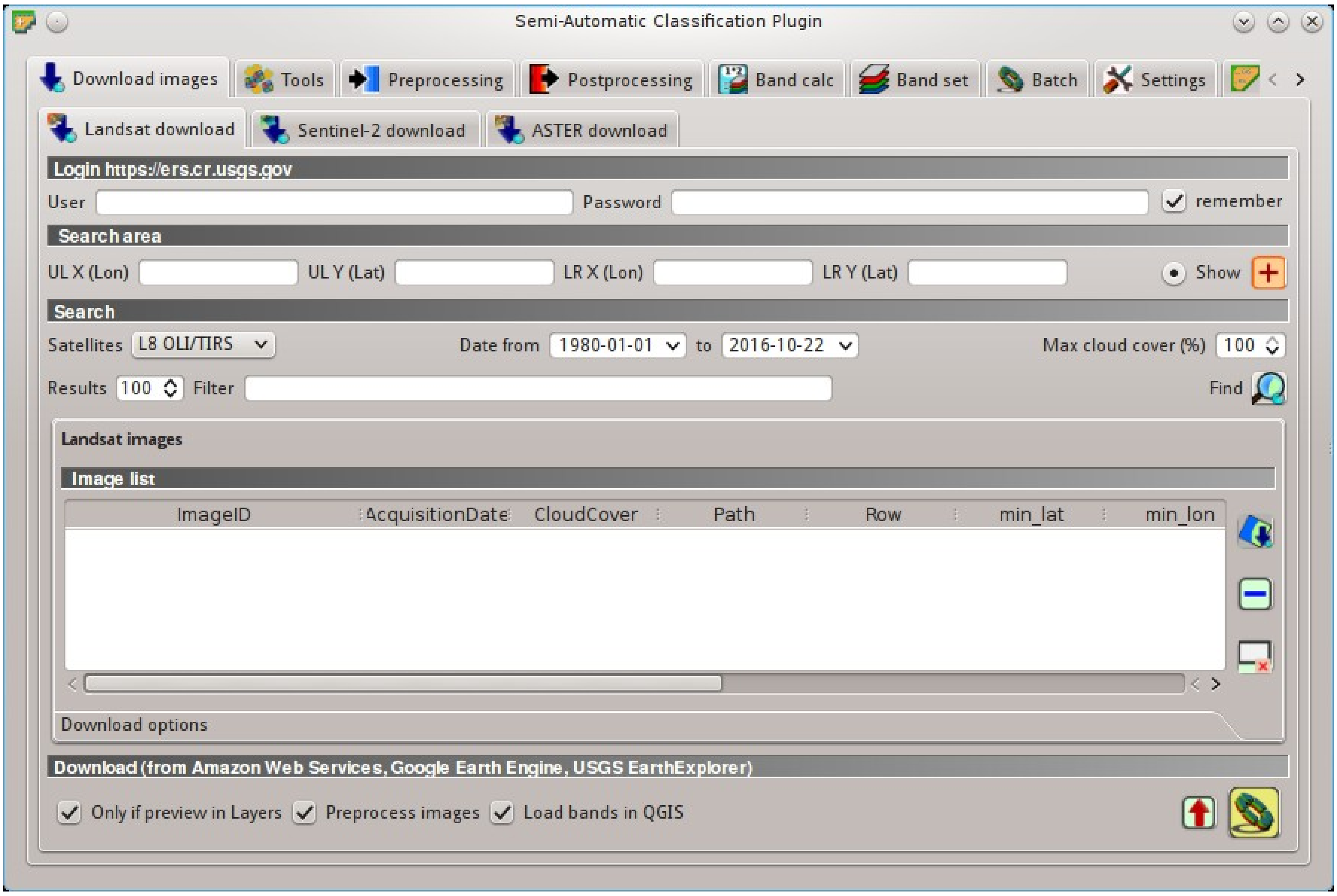
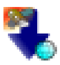


Fig. 10.1:  *Landsat download*

This tab allows for searching and downloading the whole archive of *Satellite Landsat* (pagina 143) images (from 1 MSS to 8 OLI), acquired from the 80s to present days. Search is performed through the CMR Search API developed by NASA.

Landsat images are freely available through the services: EarthExplorer , Google Earth Engine , and the Amazon Web Services (AWS) (for Landsat 8). This tool attempts to download images first from *Amazon Web Services* and *Google Earth Engine* ; only if images are not available, the download is performed through the service *EarthExplorer* in order to prevent the server from becoming saturated.

Images are downloaded as compressed archives (this tool allows for the download of single bands for Landsat 8 images provided by the *Amazon Web Services*). Also, automatic conversion to reflectance of downloaded bands is available.

Login https://ers.cr.usgs.gov/

USGS EROS credentials (https://ers.cr.usgs.gov) are required for downloads from EarthExplorer . Login using your *USGS EROS* credentials or register for free at https://ers.cr.usgs.gov/register .

- *User* : enter the user name;
- *Password* : enter the password;
- *remember*: remember user name and password in QGIS;

Search area

Define the search area by entering the coordinates (longitude and latitude) of an `Upper Left` (UL) point and `Lower Right` (LR) point, or interactively drawing an area in the map.

The definition of a search area is required before searching the images.

- *UL X (Lon)* : set the UL longitude;
- *UL Y (Lat)* : set the UL latitude;
- *LR X (Lon)* : set the LR longitude;
- *LR Y (Lat)* : set the LR latitude;
- *Show*: show or hide the search area drawn in the map;
- : define a search area by drawing a rectangle in the map; left click to set the UL point and right click to set the LR point; the area is displayed in the map;

Search

Define the search settings such as date of acquisition, maximum cloud cover, or specify Landsat satellites.

- *Satellites* : set the Landsat satellites;
- *Date from* 1980: set the starting date of acquisition;
- *to* 1980: set the ending date of acquisition;
- *Max cloud cover (%)* : maximum cloud cover in the image;
- *Results* : maximum number of images returned by the search;
- *Filter* : set a filter such as the Image ID of Landsat images (e.g. `LC81910312015006LGN00`); it is possible to enter multiple Image IDs separated by comma or semicolon (e.g. `LC81910312015006LGN00, LC81910312013224LGN00`); filtered images must be inside the search area;
- *Find* : find the images in the search area; results are displayed inside the table in *Landsat images* (pagina 53); results are added to previous results;

Tip: Search results (and the number thereof) depend on the defined area extent and the range of dates. In order to get more results, perform multiple searches defining smaller area extent and narrow acquisition dates (from and to).

Landsat images

- ***Image list*: found images are displayed in this table, which includes the following fields;**
  - *ImageID*: the Landsat Image ID;
  - *AcquisitionDate*: date of acquisition of Landsat image;
  - *CloudCover*: percentage of cloud cover in the image;
  - *Path*: WRS path of the image;
  - *Row*: WRS row of the image;
  - *min_lat*: minimum latitude of the image;
  - *min_lon*: minimum longitude of the image;
  - *max_lat*: maximum latitude of the image;
  - *max_lon*: maximum longitude of the image;
  - *USGScollection*: USGS collection code of the image;
  - *Preview*: URL of the image preview;
  - *collection*: collection code of the image;
- : display preview of highlighted images in the map; preview is roughly georeferenced on the fly;
- : remove highlighted images from the list;
- : remove all images from the list;

Download options

Landsat 8 bands

This tab allows for the selection of single bands (only for Landsat 8 images provided by the *Amazon Web Services*).

- *Band* `X`: select bands for download;
- : select or deselect all bands;

Download

Download the Landsat images in the *Landsat images* (pagina 53). During the download it is recommended not to interact with QGIS.

Download is performed according to image availability from the services EarthExplorer , Google Earth Engine , or the Amazon Web Services (AWS) . If the image is not available for download it is possible to check the availability thereof on http://earthexplorer.usgs.gov/ .

- *Only if preview in Layers*: if checked, download only those images listed in *Landsat images* (pagina 53) which are also listed in the QGIS layer panel;

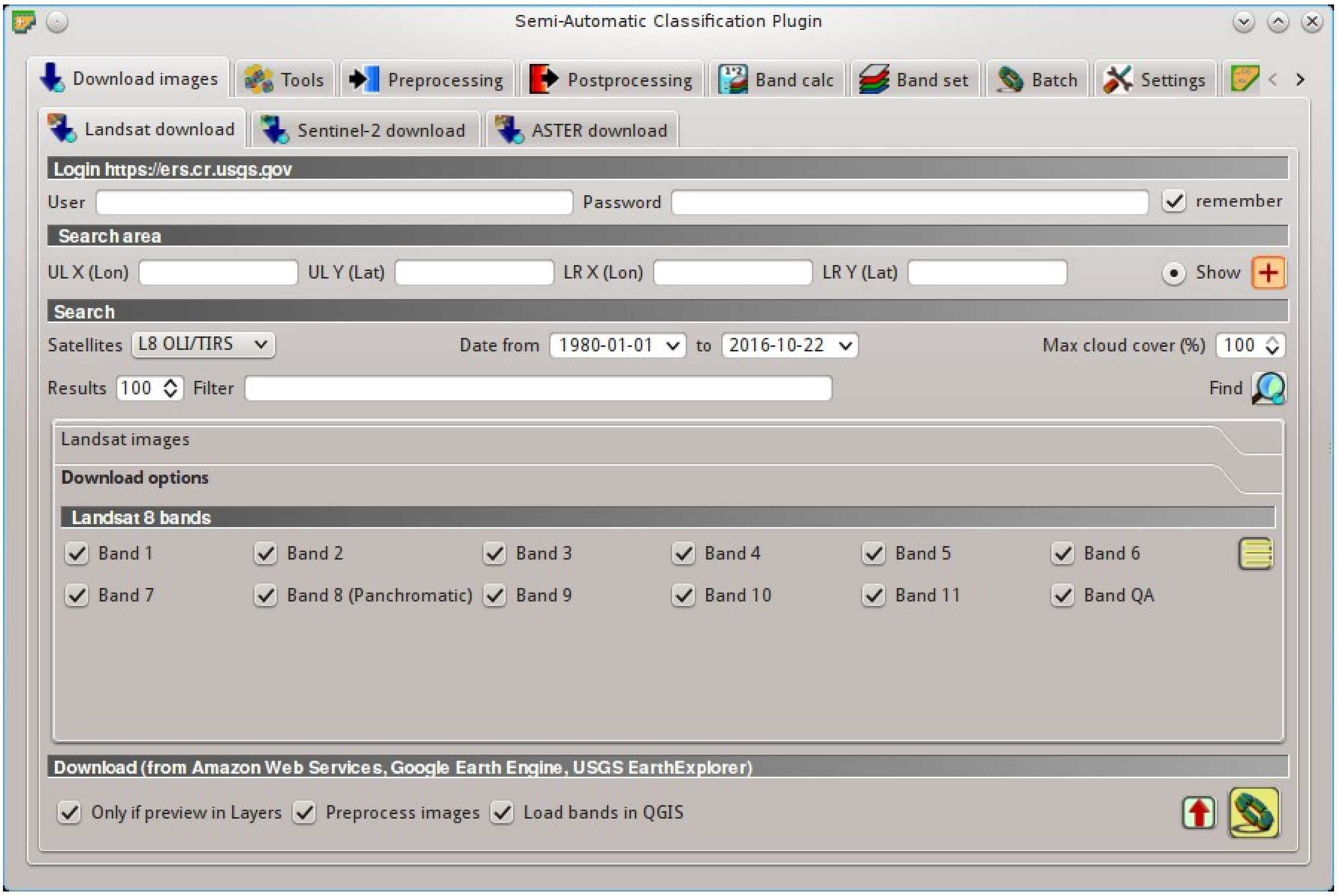


Fig. 10.2: *Download options*

-  *Preprocess images*: if checked, bands are automatically converted after the download, according to the settings defined in *Landsat* (pagina 77);
-  *Load bands in QGIS*: if checked, bands are loaded in QGIS after the download;
- : export the download links to a text file;
- : start the download process of all the images listed in *Landsat images* (pagina 53);

Sentinel-2 download

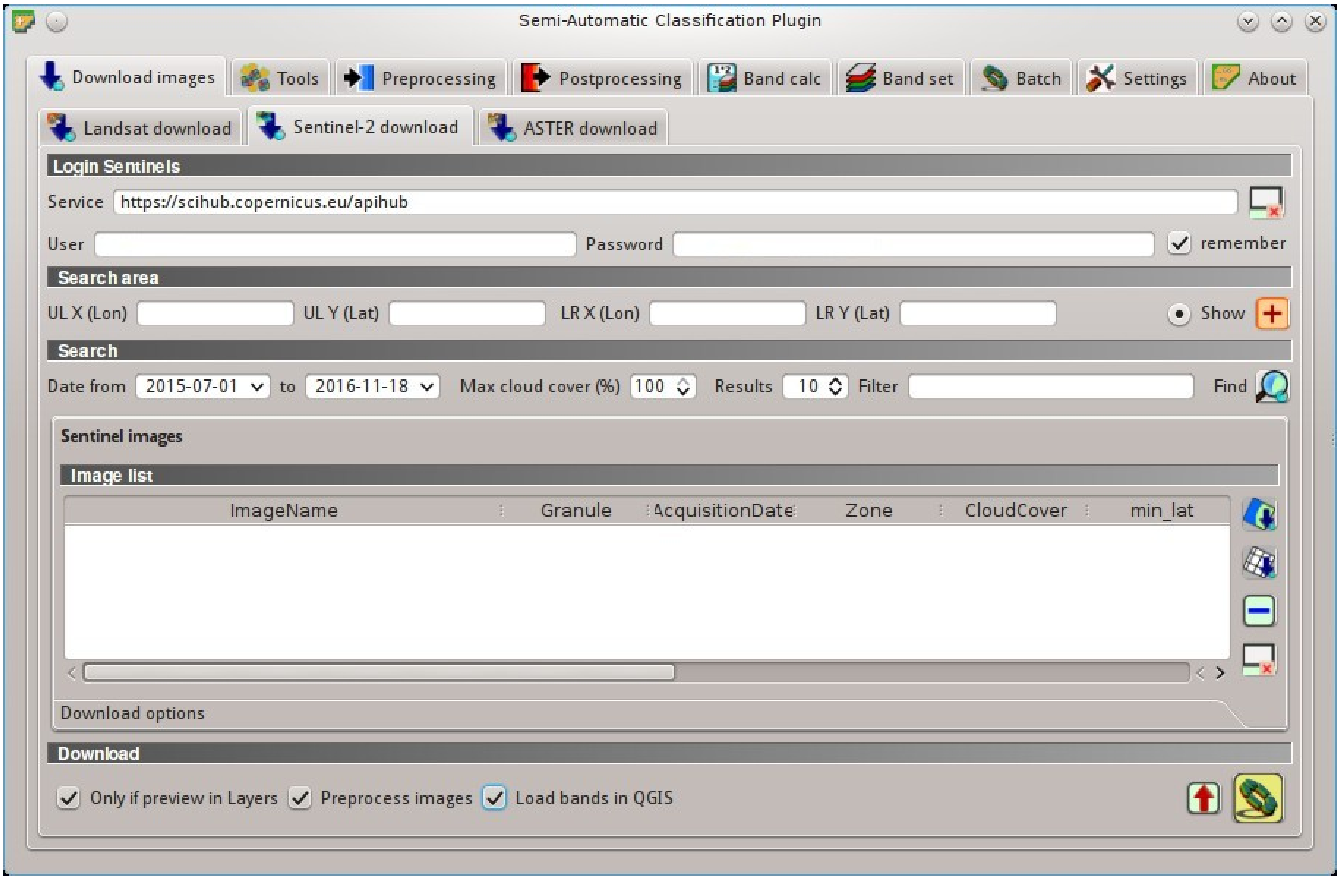
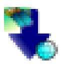


Fig. 10.3:  *Sentinel-2 download*

Sentinel-2 is a European satellite launched in 2015, developed in the frame of Copernicus land monitoring services, which acquires 13 spectral bands (see *Sentinel-2 Satellite* (pagina 145)). This tab allows for searching and downloading the free Sentinel-2 images (Level-1C) from the Sentinels Scientific Data Hub (using the Data Hub API). Images are mainly downloaded from the Amazon S3 AWS if available.

Sentinel-2 satellite has a swath width of 290km. Sentinel-2 Level-1C images are delivered in granules (also called tiles) with a side of 100km in UTM/WGS84 projection. This tool allows for the selection and download of granules and bands.

> **Tip**: In case of errors please see *Error [50] 'Internet error'. Unable to download Sentinel-2 images. Why?* (pagina 269) and *Error [56] 'SSL connection error'. Unable to download Sentinel-2 images. Why?* (pagina 269).

Login Sentinels

In order to access to Sentinel data a free registration is required at https://scihub.copernicus.eu/userguide/1SelfRegistration (other services may require different registrations). After the registration, enter the user name and password for accessing data.

- *Service* : enter the service URL (default is https://scihub.copernicus.eu/apihub); other mirror services that share the same infrastructure can be used (such as https://scihub.copernicus.eu/dhus , https://finhub.nsdc.fmi.fi , https://data.sentinel.zamg.ac.at);
- : reset the default service https://scihub.copernicus.eu/s2);
- *User* : enter the user name;
- *Password* : enter the password;
- *remember*: remember user name and password in QGIS;

Search area

Define the search area by entering the coordinates (longitude and latitude) of an `Upper Left` (UL) point and `Lower Right` (LR) point, or interactively drawing an area in the map. The definition of a search area is required before searching the images.

- *UL X (Lon)* : set the UL longitude;
- *UL Y (Lat)* : set the UL latitude;
- *LR X (Lon)* : set the LR longitude;
- *LR Y (Lat)* : set the LR latitude;
- *Show*: show or hide the search area drawn in the map;
- : define a search area by drawing a rectangle in the map; left click to set the UL point and right click to set the LR point; the area is displayed in the map;

Search

Define search settings such as the date of acquisition or search for specific Sentinel images using the Image ID or name.

- *Date from* : set the starting date of acquisition;
- *to* : set the ending date of acquisition;
- *Max cloud cover (%)* : maximum cloud cover in the image;
- *Results* : maximum number of images returned by the search;
- *Filter* : set a filter such as the Image Name of Sentinel images (e.g. `S2A_OPER_PRD_MSIL1C_PDMC_20160419T190217_R022_V20160419T101026`);
- *Find* : find the images in the search area; results are displayed inside the table in *Sentinel images* (pagina 57); results are added to previous results;

Tip: Search results (and the number thereof) depend on the defined area extent and the range of dates. In order to get more results, perform multiple searches defining smaller area extent and narrow acquisition dates (from and to).

Sentinel images

- ***Image list*: found images are displayed in this table, which includes the following fields;**
  - *ImageName*: the Sentinel Image Name;
  - *Granule*: the single granule name;
  - *AcquisitionDate*: date of acquisition of Sentinel image;
  - *Zone*: tile zone according to the US-MGRS naming convention;
  - *CloudCover*: percentage of cloud cover in the image;
  - *min_lat*: minimum latitude of the image;
  - *min_lon*: minimum longitude of the image;
  - *max_lat*: maximum latitude of the image;
  - *max_lon*: maximum longitude of the image;
  - *Size*: the size of the image (unused);
  - *Preview*: URL of the image overview;
  - *GranulePreview*: URL of the granule preview; if available, preview is downloaded from the Amazon Web Services ;
  - *ImageID*: the Sentinel Image ID;
- : display preview of highlighted granules in the map;
- : display overview of highlighted images in the map; overview is roughly georeferenced on the fly; overviews could not be available when using mirror services;
- : remove highlighted images from the list;
- : remove all images from the list;

  Tip: download this zip file containing the shapefile of Sentinel-2 granules for identifying the zone; load this shapefile in QGIS, select the granules in your search area and open the attribute table to see the zone name.

Download options

This tab allows for the selection of single bands.

- *Band* `X`: select bands for download;
- *Ancillary data*: if checked, the metadata files (a .xml file whose name contains `MTD_SAFL1C` and a .xml file whose name contains `MTD_L1C`) and the cloud mask file (a .gml file whose name contains `MSK_CLOUDS`) are downloaded;
- : select or deselect all bands;

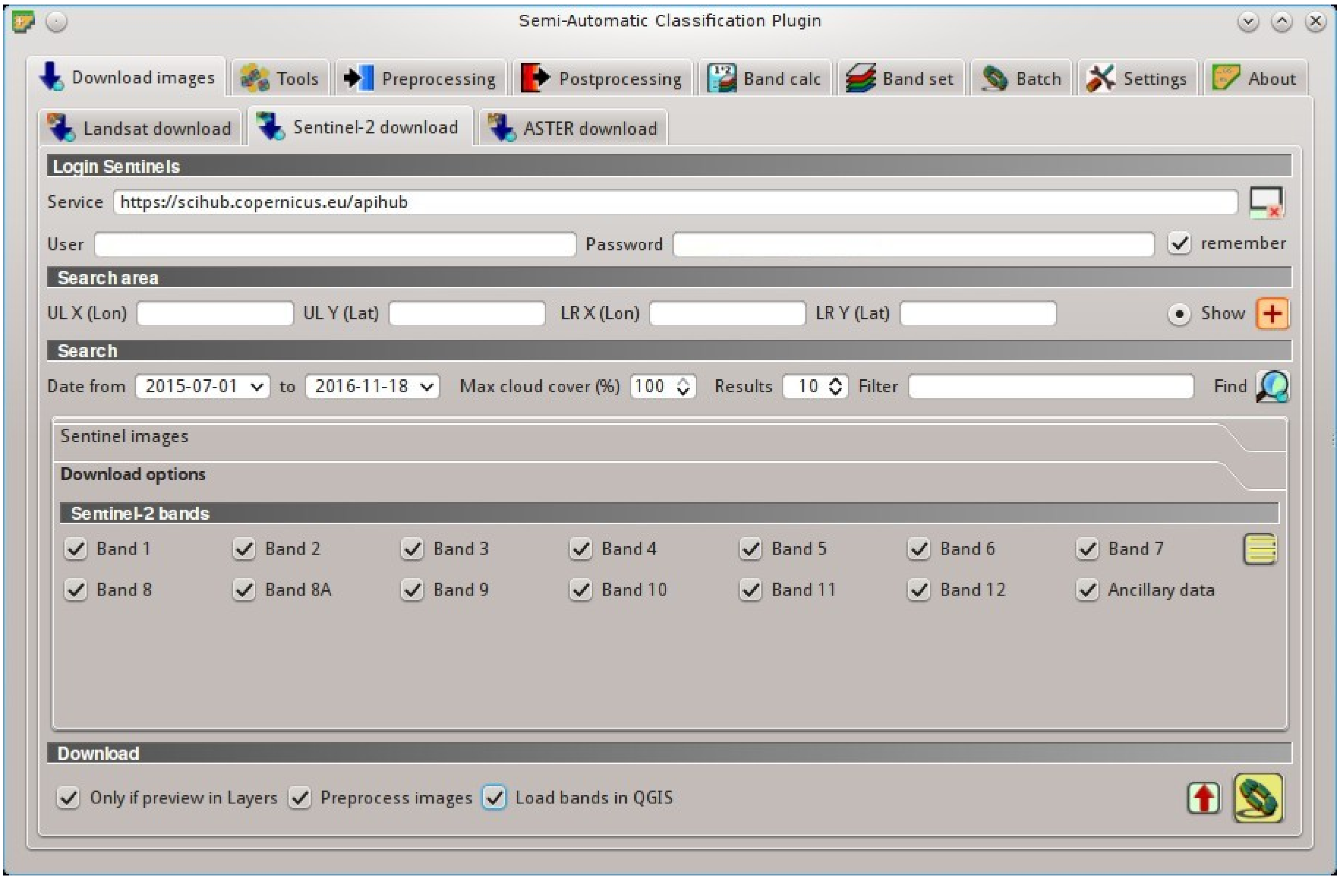


Fig. 10.4: *Download options*

Download

Download the Sentinel-2 images in the *Sentinel images* (pagina 57). Bands selected in *Download options* (pagina 57) are downloaded.

During the download it is recommended not to interact with QGIS.

- *Only if preview in Layers*: if checked, download only those images listed in *Sentinel images* (pagina 57) which are also listed in the QGIS layer panel;
- *Preprocess images*: if checked, bands are automatically converted after the download, according to the settings defined in *Sentinel-2* (pagina 79);
- *Load bands in QGIS*: if checked, bands are loaded in QGIS after the download;
- : export the download links to a text file;
- : start the download process of all the images listed in *Sentinel images* (pagina 57);

ASTER download

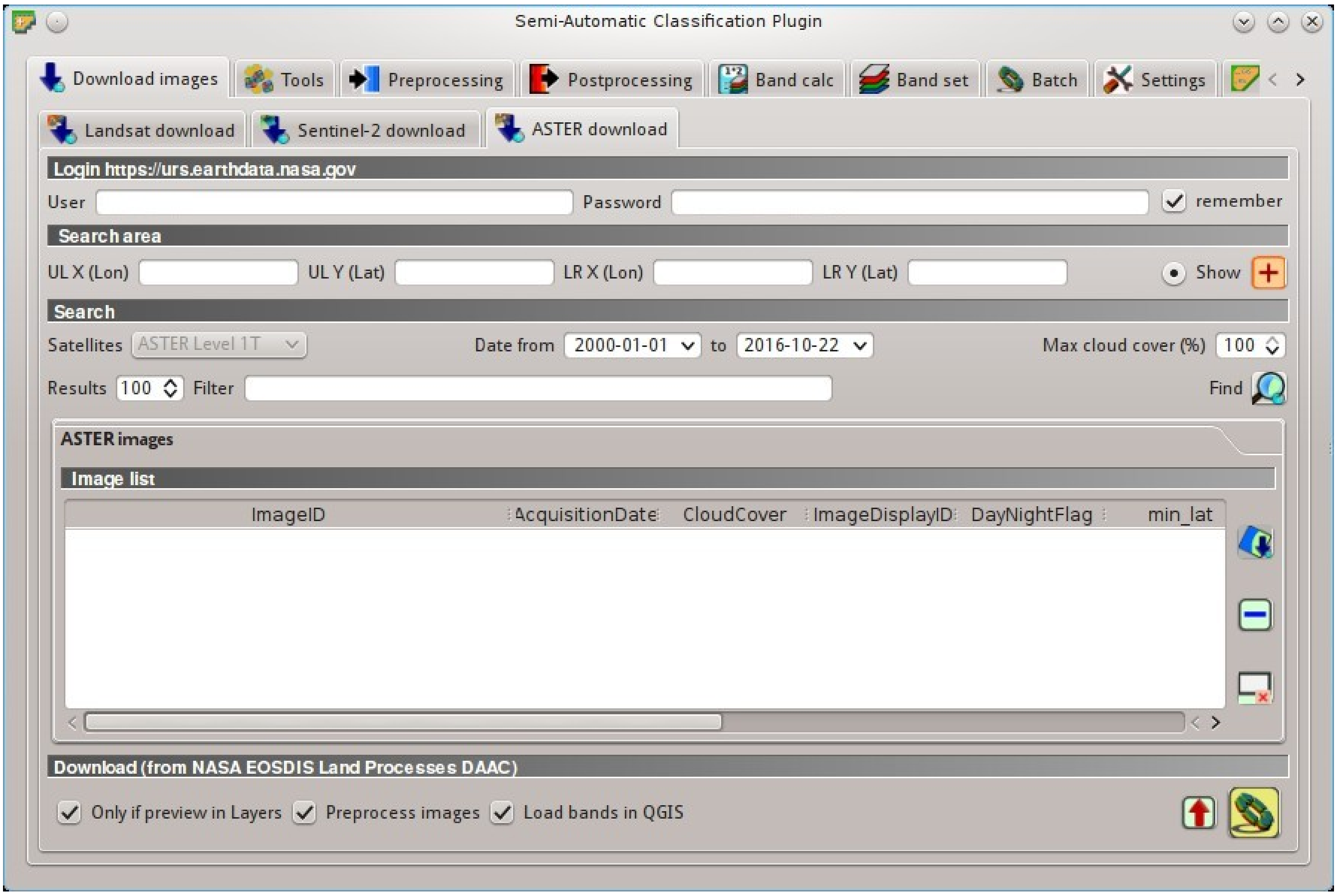


Fig. 10.5: *ASTER download*

This tab allows for searching and downloading the whole archive of free images L1T acquired by *ASTER Satellite* (pagina 145) since 2000. Search is performed through the CMR Search API developed by NASA. The ASTER L1T data products are retrieved from the online Data Pool, courtesy of the NASA Land Processes Distributed

Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, https://lpdaac.usgs.gov/data_access/data_pool.

Also, automatic conversion to reflectance of downloaded bands is available.

Login https://urs.earthdata.nasa.gov

EOSDIS Earthdata credentials (https://urs.earthdata.nasa.gov) are required for download. Login using your *EOSDIS Earthdata* credentials or register for free at https://urs.earthdata.nasa.gov/users/new .

> **Warning**: Before downloading ASTER images, you must approve LP DAAC Data Pool clicking the following https://urs.earthdata.nasa.gov/approve_app?client_id=ijpRZvb9qeKCK5ctsn75Tg

- *User* T : enter the user name;
- *Password* T : enter the password;
- *remember*: remember user name and password in QGIS;

Search area

Define the search area by entering the coordinates (longitude and latitude) of an `Upper Left` (UL) point and `Lower Right` (LR) point, or interactively drawing an area in the map.

The definition of a search area is required before searching the images.

- *UL X (Lon)* 1: set the UL longitude;
- *UL Y (Lat)* 1: set the UL latitude;
- *LR X (Lon)* 1: set the LR longitude;
- *LR Y (Lat)* 1: set the LR latitude;
- *Show*: show or hide the search area drawn in the map;
- : define a search area by drawing a rectangle in the map; left click to set the UL point and right click to set the LR point; the area is displayed in the map;

Search

Define the search settings such as date of acquisition, maximum cloud cover, or specify ASTER satellites.

- *Satellites* : set the ASTER satellites (unused);
- *Date from* 1980: set the starting date of acquisition;
- *to* 1980: set the ending date of acquisition;
- *Max cloud cover (%)* 1: maximum cloud cover in the image;
- *Results* 1: maximum number of images returned by the search;
- *Filter* T: set a filter such as the Image ID of ASTER images; it is possible to enter multiple Image IDs separated by comma or semicolon; filtered images must be inside the search area;
- *Find* : find the images in the search area; results are displayed inside the table in *ASTER images* (pagina 61); results are added to previous results;

Tip: Search results (and the number thereof) depend on the defined area extent and the range of dates. In order to get more results, perform multiple searches defining smaller area extent and narrow acquisition dates (from and to).

ASTER images

- ***Image list*: found images are displayed in this table, which includes the following fields;**
  - *ImageID*: the ASTER Image ID;
  - *AcquisitionDate*: date of acquisition of ASTER image;
  - *CloudCover*: percentage of cloud cover in the image;
  - *ImageDisaplyID*: the ASTER Image ID;
  - *DayNightFlag*: flag for acquisition during day or night;
  - *min_lat*: minimum latitude of the image;
  - *min_lon*: minimum longitude of the image;
  - *max_lat*: maximum latitude of the image;
  - *max_lon*: maximum longitude of the image;
  - *Service*: download service of the image;
  - *Preview*: URL of the image preview;
  - *collection*: collection code of the image;
- : display preview of highlighted images in the map; preview is roughly georeferenced on the fly;
- : remove highlighted images from the list;
- : remove all images from the list;

Download

Download the ASTER images in the *ASTER images* (pagina 61). During the download it is recommended not to interact with QGIS.

- *Only if preview in Layers*: if checked, download only those images listed in *ASTER images* (pagina 61) which are also listed in the QGIS layer panel;
- *Preprocess images*: if checked, bands are automatically converted after the download, according to the settings defined in *ASTER* (pagina 80);
- *Load bands in QGIS*: if checked, bands are loaded in QGIS after the download;
- : export the download links to a text file;
- : start the download process of all the images listed in *ASTER images* (pagina 61);

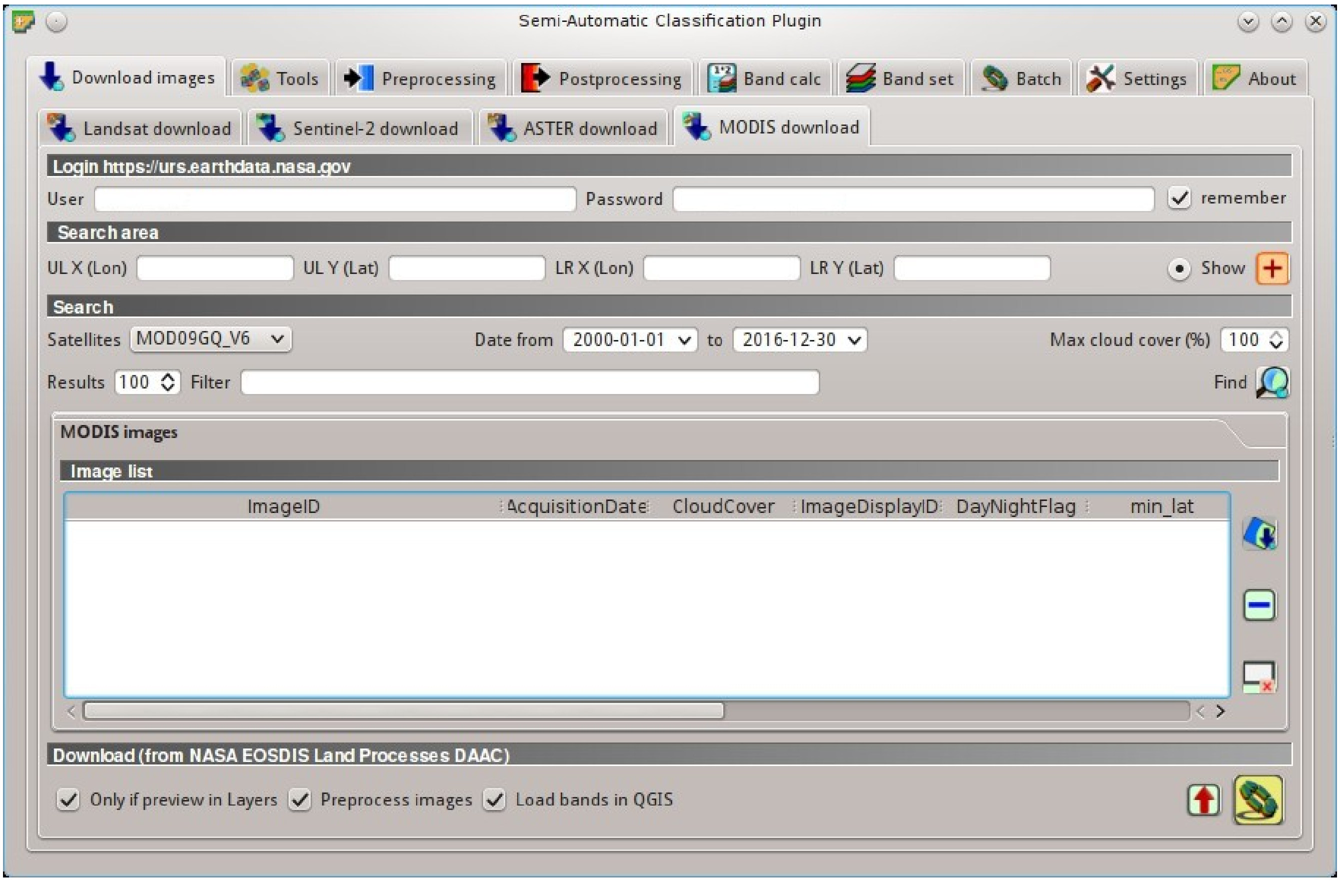


Fig. 10.6: *MODIS download*

MODIS download

This tab allows for searching and downloading the archive of free *MODIS Products* (pagina 146) acquired since 2000 (in particular MOD09GQ, MYD09GQ, MOD09GA, MYD09GA, MOD09Q1, MYD09Q1, MOD09A1, MYD09A1). Search is performed through the CMR Search API developed by NASA. MODIS products are retrieved from the online Data Pool, courtesy of the NASA Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, https://lpdaac.usgs.gov/data_access/data_pool.

Also, automatic reprojection of downloaded bands is available.

Login https://urs.earthdata.nasa.gov

EOSDIS Earthdata credentials (https://urs.earthdata.nasa.gov) are required for download. Login using your *EOSDIS Earthdata* credentials or register for free at https://urs.earthdata.nasa.gov/users/new .

> **Warning**: Before downloading MODIS images, you must approve LP DAAC Data Pool clicking the following https://urs.earthdata.nasa.gov/approve_app?client_id=ijpRZvb9qeKCK5ctsn75Tg

- *User* T : enter the user name;
- *Password* T : enter the password;
- *remember*: remember user name and password in QGIS;

Search area

Define the search area by entering the coordinates (longitude and latitude) of an `Upper Left` (UL) point and `Lower Right` (LR) point, or interactively drawing an area in the map.

The definition of a search area is required before searching the images.

- *UL X (Lon)* 1: set the UL longitude;
- *UL Y (Lat)* 1: set the UL latitude;
- *LR X (Lon)* 1: set the LR longitude;
- *LR Y (Lat)* 1: set the LR latitude;
- *Show*: show or hide the search area drawn in the map;
- : define a search area by drawing a rectangle in the map; left click to set the UL point and right click to set the LR point; the area is displayed in the map;

Search

Define the search settings such as date of acquisition, maximum cloud cover, or specify MODIS product.

- *Products* : set the MODIS products;
- *Date from* 1980: set the starting date of acquisition;
- *to* 1980: set the ending date of acquisition;
- *Max cloud cover (%)* 1: maximum cloud cover in the image (unused);
- *Results* 1: maximum number of images returned by the search;

- *Filter* : set a filter such as the Image ID of MODIS images; it is possible to enter multiple Image IDs separated by comma or semicolon; filtered images must be inside the search area;
- *Find* : find the images in the search area; results are displayed inside the table in *MODIS images* (pagina 64); results are added to previous results;

  Tip: Search results (and the number thereof) depend on the defined area extent and the range of dates. In order to get more results, perform multiple searches defining smaller area extent and narrow acquisition dates (from and to).

MODIS images

- ***Image list*: found images are displayed in this table, which includes the following fields;**
  - *ImageID*: the MODIS Image ID;
  - *AcquisitionDate*: date of acquisition of MODIS image;
  - *CloudCover*: percentage of cloud cover in the image;
  - *ImageDisaplyID*: the MODIS Image ID;
  - *DayNightFlag*: flag for acquisition during day or night;
  - *min_lat*: minimum latitude of the image;
  - *min_lon*: minimum longitude of the image;
  - *max_lat*: maximum latitude of the image;
  - *max_lon*: maximum longitude of the image;
  - *Service*: download service of the image;
  - *Preview*: URL of the image preview;
  - *collection*: collection code of the image;
- : display preview of highlighted images in the map; preview is roughly georeferenced on the fly;
- : remove highlighted images from the list;
- : remove all images from the list;

Download

Download the MODIS images in the *MODIS images* (pagina 64). During the download it is recommended not to interact with QGIS.

- *Only if preview in Layers*: if checked, download only those images listed in *MODIS images* (pagina 64) which are also listed in the QGIS layer panel;
- *Preprocess images*: if checked, bands are automatically converted after the download, according to the settings defined in *MODIS* (pagina 82);
- *Load bands in QGIS*: if checked, bands are loaded in QGIS after the download;
- : export the download links to a text file;

- : start the download process of all the images listed in *MODIS images* (pagina 64);

Tools

The tab `Tools` includes several tools for manipulating ROIs and spectral signatures.

Multiple ROI Creation

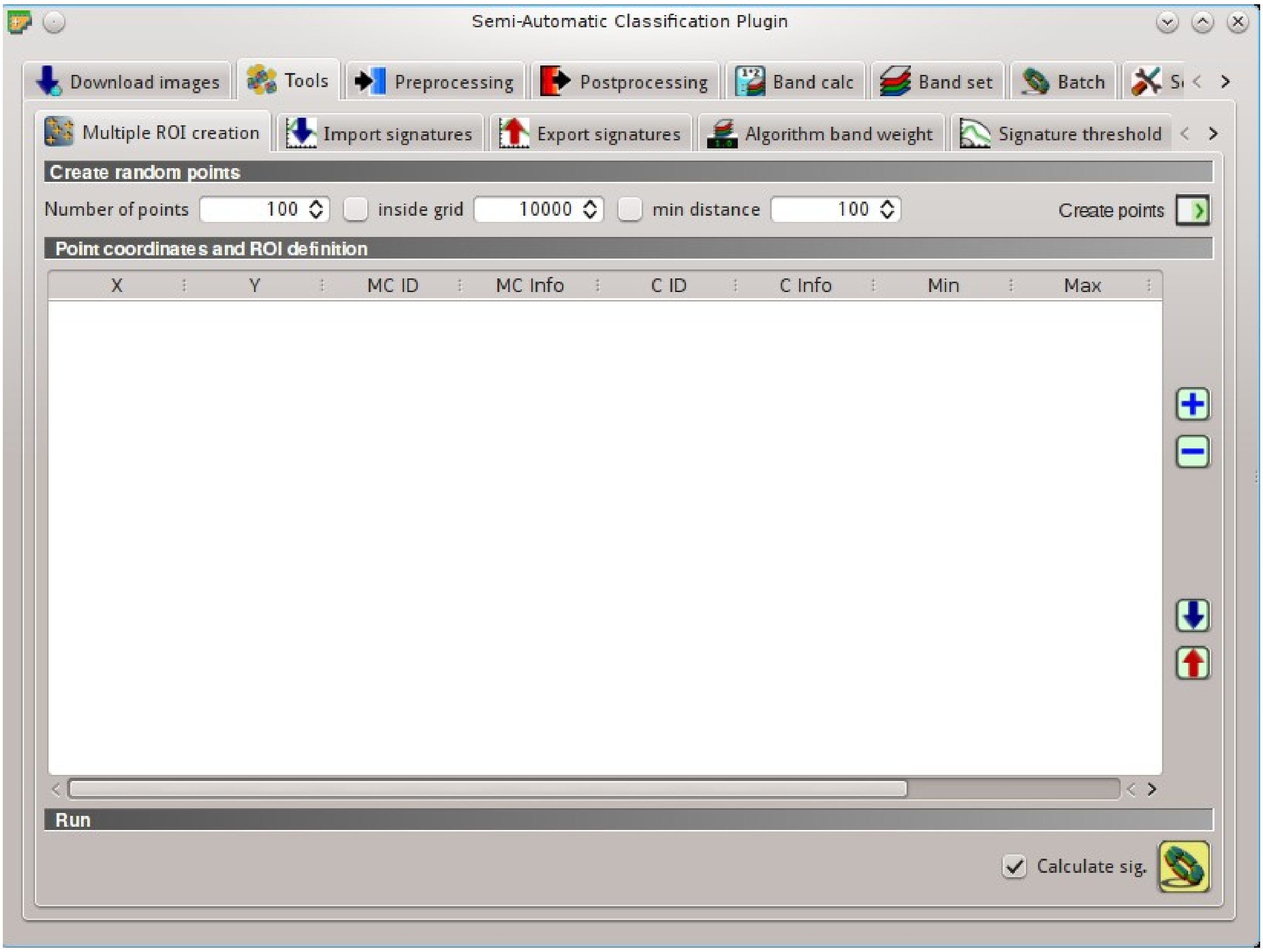


Fig. 10.7: *Multiple ROI Creation*

This tab allows for the automatic creation of ROIs, useful for the rapid classification of multi-temporal images, or for accuracy assessment. Given a list of point coordinates and ROI options, this tool performs the region growing of ROIs. Created ROIs are automatically saved to the *Training input* (pagina 40).

Create random points

- *Number of points* : set a number of points that will be created when *Create points* is clicked;

- *inside grid* : if checked, the *input image* area is divided in cells where the size thereof is defined in the combobox (image unit, usually meters); points defined in `Number of random points` are created randomly within each cell;
- *min distance* : if checked, random points have a minimum distance defined in the combobox (image unit, usually meters); setting a minimum distance can result in fewer points than the number defined in *Number of points*;
- *Create points* : create random points inside the *input image* area;

Point coordinates and ROI definition

- ***Point coordinates and ROI definition*: table containing the following fields;**
  - *X* : point X coordinate (float);
  - *Y* : point Y coordinate (float);
  - *MC ID*: ROI Macroclass ID (int);
  - *MC Info*: ROI Macroclass information (text);
  - *C ID*: ROI Class ID (int);
  - *C Info*: ROI Class information (text);
  - *Min* : the minimum area of a ROI (in pixel unit);
  - *Max* : the maximum width of a ROI (in pixel unit);
  - *Dist* : the interval which defines the maximum spectral distance between the seed pixel and the surrounding pixels (in radiometry unit);
  - *Rapid ROI band* : if a band number is defined, ROI is created only using the selected band, similarly to *Rapid ROI band* in *Creazione ROI* (pagina 42) ;
- : add a new row to the table; all the table fields must be filled for the ROI creation;
- : delete the highlighted rows from the table;
- : import a point list from text file to the table; every line of the text file must contain values separated by tabs of `X`, `Y`, `MC ID`, `MC Info`, `Class ID`, `C Info`, `Min`, `Max`, `Dist`, and optionally the `Rapid ROI band`;
- : export the point list to text file;

Run

- *Calculate sig.*: if checked, the spectral signature is calculated while the ROI is saved to *Training input* (pagina 40);
- : start the ROI creation process for all the points and save ROIs to the *Training input* (pagina 40);

Import signatures

The tab *Import signatures* allows for importing spectral signatures from various sources.

Import library file

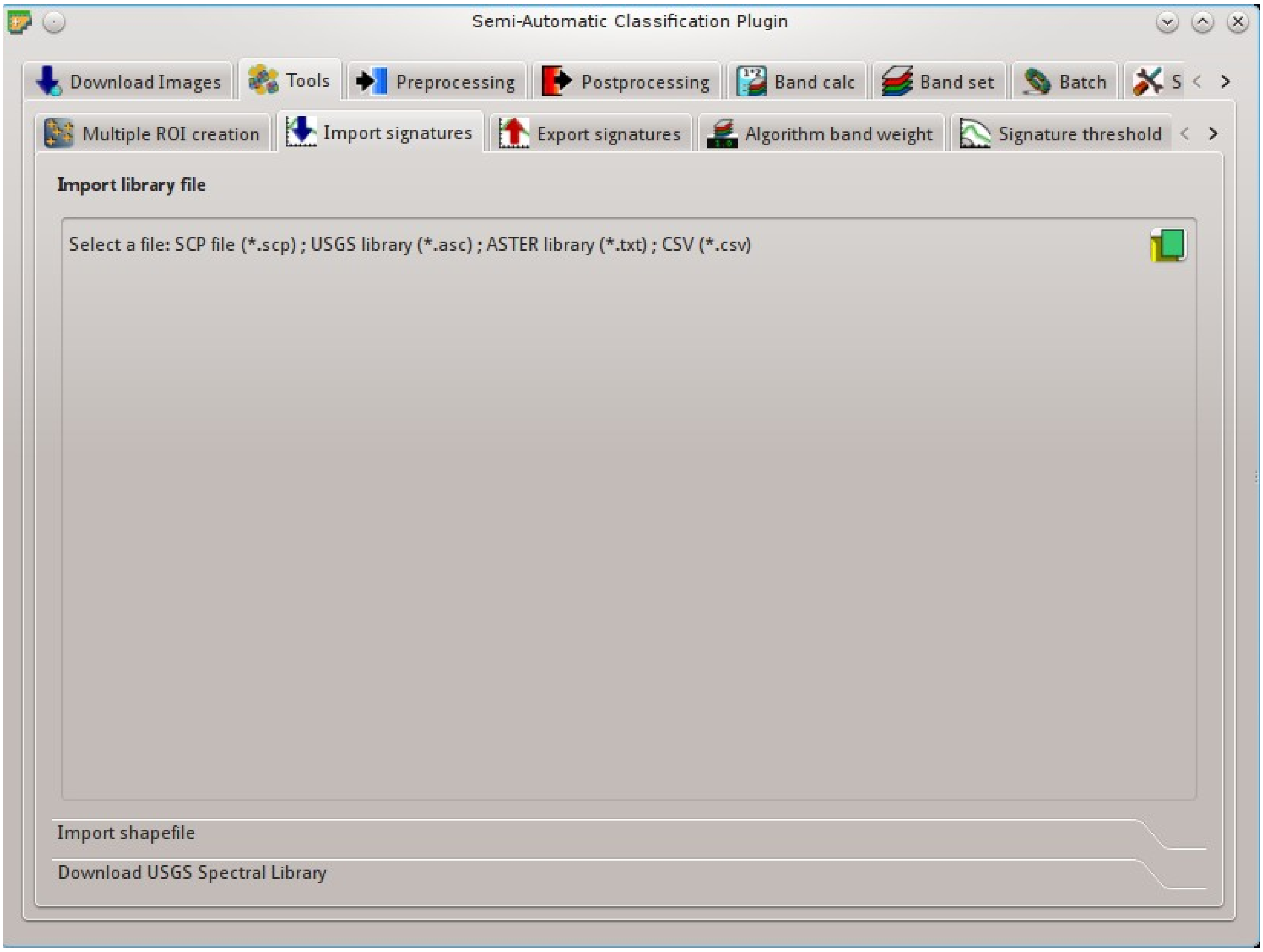


Fig. 10.8: *Import library file*

This tool allows for importing spectral signatures from various sources: a previously saved *Training input* (pagina 40) (.scp file); a USGS Spectral Library (.asc file); a previously exported CSV file. In case of USGS Spectral Library, the library is automatically sampled according to the image band wavelengths defined in the *Band set* (pagina 110), and added to the *ROI Signature list* (pagina 41);

- *Select a file* : open a file to be imported in the *Training input* (pagina 40);

Import shapefile

This tool allows for importing a shapefile, selecting the corresponding fields of the *Training input* (pagina 40).

- *Select a shapefile* : open a shapefile;
- *MC ID field* : select the shapefile field corresponding to MC ID;

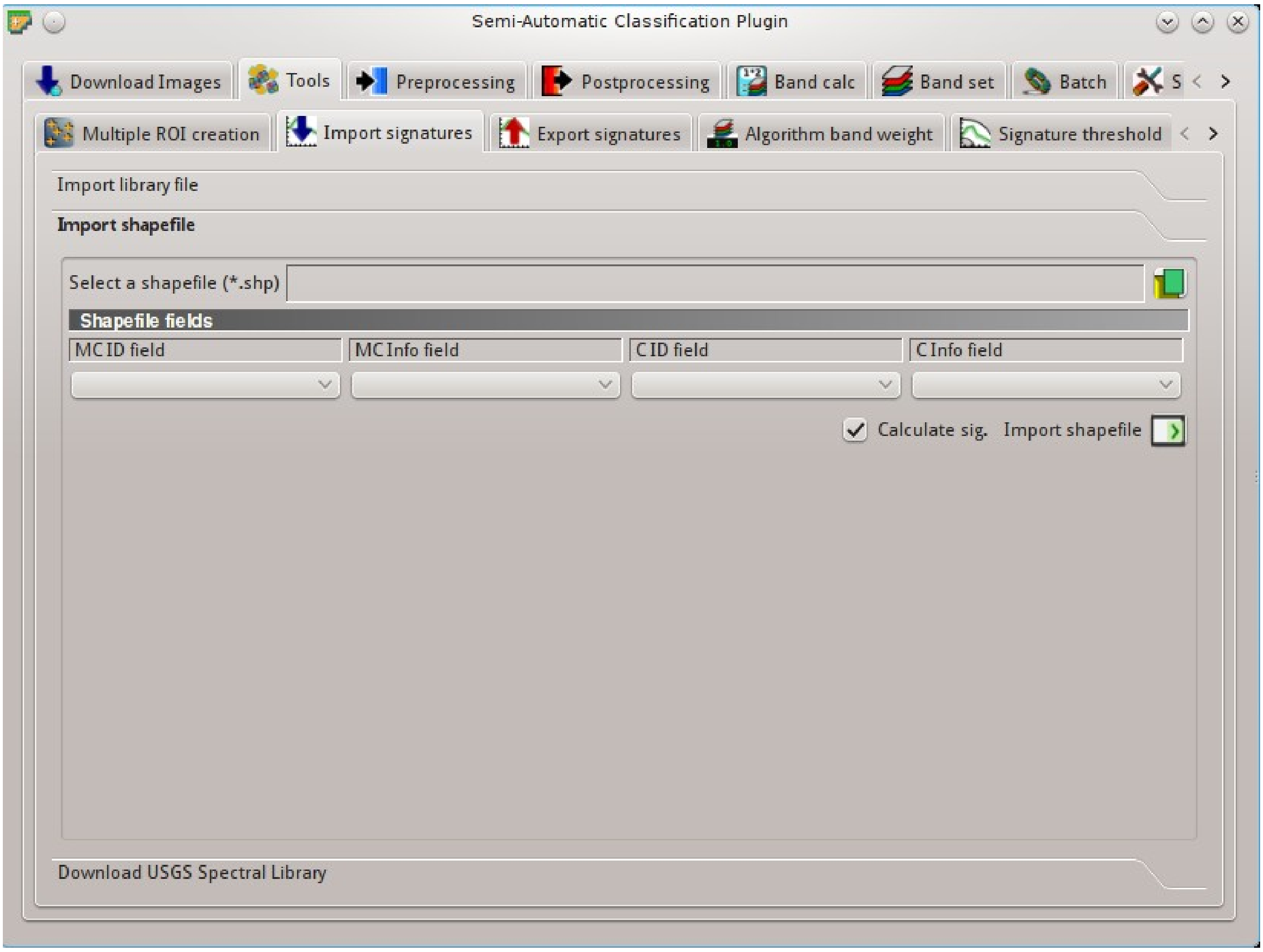


Fig. 10.9: *Import shapefile*

- *MC Info field* : select the shapefile field corresponding to MC Info;
- *C ID field* : select the shapefile field corresponding to C ID;
- *C Info field* : select the shapefile field corresponding to C Info;
- *Calculate sig.*: if checked, the spectral signature is calculated while the ROI is saved to *Training input* (pagina 40);
- *Import shapefile* : import all the shapefile polygons as ROIs in the *Training input* (pagina 40);

Download USGS Spectral Library

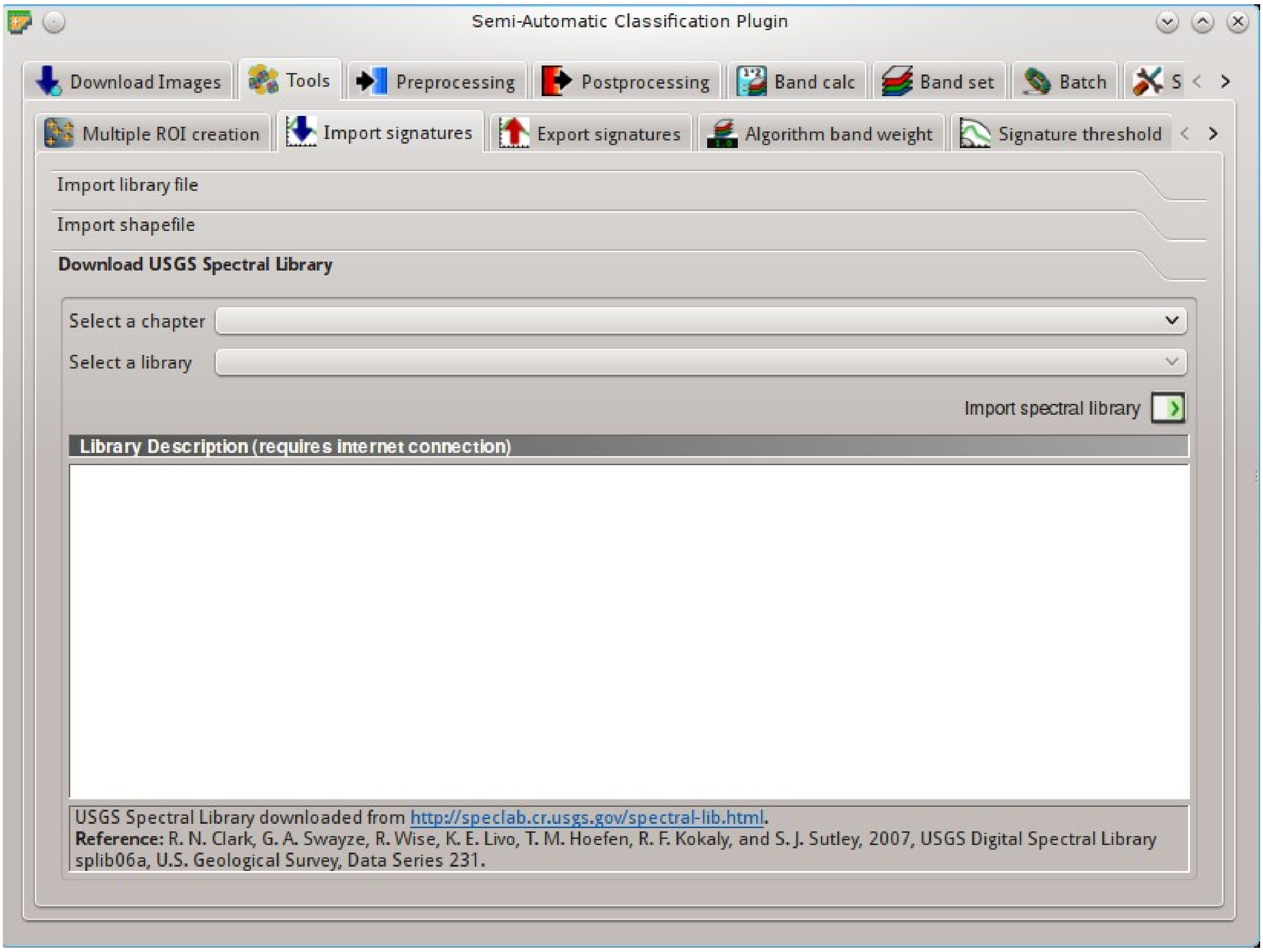


Fig. 10.10: *Download USGS Spectral Library*

The tab *Download USGS Spectral Library* allows for the download of the USGS spectral library (Clark, R.N., Swayze, G.A., Wise, R., Livo, E., Hoefen, T., Kokaly, R., Sutley, S.J., 2007, USGS digital spectral library splib06a: U.S. Geological Survey, Digital Data Series 231).

The libraries are grouped in chapters including Minerals, Mixtures, Coatings, Volatiles, Man-Made, Plants, Vegetation Communities, Mixtures with Vegetation, and Microorganisms. An internet connection is required.

- *Select a chapter* : select one of the library chapters; after the selection, chapter libraries are shown in *Select a library*;

- *Select a library* : select one of the libraries; the library description is displayed in the frame *Library description*;
- *Import spectral library* : download the library and add the sampled spectral signature to the *ROI Signature list* (pagina 41) using the parameters defined in *Creazione ROI* (pagina 42); the library is automatically sampled according to the image band wavelengths defined in the *Band set* (pagina 110), and added to the *ROI Signature list* (pagina 41);

  Tip: Spectral libraries downloaded from the `USGS Spectral Library` can be used with Minimum Distance or Spectral Angle Mapping algorithms, but not Maximum Likelihood because this algorithm needs the covariance matrix that is not included in the spectral libraries.

Export signatures

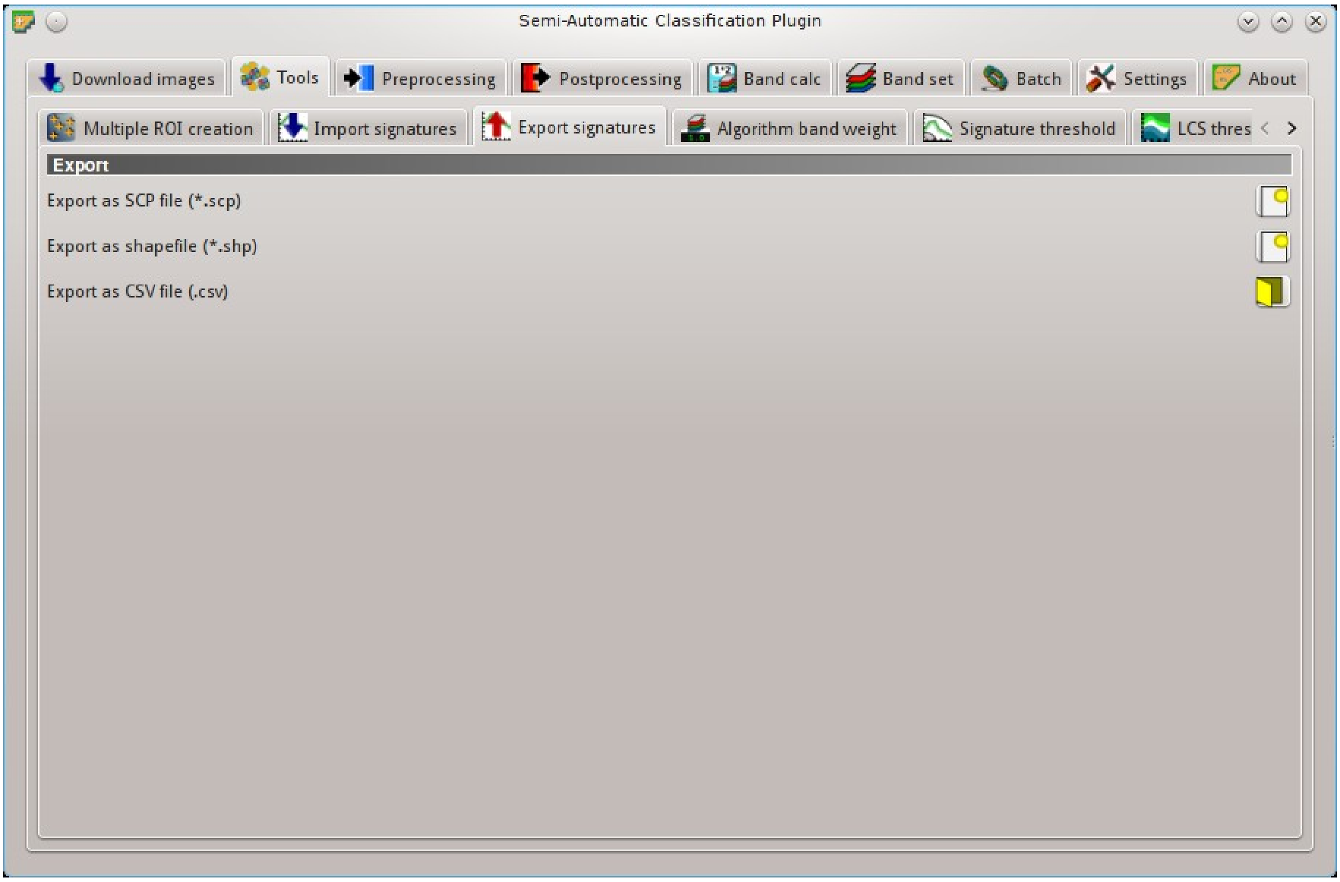


Fig. 10.11: *Export signatures*

This tool allows for exporting the signatures highlighted in the *ROI Signature list* (pagina 41).

- *Export as SCP file* : create a new .scp file and export highlighted ROIs and spectral signatures as *SCP* file (* .scp);
- *Export as shapefile* : export highlighted ROIs (spectral signature data excluded) as a new shapefile (* .shp);
- *Export as CSV file* : open a directory, and export highlighted spectral signatures as individual CSV files (* .csv) separated by semicolon (;);

Algorithm band weight

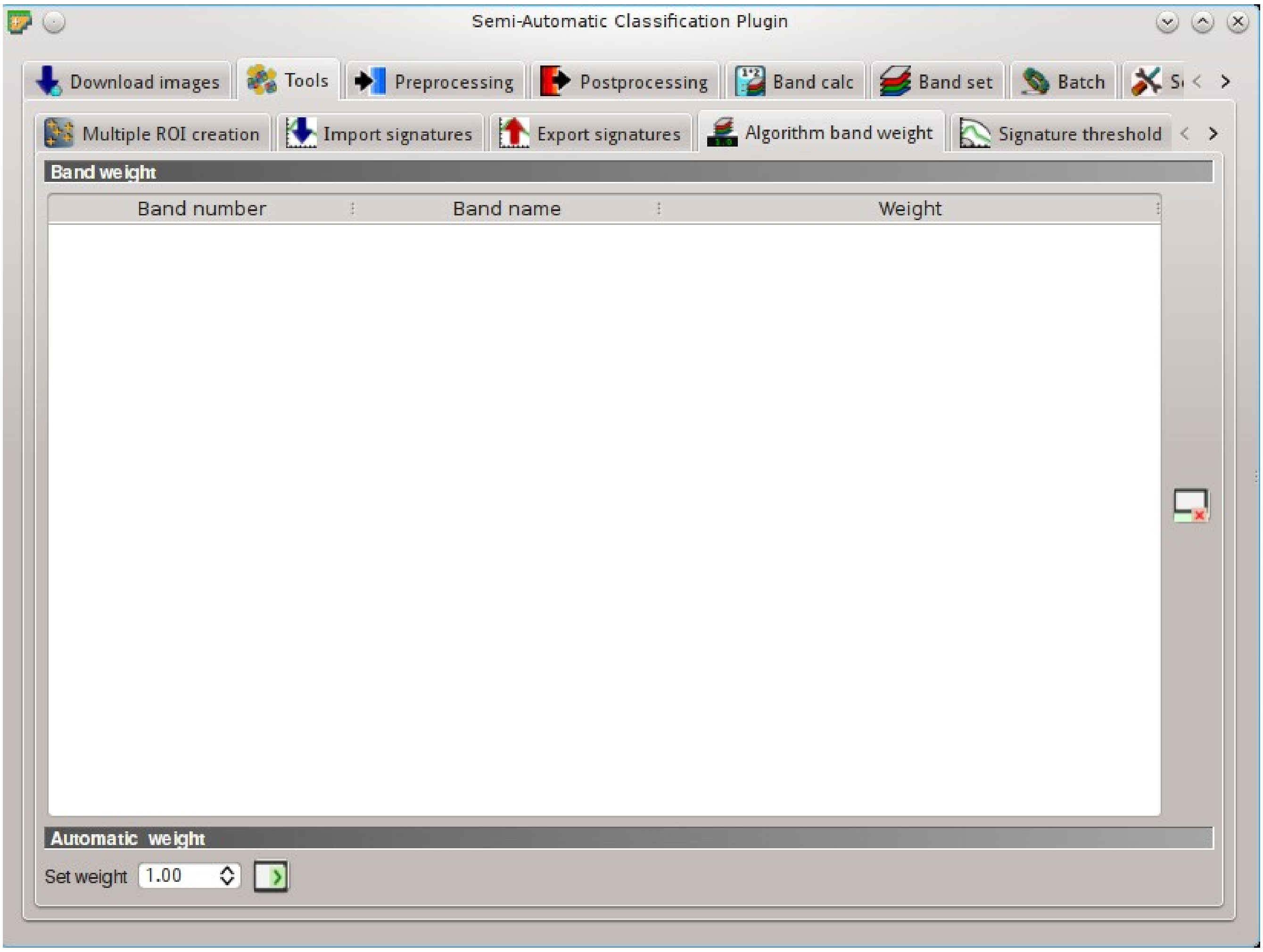


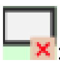
Fig. 10.12:  *Algorithm band weight*

This tab allows for the definition of band weights that are useful for improving the spectral separability of materials at certain wavelengths (bands). During the classification process, band values and spectral signature values are multiplied by the corresponding band weights, thus modifying the spectral distances.

Band weight

-  ***Band weight*: table containing the following fields;**
  - *Band number* : number of the band in the *Band set*;
  - *Band name* : name of the band;
  - *Weight* : weight of the band; this value can be edited;

Automatic weight

- : reset all band weights to 1;

- *Set weight* : set the defined value as weight for all the highlighted bands in the table;

Signature threshold

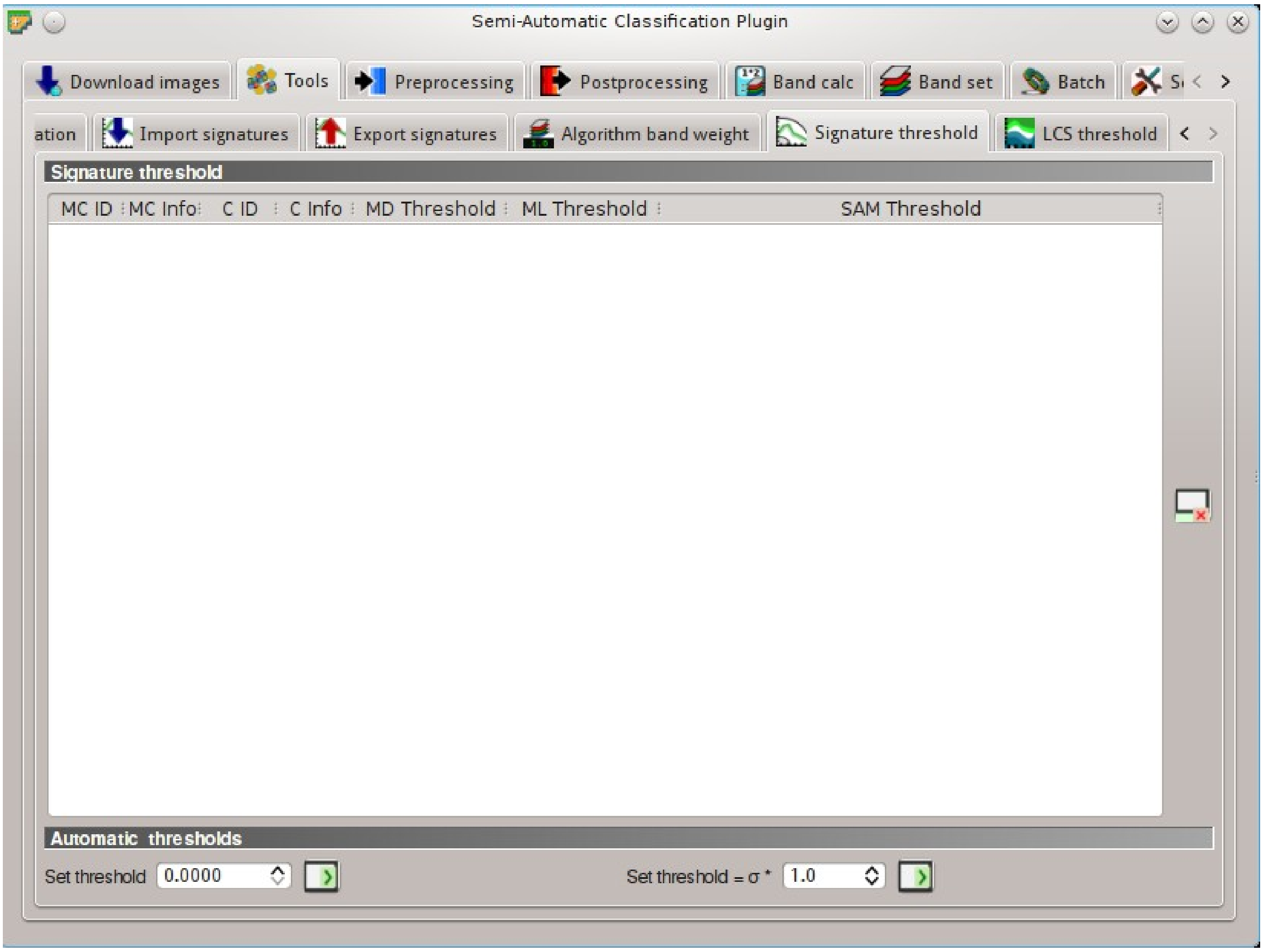


Fig. 10.13: *Signature threshold*

This tab allows for the definition of a classification threshold for each spectral signature. All the signatures contained in the *Training input* (pagina 40) are listed. This is useful for improving the classification results, especially when spectral signatures are similar. Thresholds of signatures are saved in the *Training input* (pagina 40).

If threshold is 0 then no threshold is applied. Depending on the selected *Classification algorithm* (pagina 44) the threshold value is evaluated differently:

- for Minimum Distance, pixels are unclassified if distance is greater than threshold value;
- for Maximum Likelihood, pixels are unclassified if probability is less than threshold value (max 100);
- for Spectral Angle Mapping, pixels are unclassified if spectral angle distance is greater than threshold value (max 90).

Signature threshold

- ***Signature threshold*: table containing the following fields;**

  - *MC ID*: signature Macroclass ID;
  - *MC Info*: signature Macroclass Information;
  - *C ID*: signature Class ID;
  - *C Info*: signature Class Information;
  - *MD Threshold*: Minimum Distance threshold; this value can be edited;
  - *ML Threshold*: Maximum Likelihood threshold; this value can be edited;
  - *SAM Threshold*: Spectral Angle Mapping threshold; this value can be edited;

- : reset all signatures thresholds to 0 (i.e. no threshold used);

Automatic thresholds

- *Set threshold* 1 : set the defined value as threshold for all the highlighted signatures in the table;
- *Set threshold = σ ** 1 : for all the highlighted signatures, set an automatic threshold calculated as the distance (or angle) between mean signature and (mean signature + (σ * v)), where σ is the standard deviation and v is the defined value; currently works for Minimum Distance and Spectral Angle Mapping;

LCS threshold

This tab allows for setting the signature thresholds used by *Land Cover Signature Classification* (pagina 156). All the signatures contained in the *Training input* (pagina 40) are listed; also, signature thresholds are saved in the *Training input* (pagina 40).

Overlapping signatures (belonging to different classes or macroclasses) are highlighted in orange in the table *LC Signature threshold*; the overlapping check is performed considering *MC ID* or *C ID* according to the setting *Use* *MC ID* *C ID* in *Classification algorithm* (pagina 44). Overlapping signatures sharing the same *ID* are not highlighted.

LC Signature threshold

- ***LC Signature threshold*: table containing the following fields;**
  - *MC ID*: signature Macroclass ID;
  - *MC Info*: signature Macroclass Information;
  - *C ID*: signature Class ID;
  - *C Info*: signature Class Information;
  - *Color [overlap MC_ID-C_ID]*: signature color; also, the combination *MC ID-C ID* is displayed in case of overlap with other signatures (see *Land Cover Signature Classification* (pagina 156));
  - *Min B* `X`: minimum value of band `X`; this value can be edited;
  - *Max B* `X`: maximum value of band `X`; this value can be edited;
- : show the ROI spectral signature in the *Spectral Signature Plot* (pagina 123); spectral signature is calculated from the *Input image* (pagina 38);

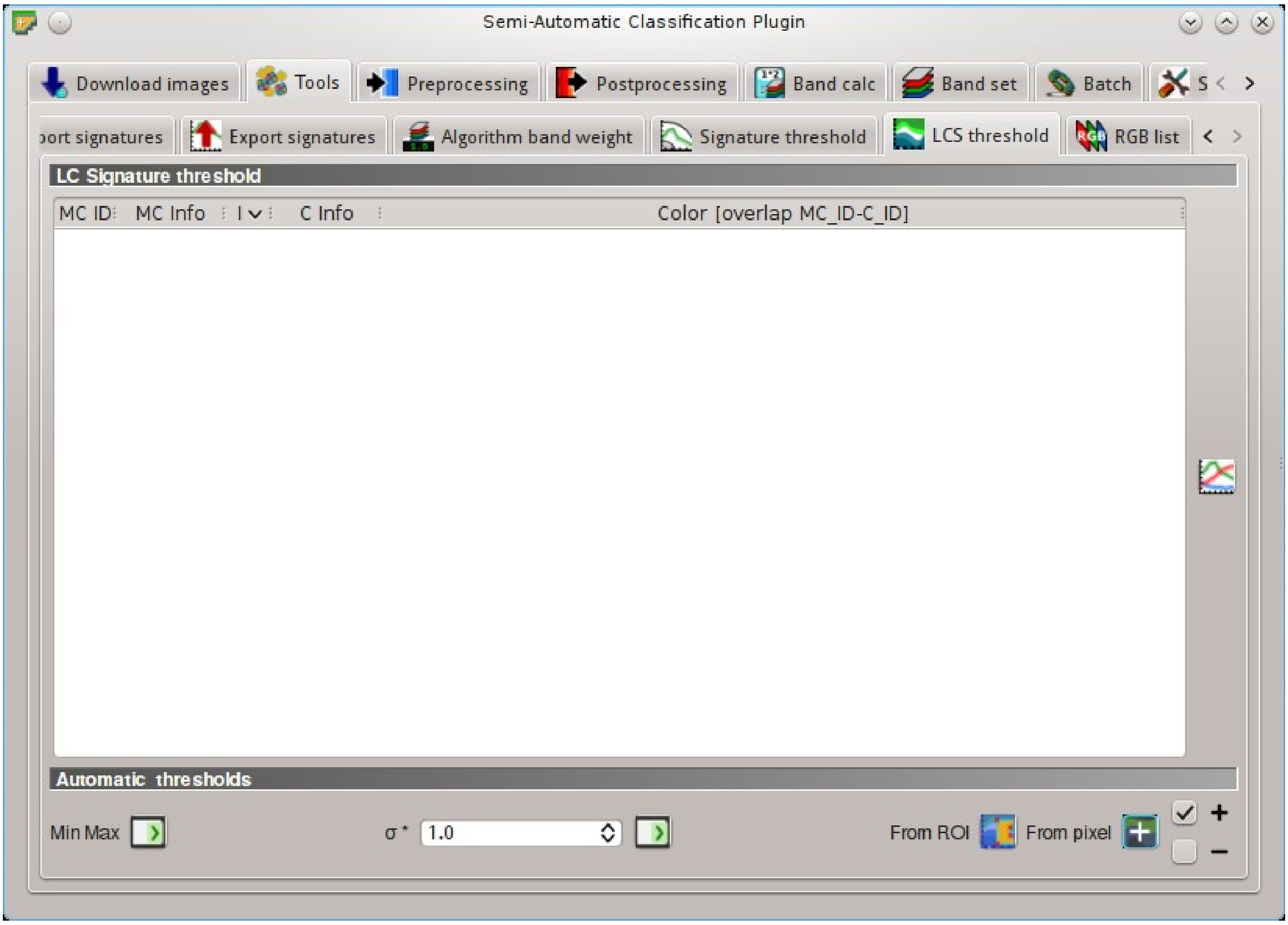


Fig. 10.14:  *LCS threshold*

Automatic thresholds

Set thresholds automatically for highlighted signatures in the table *LC Signature threshold*; if no signature is highlighted, then the threshold is applied to all the signatures.

- *Min Max* : set the threshold based on the minimum and maximum of each band;
- σ * 1 : set an automatic threshold calculated as (band value + (σ * v)), where σ is the standard deviation of each band and v is the defined value;
- ***From ROI*** **: set the threshold using the temporary ROI pixel values, according to the following checkboxes:**
  - +: if checked, signature threshold is extended to include pixel signature;
  - −: if checked, signature threshold is reduced to exclude pixel signature;
- ***From pixel*** **: set the threshold by clicking on a pixel, according to the following checkboxes:**
  - +: if checked, signature threshold is extended to include pixel signature;
  - −: if checked, signature threshold is reduced to exclude pixel signature;

RGB list

This tab allows for managing the RGB *Colore Composito* (pagina 147) used in the list *RGB=* of the *Image control* (pagina 33).

RGB list

- ***RGB list*: table containing the following fields;**
  - *RGB*: RGB combination; this field can be manually edited;
- : move highlighted RGB combination upward;
- : move highlighted RGB combination downward;
- : automatically sort RGB combinations by name;
- : add a row to the table;
- : remove highlighted rows from the table;
- : clear all RGB combinations from *RGB list*;
- : export the *RGB list* to a file (i.e. `.csv`);
- : import a previously saved *RGB list* from file (i.e. `.csv`);

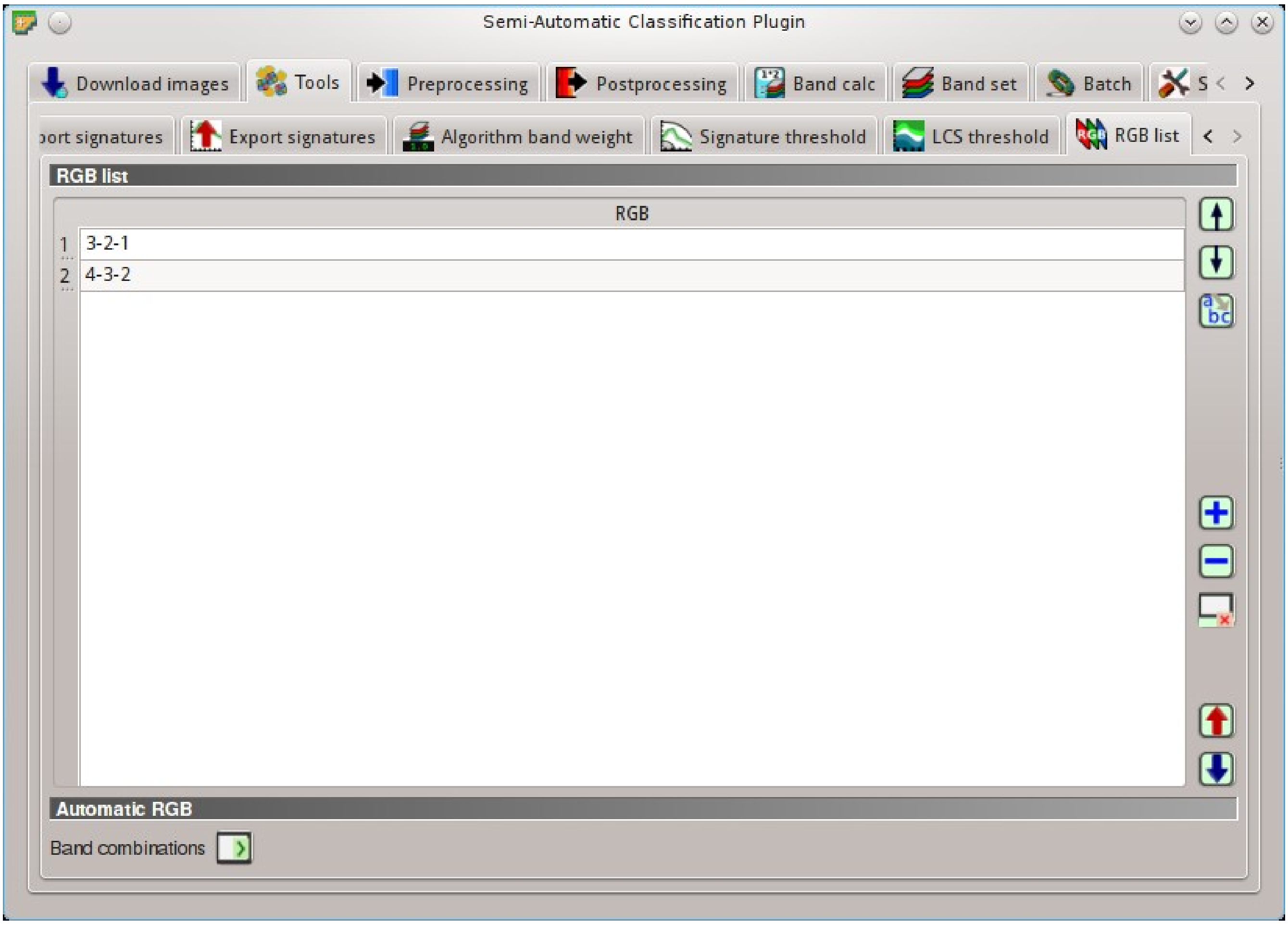


Fig. 10.15:  *RGB list*

Automatic RGB

- *Band combinations* : add the combinations of all bands (i.e. permutation) to the *RGB list* (pagina 75) (e.g. 1-2-3, 1-2-4, ..., 3-2-1);

Preprocessamento

The tab *Preprocessing* provides several tools for data manipulation which are useful before the actual classification process.

Landsat

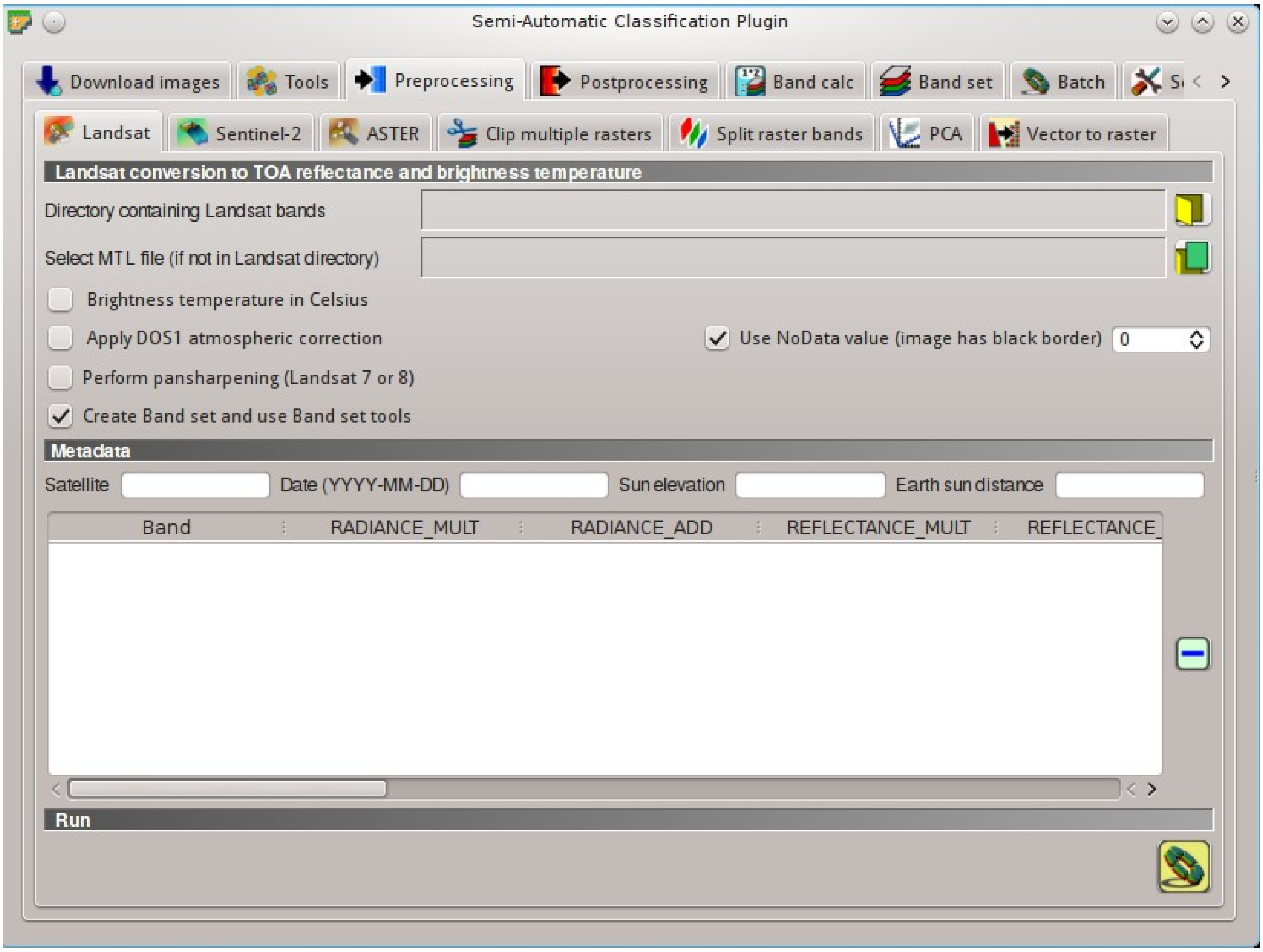


Fig. 10.16: *Landsat*

This tab allows for the conversion of **Landsat 1, 2, and 3 MSS** and **Landsat 4, 5, 7, and 8** images from DN (i.e. Digital Numbers) to the physical measure of Top Of Atmosphere reflectance (TOA), or the application of a simple atmospheric correction using the DOS1 method (Dark Object Subtraction 1), which is an image-based technique (for more information about the Landsat conversion to TOA and DOS1 correction, see *Image conversion to reflectance* (pagina 163)). Pan-sharpening is also available; for more information read *Pan-sharpening* (pagina 148).

Once the input is selected, available bands are listed in the metadata table.

Landsat conversion to TOA reflectance and brightness temperature

- *Directory containing Landsat bands* : open a directory containing Landsat bands; names of Landsat bands must end with the corresponding number; if the metadata file is included in this directory then *Metadata* (pagina 78) are automatically filled;
- *Select MTL file* : if the metadata file is not included in the *Directory containing Landsat bands*, select the path of the metadata file in order to fill the *Metadata* (pagina 78) automatically;
- *Brightness temperature in Celsius*: if checked, convert brightness temperature to Celsius (if a Landsat thermal band is listed in *Metadata* (pagina 78)); if unchecked temperature is in Kelvin;
- *Apply DOS1 atmospheric correction*: if checked, the *Correzione DOS1* (pagina 164) is applied to all the bands (thermal bands excluded);
- *Use NoData value (image has black border)* : if checked, pixels having `NoData` value are not counted during conversion and the DOS1 calculation of DNmin; it is useful when image has a black border (usually pixel value = 0);
- *Perform pan-sharpening*: if checked, a Brovey Transform is applied for the *Pan-sharpening* (pagina 148) of Landsat bands;
- *Create Band set and use Band set tools*: if checked, the *Band set* is created after the conversion; also, the *Band set* is processed according to the tools checked in the *Band set* (pagina 110);

Metadata

All the bands found in the *Directory containing Landsat bands* are listed in the table *Metadata*. If the Landsat metadata file (a .txt or .met file with the suffix MTL) is provided, then *Metadata* are automatically filled. For information about *Metadata* fields read this page and this one .

- *Satellite* : satellite name (e.g. Landsat8);
- *Date* : date acquired (e.g. 2013-04-15);
- *Sun elevation* : Sun elevation in degrees;
- *Earth sun distance* : Earth Sun distance in astronomical units (automatically calculated if *Date* is filled;
- : remove highlighted bands from the table *Metadata*;
- ***Metadata*: table containing the following fields;**
  - *Band*: band name;
  - *RADIANCE_MULT*: multiplicative rescaling factor;
  - *RADIANCE_ADD*: additive rescaling factor;
  - *REFLECTANCE_MULT*: multiplicative rescaling factor;
  - *REFLECTANCE_ADD*: additive rescaling factor;
  - *RADIANCE_MAXIMUM*: radiance maximum;

- *REFLECTANCE_MAXIMUM*: reflectance maximum;
- *K1_CONSTANT*: thermal conversion constant;
- *K2_CONSTANT*: thermal conversion constant;
- *LMAX*: spectral radiance that is scaled to QCALMAX;
- *LMIN*: spectral radiance that is scaled to QCALMIN;
- *QCALMAX*: minimum quantized calibrated pixel value;
- *QCALMIN*: maximum quantized calibrated pixel value;

Run

- : select an output directory and start the conversion process; only bands listed in the table *Metadata* are converted; converted bands are saved in the output directory with the prefix `RT_` and automatically loaded in QGIS;

Sentinel-2

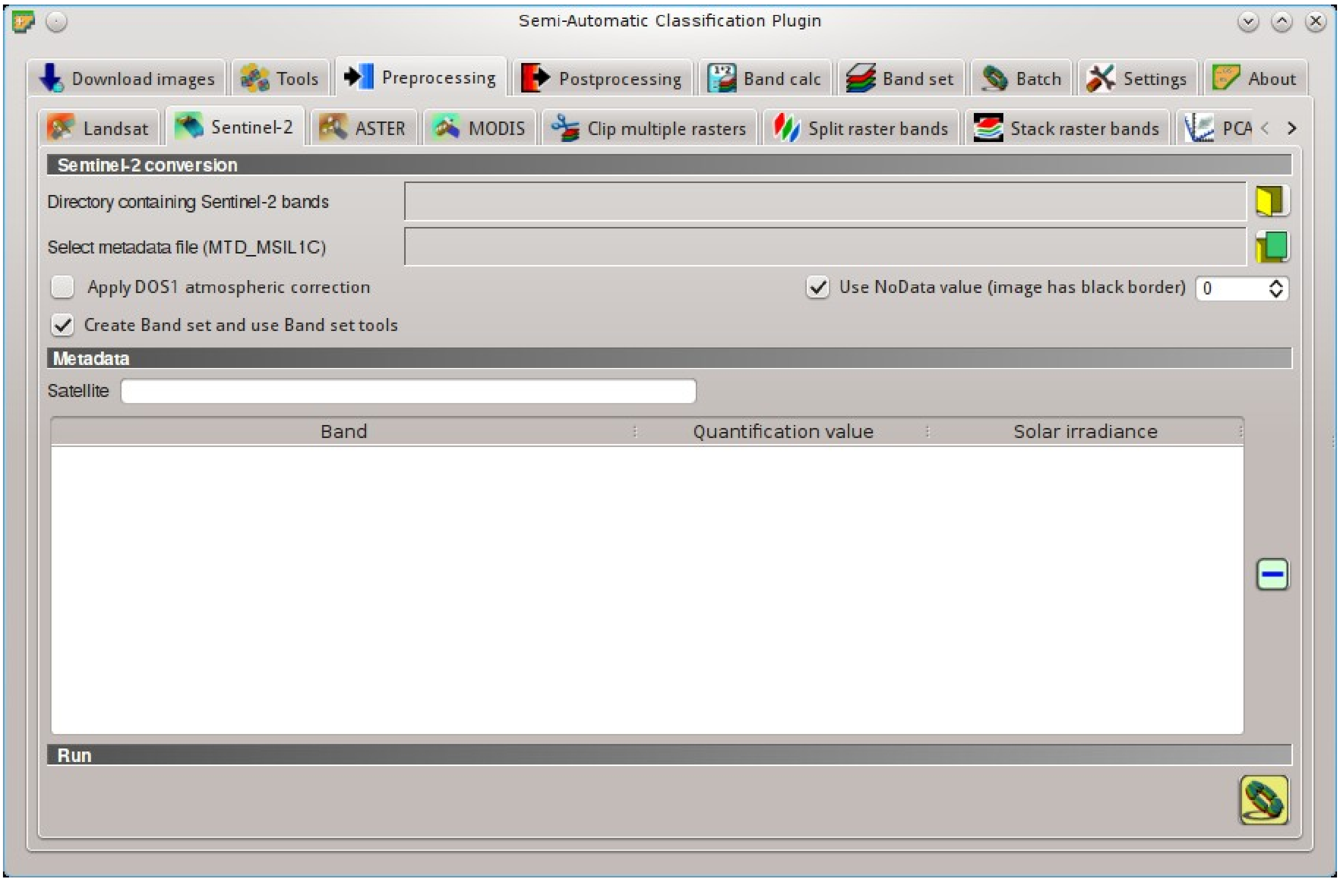
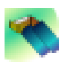


Fig. 10.17:  *Sentinel-2*

This tab allows for the conversion of **Sentinel-2** images to the physical measure of Top Of Atmosphere reflectance (TOA), or the application of a simple atmospheric correction using the DOS1 method (Dark Object Subtraction 1), which is an image-based technique (for more information about conversion to TOA and DOS1 correction, see *Image conversion to reflectance* (pagina 163)).

Once the input is selected, available bands are listed in the metadata table.

Sentinel-2 conversion

- *Directory containing Sentinel-2 bands* : open a directory containing Sentinel-2 bands; names of Sentinel-2 bands must end with the corresponding number; if the metadata file is included in this directory then *Metadata* (pagina 80) are automatically filled;
- *Select metadata file* : select the metadata file which is a .xml file whose name contains `MTD_MSIL1C`);
- *Apply DOS1 atmospheric correction*: if checked, the *Correzione DOS1* (pagina 164) is applied to all the bands;
- *Use NoData value (image has black border)* : if checked, pixels having `NoData` value are not counted during conversion and the DOS1 calculation of DNmin; it is useful when image has a black border (usually pixel value = 0);
- *Create Band set and use Band set tools*: if checked, the *Band set* is created after the conversion; also, the *Band set* is processed according to the tools checked in the *Band set* (pagina 110);

Metadata

All the bands found in the *Directory containing Sentinel-2 bands* are listed in the table *Metadata*. If the Sentinel-2 metadata file (a .xml file whose name contains `MTD_MSIL1C`) is provided, then *Metadata* are automatically filled. For information about *Metadata* fields read this informative page .

- *Satellite* : satellite name (e.g. Sentinel-2A);
- : remove highlighted bands from the table *Metadata*;
- ***Metadata*: table containing the following fields;**
  - *Band*: band name;
  - *Quantification value*: value for conversion to TOA reflectance;
  - *Solar irradiance*: solar irradiance of band;

Run

- : select an output directory and start the conversion process; only bands listed in the table *Metadata* are converted; converted bands are saved in the output directory with the prefix `RT_` and automatically loaded in QGIS;

ASTER

This tab allows for the conversion of **ASTER L1T** images to the physical measure of Top Of Atmosphere reflectance (TOA), or the application of a simple atmospheric correction using the DOS1 method (Dark Object Subtraction 1), which is an image-based technique (for more information about conversion to TOA and DOS1 correction, see *Image conversion to reflectance* (pagina 163)).

Once the input is selected, available bands are listed in the metadata table.

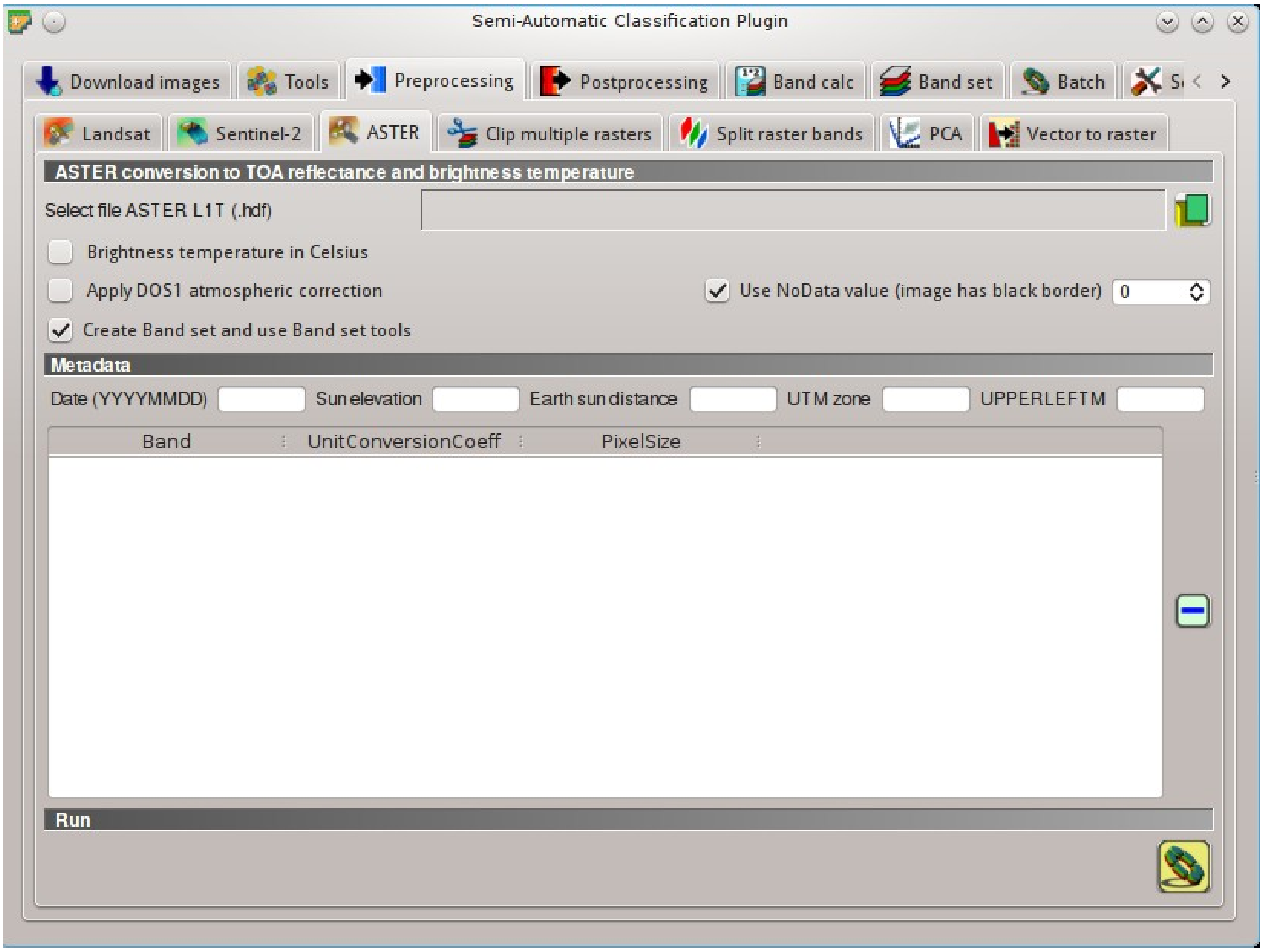


Fig. 10.18:  *ASTER*

ASTER conversion

- *Select file ASTER L1T* : select an ASTER image (file .hdf);
- *Apply DOS1 atmospheric correction*: if checked, the *Correzione DOS1* (pagina 164) is applied to all the bands;
- *Use NoData value (image has black border)* : if checked, pixels having `NoData` value are not counted during conversion and the DOS1 calculation of DNmin; it is useful when image has a black border (usually pixel value = 0);
- *Create Band set and use Band set tools*: if checked, the *Band set* is created after the conversion; also, the *Band set* is processed according to the tools checked in the *Band set* (pagina 110);

Metadata

All the bands found in the *Select file ASTER L1T* are listed in the table *Metadata*. For information about *Metadata* fields visit the ASTER page .

- *Date* : date acquired (e.g. 20130415);
- *Sun elevation* : Sun elevation in degrees;
- *Earth sun distance* : Earth Sun distance in astronomical units (automatically calculated if *Date* is filled;
- *UTM zone* : UTM zone code of the image;
- *UPPERLEFTM* : coordinates of the upper left corner of the image;
- : remove highlighted bands from the table *Metadata*;
- ***Metadata*: table containing the following fields;**
  - *Band*: band name;
  - *UnitConversionCoeff*: value for radiance conversion;
  - *PixelSize*: solar irradiance of band;

Run

- : select an output directory and start the conversion process; only bands listed in the table *Metadata* are converted; converted bands are saved in the output directory with the prefix `RT_` and automatically loaded in QGIS;

MODIS

This tab allows for the conversion of **MODIS** images to .tif format, and the reprojection to WGS 84.

Once the input is selected, available bands are listed in the metadata table.

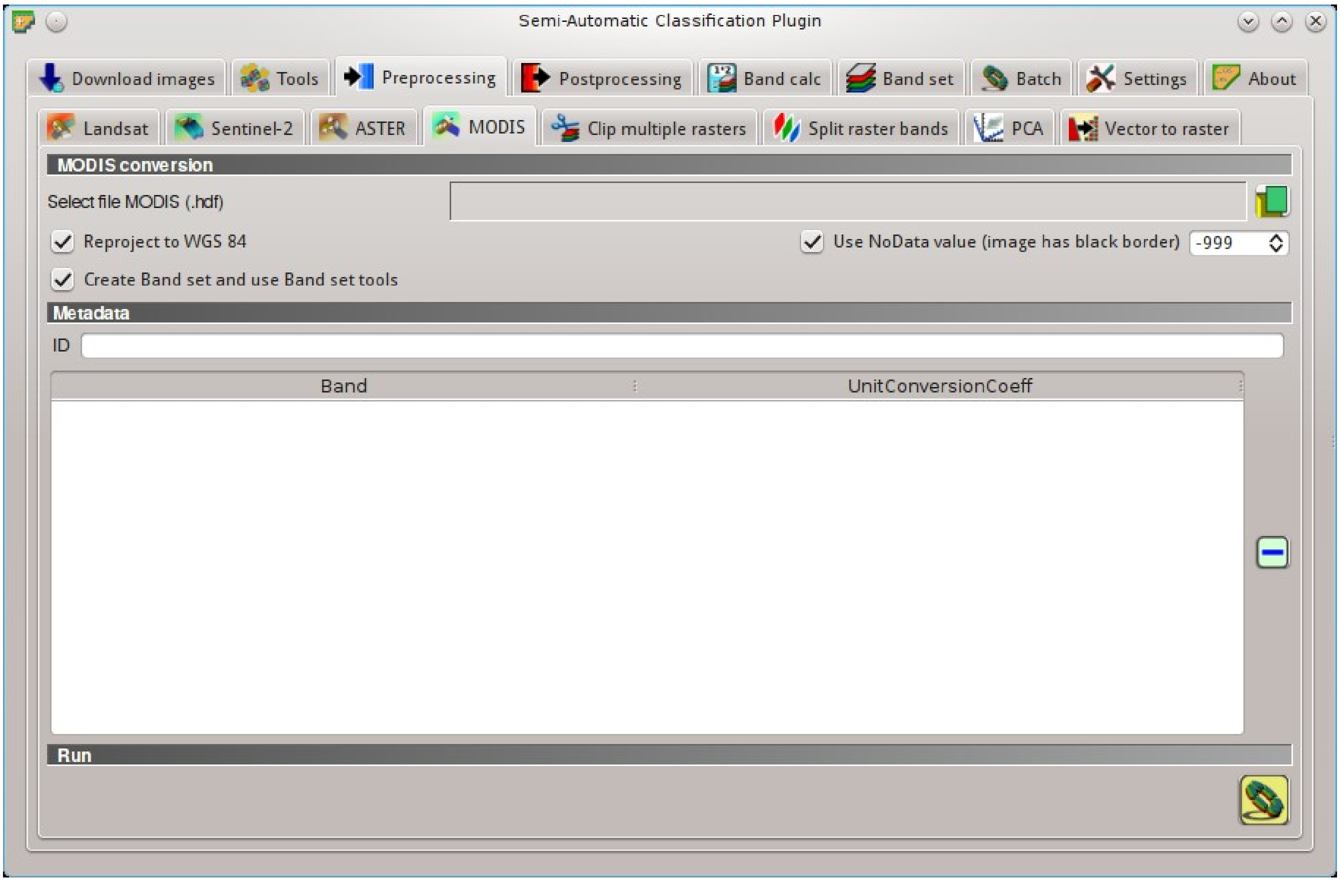


Fig. 10.19:  *MODIS*

MODIS conversion

- *Select file MODIS* : select a MODIS image (file .hdf);
- *Reproject to WGS 84*: if checked, reproject bands to WGS 84, required for use in *SCP*;
- *Use NoData value (image has black border)* : if checked, pixels having `NoData` value are not counted during conversion and the DOS1 calculation of DNmin; it is useful when image has a black border (usually pixel value = 0);
- *Create Band set and use Band set tools*: if checked, the *Band set* is created after the conversion; also, the *Band set* is processed according to the tools checked in the *Band set* (pagina 110);

Metadata

All the bands found in the *Select file MODIS* are listed in the table *Metadata*. For information about *Metadata* fields visit the MODIS page .

- *ID* : ID of the image;
- : remove highlighted bands from the table *Metadata*;
- ***Metadata*: table containing the following fields;**
  - *Band*: band name;
  - *UnitConversionCoeff*: value for conversion;

Run

- : select an output directory and start the conversion process; only bands listed in the table *Metadata* are converted; converted bands are saved in the output directory with the prefix `RT_` and automatically loaded in QGIS;

Clip multiple rasters

This tab allows for cutting several image bands at once, using a rectangle defined with point coordinates or a boundary defined with a shapefile.

Raster list

- : refresh layer list;
- : select all the rasters;

Clip coordinates

Set the Upper Left (UL) and Lower Right (LR) point coordinates of the rectangle used for clipping; it is possible to enter the coordinates manually. Alternatively use a shapefile.

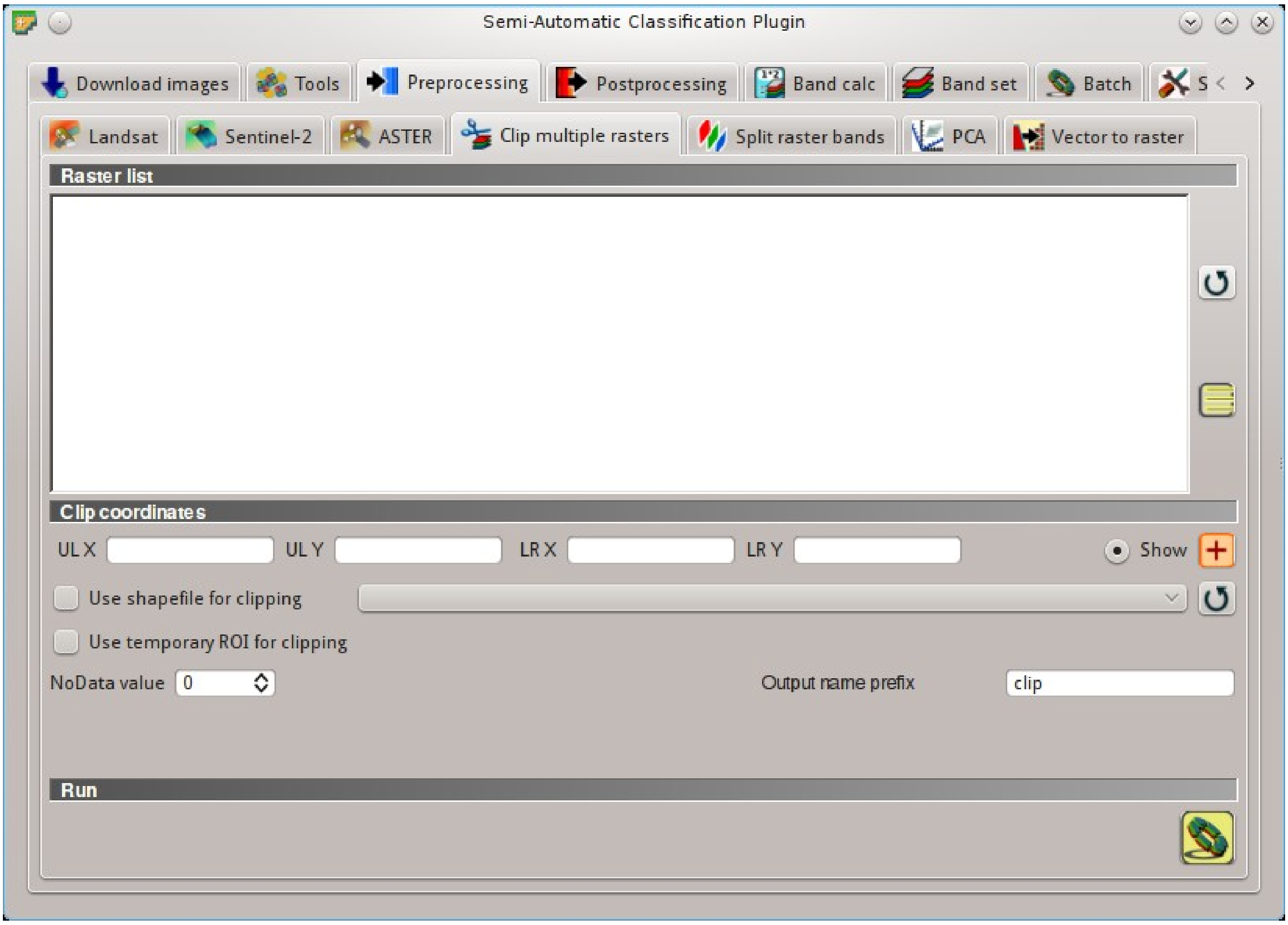


Fig. 10.20: *Clip multiple rasters*

- *UL X* : set the UL X coordinate;
- *UL Y* : set the UL Y coordinate;
- *LR X* : set the LR X coordinate;
- *LR Y* : set the LR Y coordinate;
- *Show*: show or hide the clip area drawn in the map;
- : define a clip area by drawing a rectangle in the map; left click to set the UL point and right click to set the LR point; the area is displayed in the map;
- *Use shapefile for clipping* : if checked, use the selected shapefile (already loaded in QGIS) for clipping; UL and LR coordinates are ignored;
- *Use temporary ROI for clipping*: if checked, use a temporary ROI (see *Creazione ROI* (pagina 42)) for clipping; UL and LR coordinates are ignored;
- : refresh layer list;
- *NoData value* : if checked, set the value for `NoData` pixels (e.g. pixels outside the clipped area);
- *Output name prefix* : set the prefix for output file names (default is `clip`);

Run

- : choose an output destination and clip selected rasters; only rasters selected in the *Raster list* (pagina 84) are clipped and automatically loaded in QGIS;

Split raster bands

Split a multiband raster to single bands.

Raster input

- *Select a multiband raster* : select a multiband raster already loaded in QGIS;
- : refresh layer list;
- *Output name prefix* : set the prefix for output file names (default is `split`);

Run

- : choose the output destination and split selected raster; output bands are automatically loaded in QGIS;

Stack raster bands

Stack raster bands into a single file.

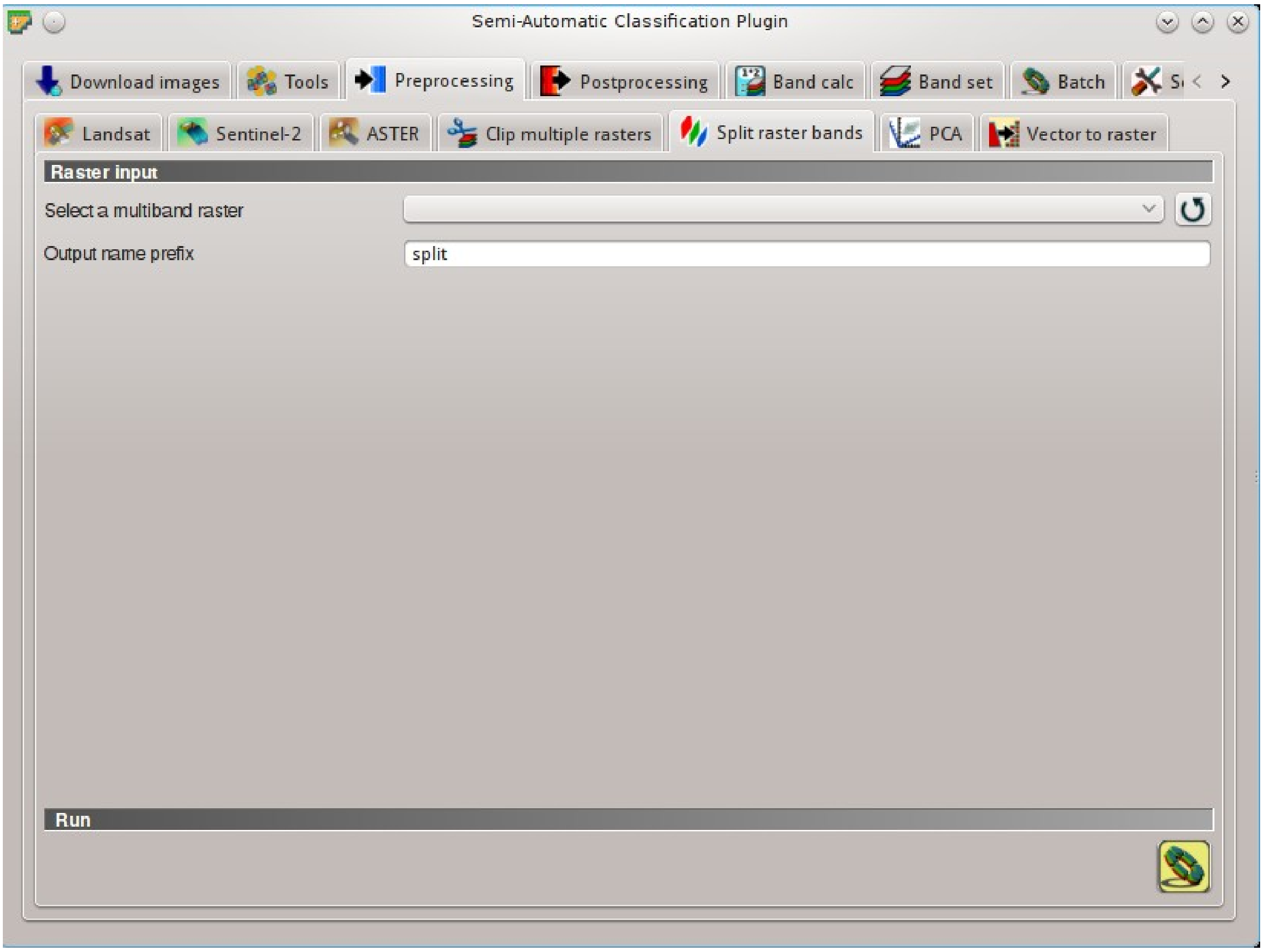


Fig. 10.21:  *Split raster bands*

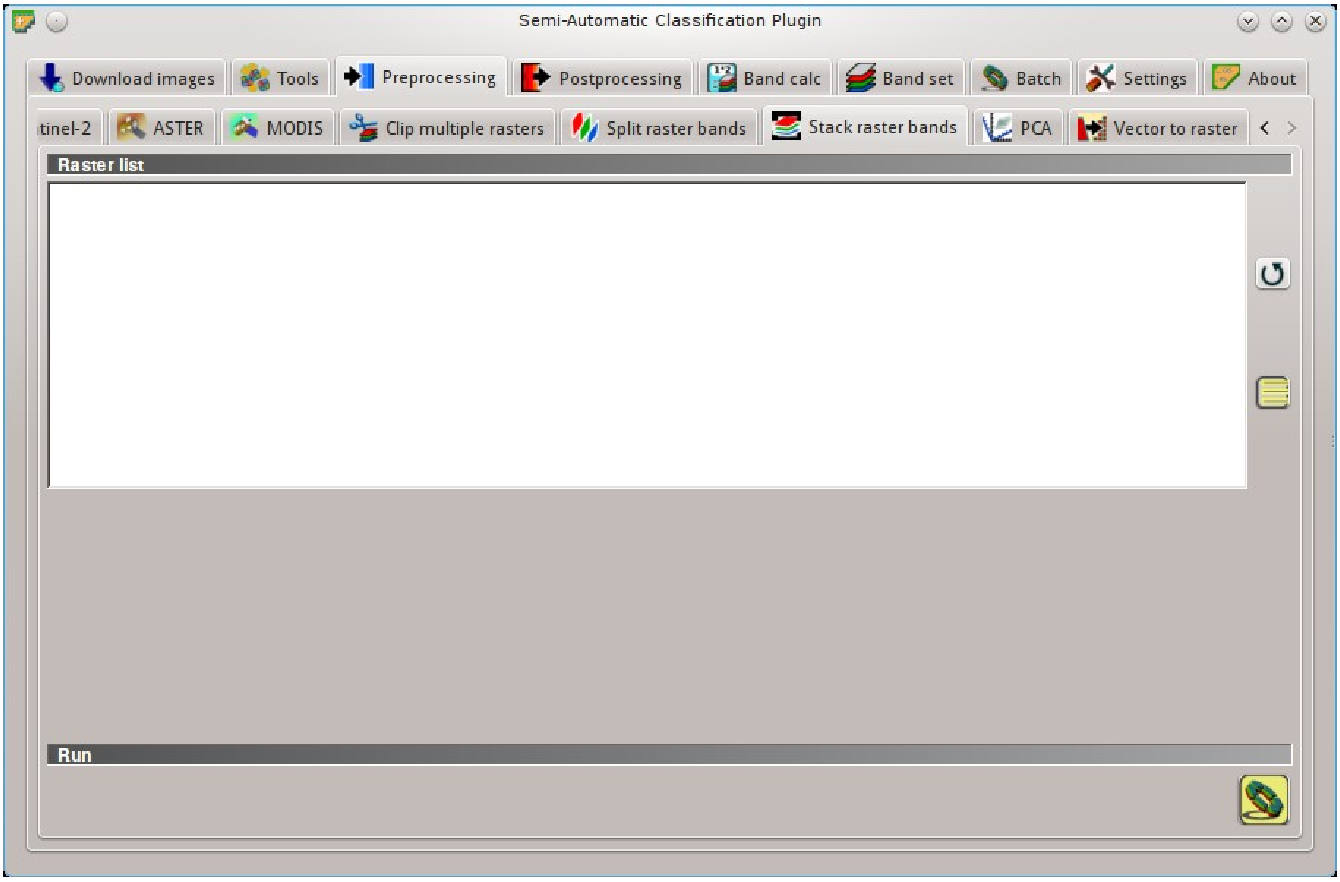
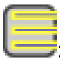


Fig. 10.22: *Stack raster bands*

Raster list

- : refresh layer list;
- : select all the rasters;

Run

- : choose the output destination and stack selected rasters; output is automatically loaded in QGIS;

PCA

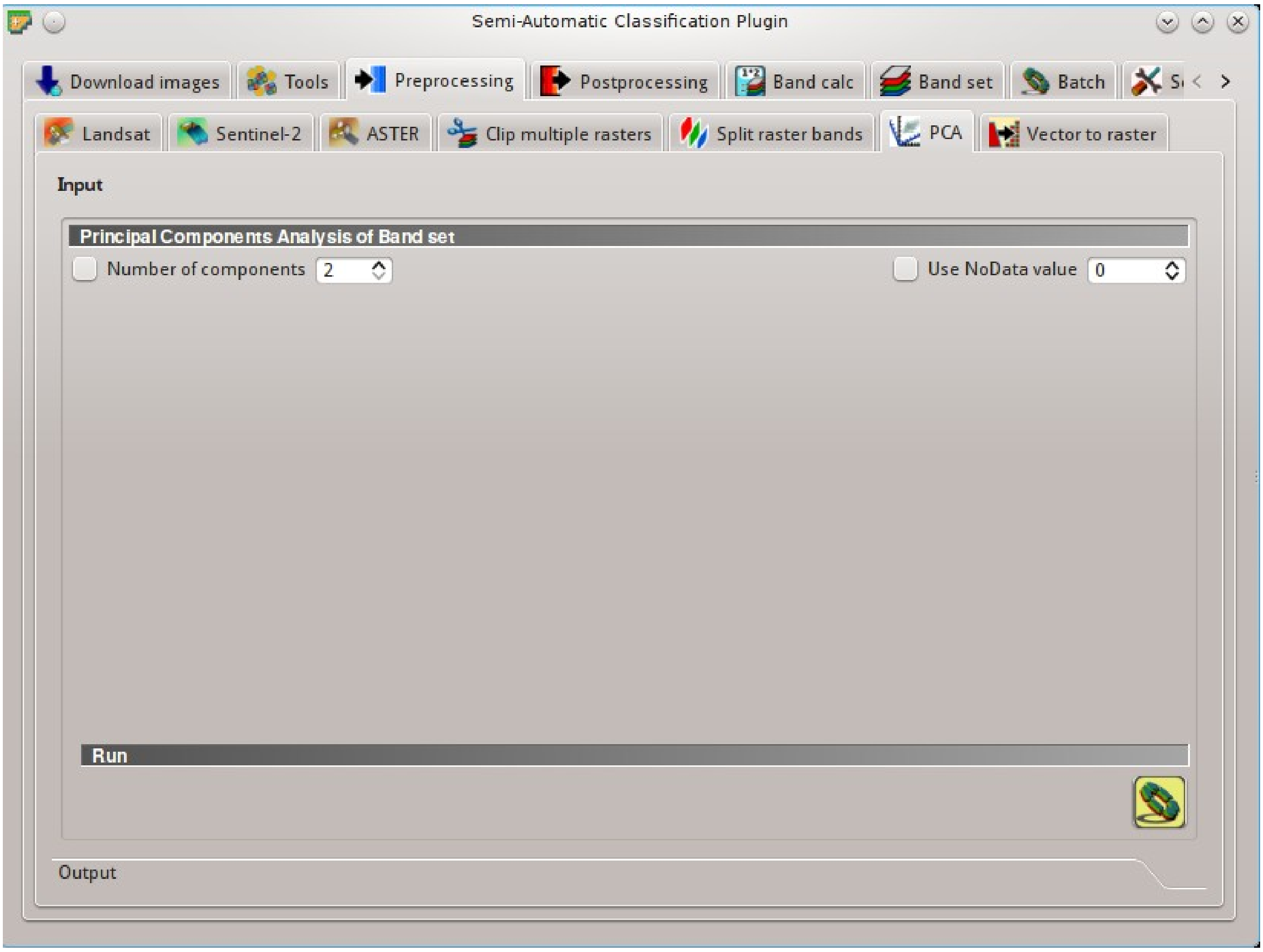


Fig. 10.23:  *PCA*

This tab allows for the PCA (*Principal Component Analysis* (pagina 147)) of bands loaded in the *Band set*.

Principal Component Analysis of Band set

- *Number of components*: if checked, set the number of calculated components; if unchecked, all the components are calculated;
- *Use NoData value*: if checked, set the value of `NoData` pixels, ignored during the calculation;

Run

- : select an output directory and start the calculation process; principal components are calculated and saved as raster files; also, the details about the PCA are displayed in the tab *Output* and saved in a .txt file in the output directory;

Vector to raster

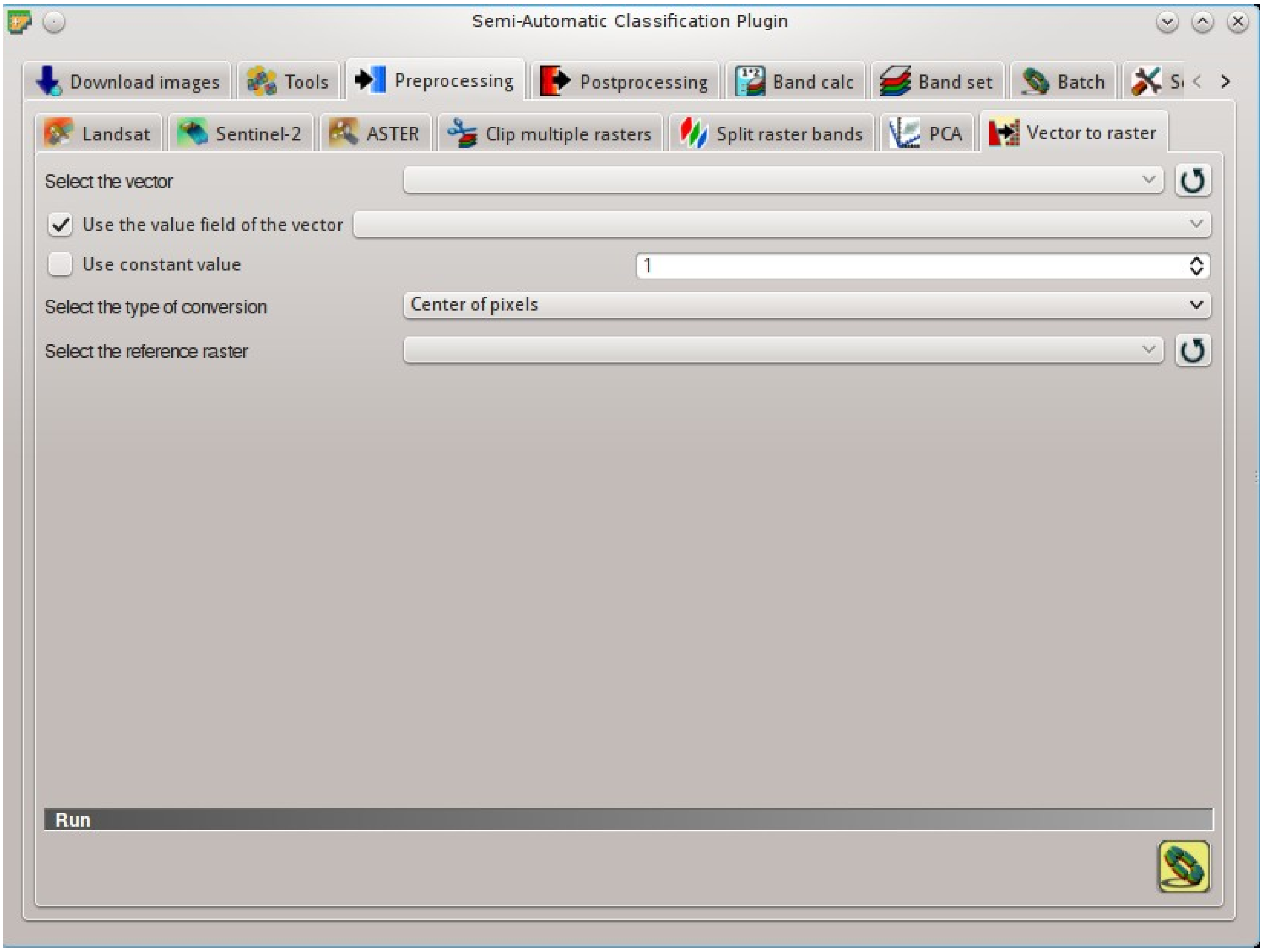


Fig. 10.24: *Vector to raster*

This tab allows for the conversion of a vector to raster format.

- *Select the vector*: select a vector already loaded in QGIS;

- : refresh layer list;
- *Use the value field of the vector* : if checked, the selected field is used as attribute for the conversion; pixels of the output raster have the same values as the vector attribute;
- *Use constant value* : if checked, the polygons are converted to raster using the selected constant value;
- ***Select the type of conversion*** **: select the type of conversion between *Center of pixels* and *All pixels touched*:**
  - *Center of pixels*: during the conversion, vector is compared to the reference raster; output raster pixels are attributed to a polygon if pixel center is within that polygon;
  - *All pixels touched*: during the conversion, vector is compared to the reference raster; output raster pixels are attributed to a polygon if pixel touches that polygon;
- *Select the reference raster* : select a reference raster; pixels of the output raster have the same size and alignment as the reference raster;
- : refresh layer list;

Run

- : choose the output destination and start the conversion to raster;

Postprocessamento

The tab *Postprocessing* provides several functions that can be applied to the classification output.

Accuracy

This tab allows for the validation of a classification (read *Valutazione dell'Accuratezza* (pagina 160)). Classification is compared to a reference raster or reference shapefile (which is automatically converted to raster). If a shapefile is selected as reference, it is possible to choose a field describing class values.

Several statistics are calculated such as overall accuracy, user's accuracy, producer's accuracy, and Kappa hat. The output is an `error raster` that is a `.tif` file showing the errors in the map, where pixel values represent the categories of comparison (i.e. combinations identified by the `ErrorMatrixCode` in the error matrix) between the classification and reference. Also, a text file containing the error matrix (i.e. a `.csv` file separated by tab) is created with the same name defined for the `.tif` file.

Input

- *Select the classification to assess* : select a classification raster (already loaded in QGIS);
- : refresh layer list;
- *Select the reference shapefile or raster* : select a raster or a shapefile (already loaded in QGIS), used as reference layer (ground truth) for the accuracy assessment;
- : refresh layer list;

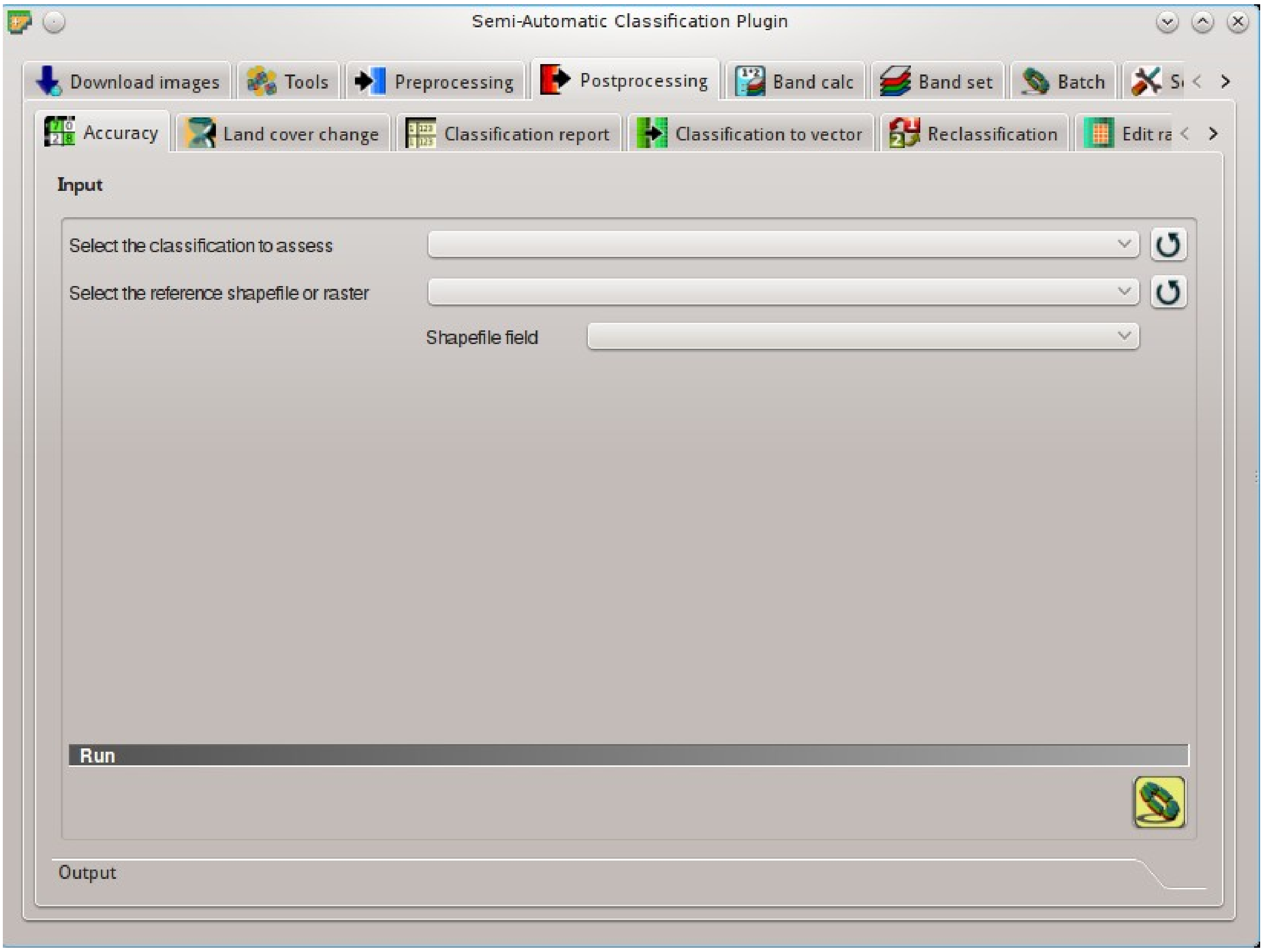


Fig. 10.25:  *Accuracy*

- *Shapefile field* : if a shapefile is selected as reference, select a shapefile field containing numeric class values;

Run

- : choose the output destination and start the calculation; the error matrix is displayed in the tab *Output* and the `error raster` is loaded in QGIS;

Land cover change

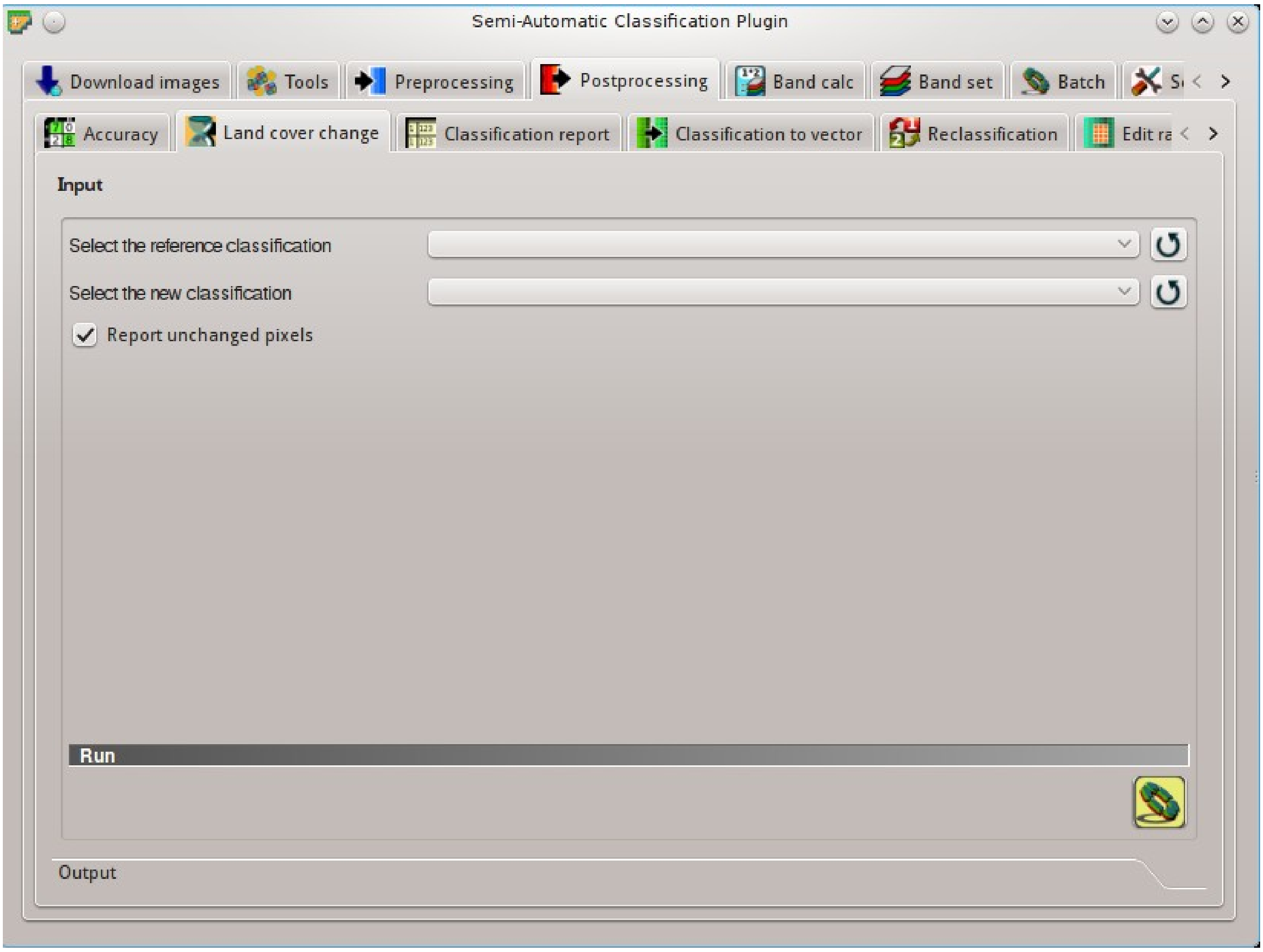


Fig. 10.26: *Land cover change*

The tab `Land cover change` allows for the comparison between two classifications in order to assess land cover changes. Output is a `land cover change raster` (i.e. a file .tif showing the changes in the map, where each pixel represents a category of comparison (i.e. combinations) between the two classifications, which is the `ChangeCode` in the land cover change statistics) and a text file containing the land cover change statistics (i.e. a file .csv separated by tab, with the same name defined for the .tif file).

Input

- *Select the reference classification* : select a reference classification raster (already loaded in QGIS);

- : refresh layer list;
- *Select the new classification* : select a new classification raster (already loaded in QGIS), to be compared with the reference classification;
- : refresh layer list;
- *Report unchanged pixels*: if checked, report also unchanged pixels (having the same value in both classifications);

Run

- : choose the output destination and start the calculation; the land cover change statistics are displayed in the tab *Output* (and saved in a text file) and the `land cover change raster` is loaded in QGIS;

Classification report

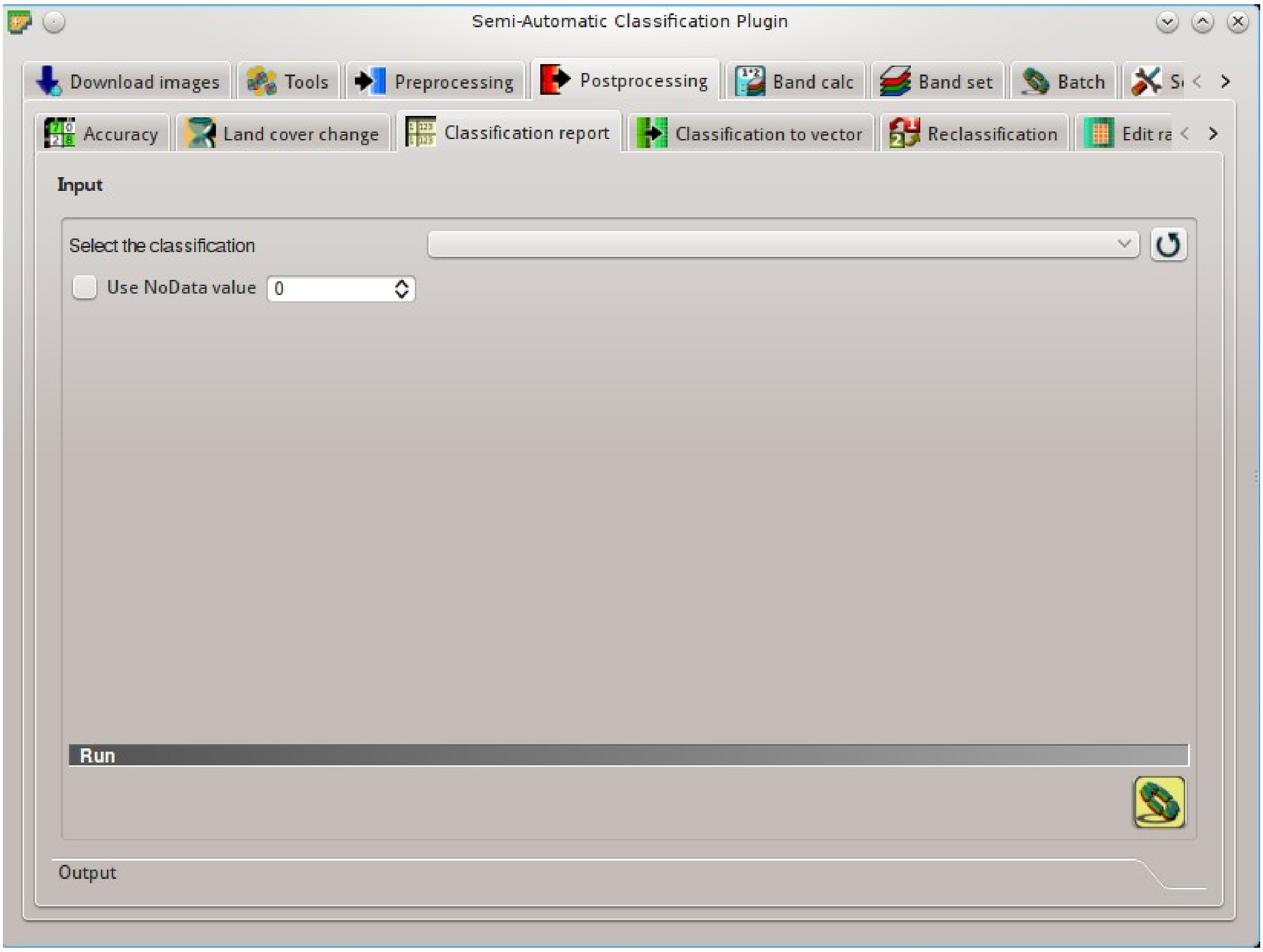


Fig. 10.27: *Classification report*

This tab allows for the calculation of class statistics such as number of pixels, percentage and area (area unit is defined from the image itself).

Input

- *Select the classification* : select a classification raster (already loaded in QGIS);
- : refresh layer list;
- *Use NoData value* : if checked, `NoData` value will be excluded from the report;

Run

- : choose the output destination and start the calculation; the report is saved in a text file and displayed in the tab *Output*;

Cross classification

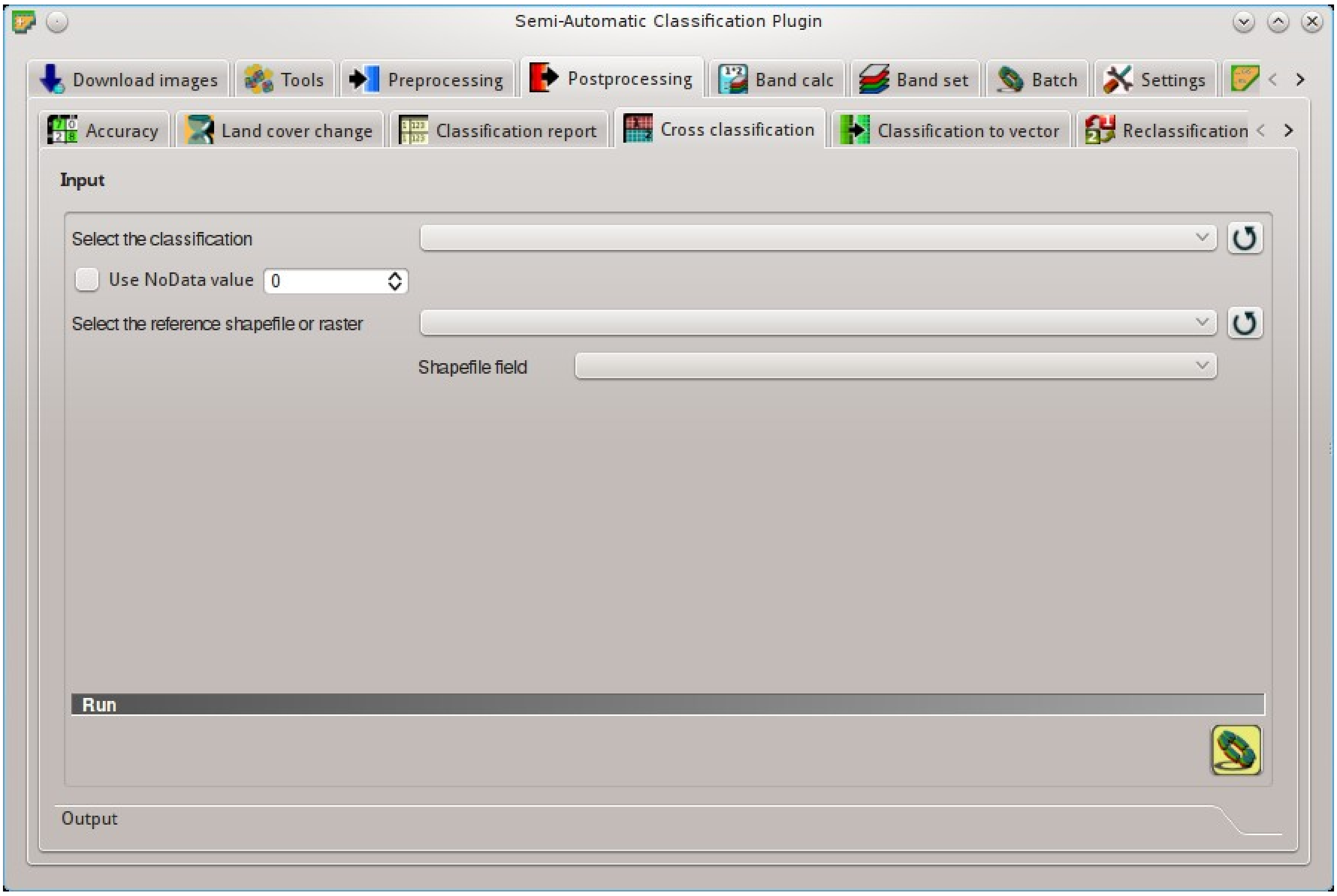


Fig. 10.28: *Cross classification*

This tab allows for the calculation of a cross classification raster and matrix. Classification is compared to a reference raster or reference shapefile (which is automatically converted to raster). This is useful for calculating the area for every combination between reference classes and classification values. If a shapefile is selected as reference, it is possible to choose a field describing class values.

The output is a `cross raster` that is a `.tif` file where pixel values represent the categories of comparison (i.e. combinations identified by the `CrossMatrixCode`) between the classification and reference. Also, a text file containing the cross matrix (i.e. a `.csv` file separated by tab) is created with the same name defined for the `.tif` file.

Input

- *Select the classification* : select a classification raster (already loaded in QGIS);
- : refresh layer list;
- *Use NoData value* : if checked, `NoData` value will be excluded from the calculation;
- *Select the reference shapefile or raster* : select a raster or a shapefile (already loaded in QGIS), used as reference layer;
- : refresh layer list;
- *Shapefile field* : if a shapefile is selected as reference, select a shapefile field containing numeric class values;

Run

- : choose the output destination and start the calculation; the cross matrix is displayed in the tab *Output* and the `cross raster` is loaded in QGIS;

Classification to vector

This tab allows for the conversion of a classification raster to vector shapefile.

- *Select the classification* : select a classification raster (already loaded in QGIS);
- : refresh layer list;

Symbology

- ***Use code from Signature list*** **: if checked, color and class information are defined from** ***ROI Signature list*** **(pag**
  - `MC ID`: use the ID of macroclasses;
  - `C ID`: use the ID of classes;

Run

- : choose the output destination and start the conversion;

Reclassification

This tab allows for the reclassification (i.e. assigning a new class code to raster pixels). In particular, it eases the conversion from C ID to MC ID values.

- *Select the classification* : select a classification raster (already loaded in QGIS);

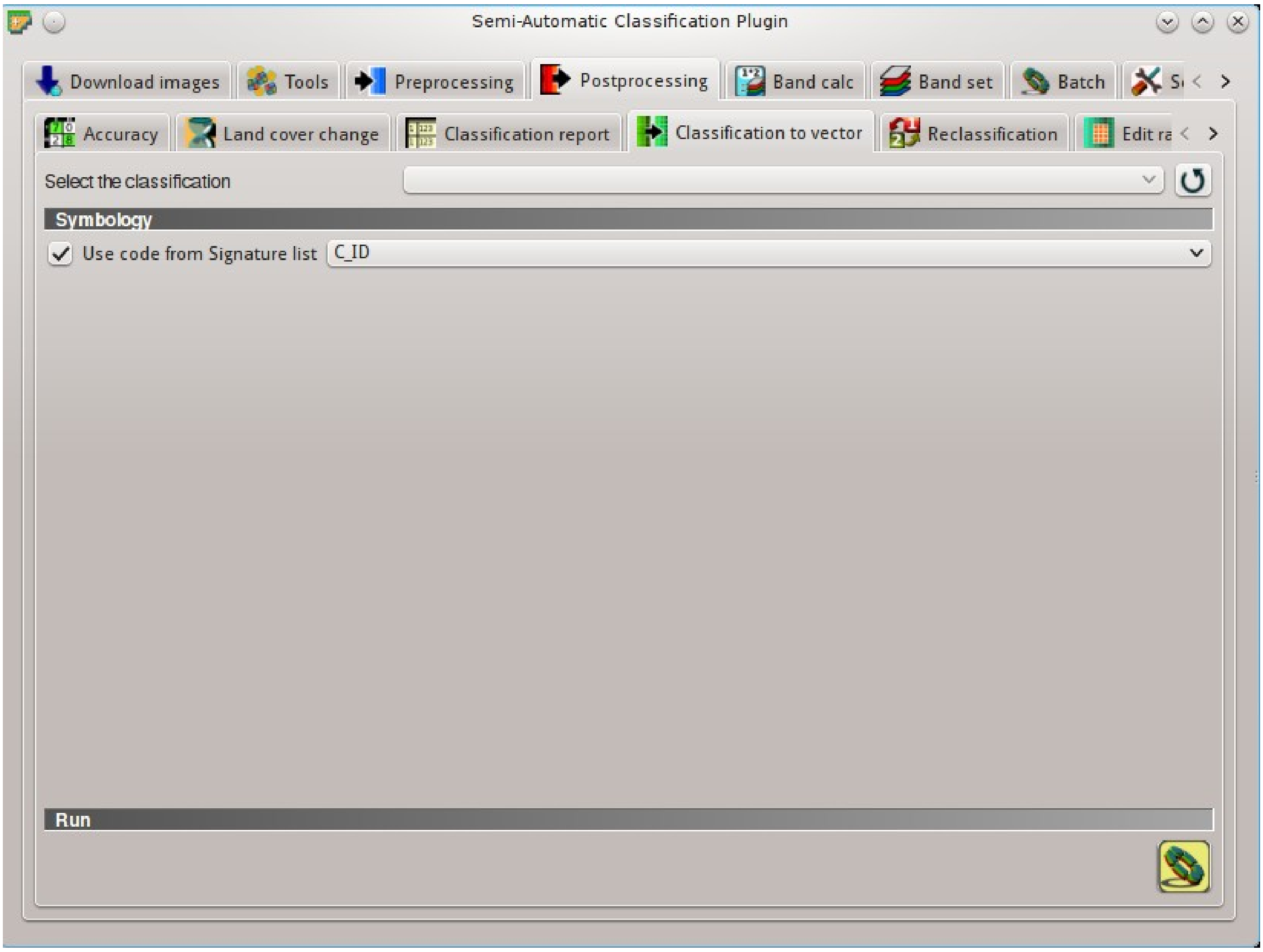


Fig. 10.29:  *Classification to vector*

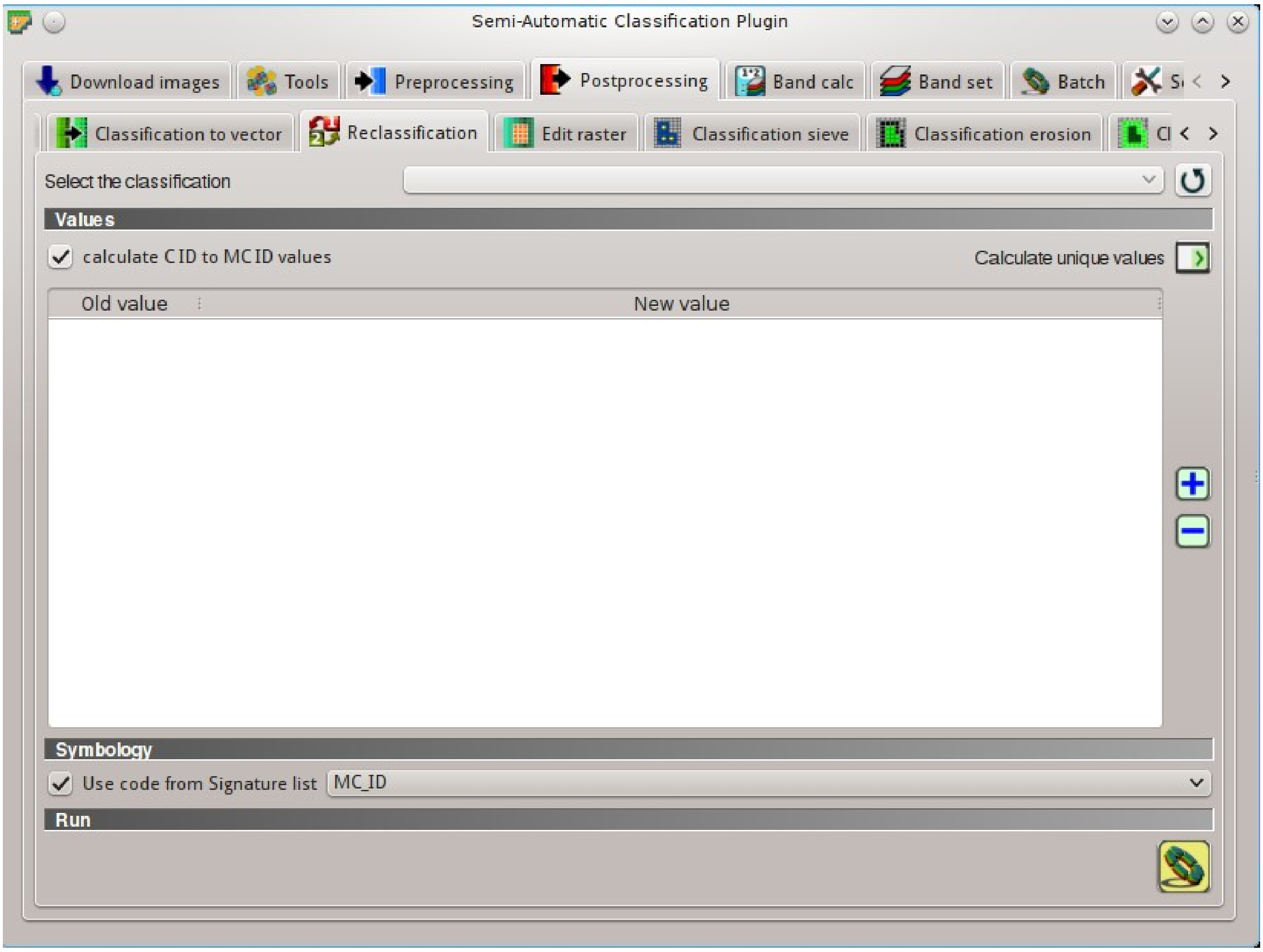


Fig. 10.30:  *Reclassification*

- : refresh layer list;

Values

- *calculate C ID to MC ID values*: if checked, the reclassification table is filled according to the *ROI Signature list* (pagina 41) when *Calculate unique values* is clicked;
- *Calculate unique values* : calculate unique values in the classification and fill the reclassification table;
- ***Values*: table containing the following fields;**
  - *Old value*: set the expression defining old values to be reclassified; `Old value` can be a value or an expressions defined using the variable name `raster` (custom names can be defined in *Variable name for expressions* (pagina 118)), following Python operators (e.g. `raster > 3` select all pixels having value > 3 ; `raster > 5 | raster < 2` select all pixels having value > 5 or < 2 ; `raster >= 2 & raster <= 5` select all pixel values between 2 and 5);
  - *New value*: set the new value for the old values defined in `Old value`;
- : add a row to the table;
- : remove highlighted rows from the table;

Symbology

- ***Use code from Signature list* : if checked, color and class information are defined from *ROI Signature list* (pag**
  - `MC ID`: use the ID of macroclasses;
  - `C ID`: use the ID of classes;

Run

- : choose the output destination and start the calculation; reclassified raster is loaded in QGIS;

Edit raster

This tab allows for the direct editing of pixel values in a raster. Only pixels beneath ROI polygons or vector polygons are edited.

> **Attention**: the input raster is directly edited; it is recommended to create a **backup copy** of the input raster before using this tool in order to prevent data loss.

This tool can rapidly edit large rasters, especially when editing polygons are small, because pixel values are edited directly. In addition, the *SCP Edit Toolbar* (pagina 135) is available for easing the raster editing using multiple values.

- *Select the input raster* : select a raster (already loaded in QGIS);
- : refresh layer list;

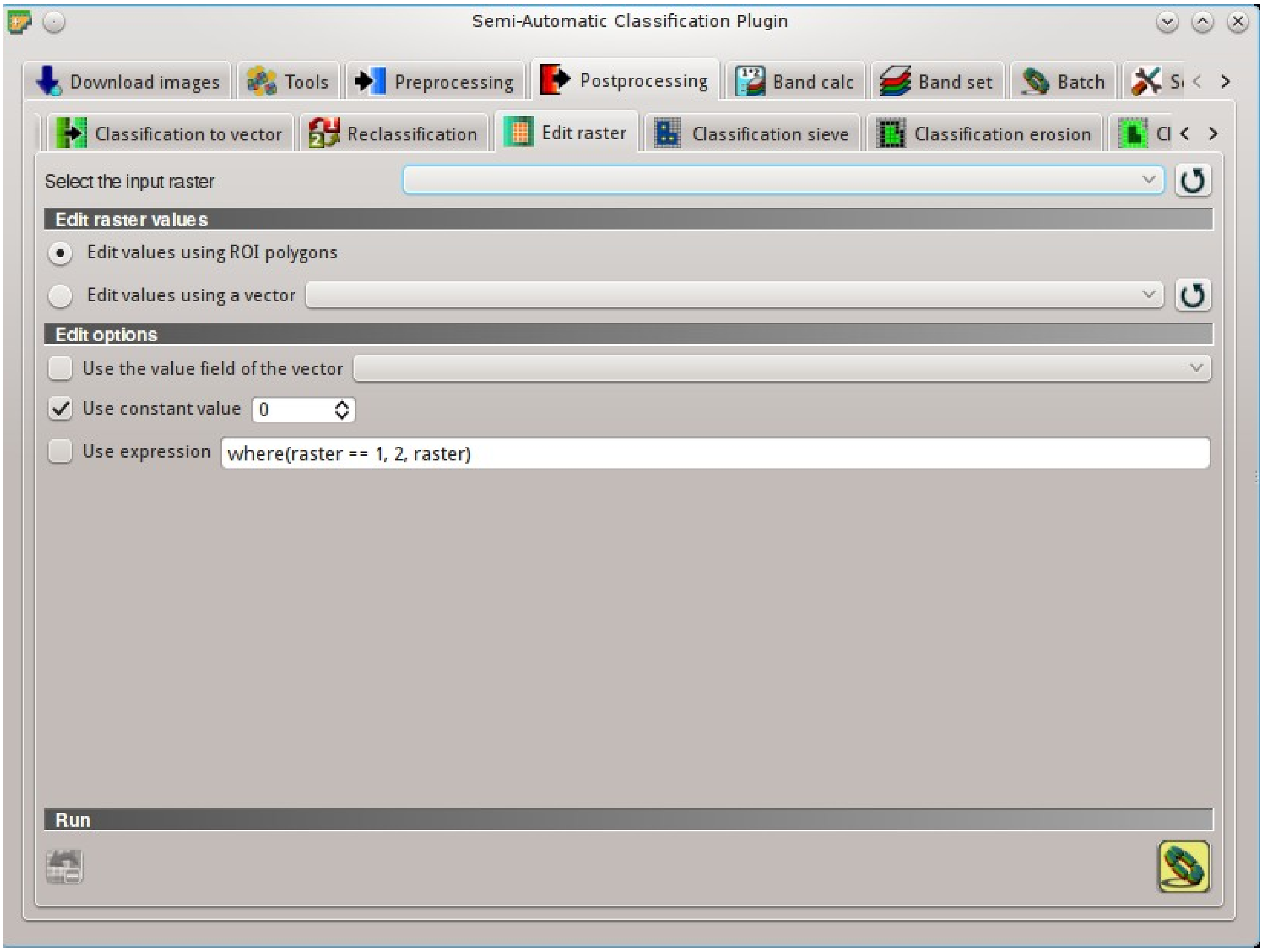
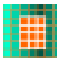


Fig. 10.31:  *Edit raster*

Edit raster values

- *Edit values using ROI polygons*: if checked, raster is edited using temporary ROI polygons in the map;
- *Edit values using a vector* : if checked, raster is edited using all the polygons of selected vector;
- : refresh layer list;

Edit options

- *Use the value field of the vector* : if checked, raster is edited using the selected vector (in *Edit values using a vector*) and the polygon values of selected vector field;
- *Use constant value* : if checked, raster is edited using the selected constant value;
- *Use expression* : if checked, raster is edited according to the entered expression; the expression must contain one or more `where`; the following example expression `where(raster == 1, 2, raster)` is already entered, which sets 2 where `raster` equals 1, and leaves unchanged the values where `raster` is not equal to 1;

Run

- : undo the last raster edit (available only when using ROI polygons);
- : edit the raster;

Classification sieve

This tab allows for the replacement of isolated pixel values with the value of the largest neighbour patch (based on GDAL Sieve). It is useful for removing small patches from a classification.

- *Select the classification* : select a raster (already loaded in QGIS);
- : refresh layer list;
- *Size threshold* : size of the patch to be replaced (in pixel unit); all patches smaller the the selected number of pixels will be replaced by the value of the largest neighbour patch;
- ***Pixel connection*** **: select the type of pixel connection:**
  - *4*: in a 3x3 window, diagonal pixels are not considered connected;
  - *8*: in a 3x3 window, diagonal pixels are considered connected;

Run

- : choose the output destination and start the calculation;

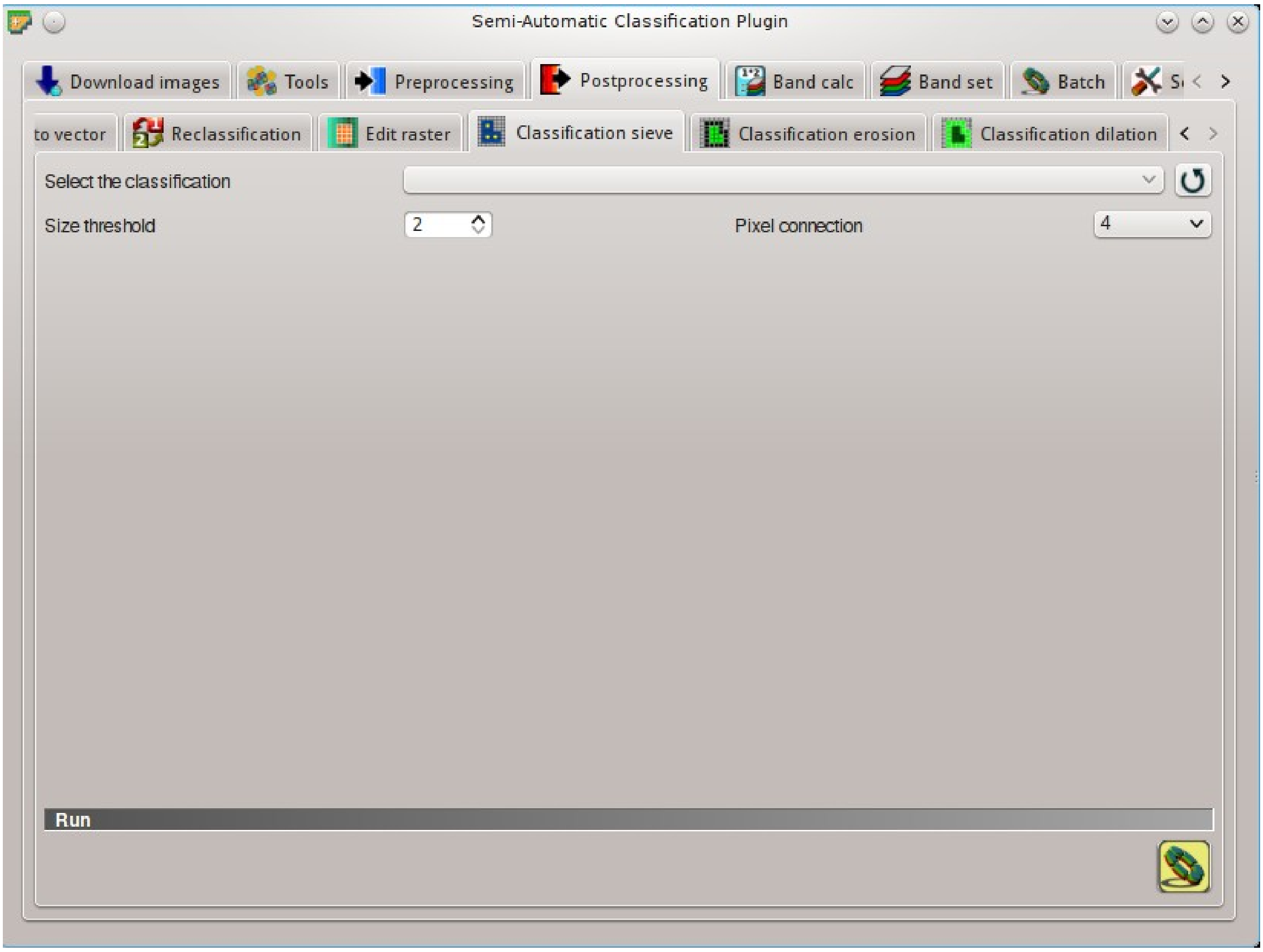
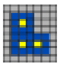


Fig. 10.32:  *Classification sieve*

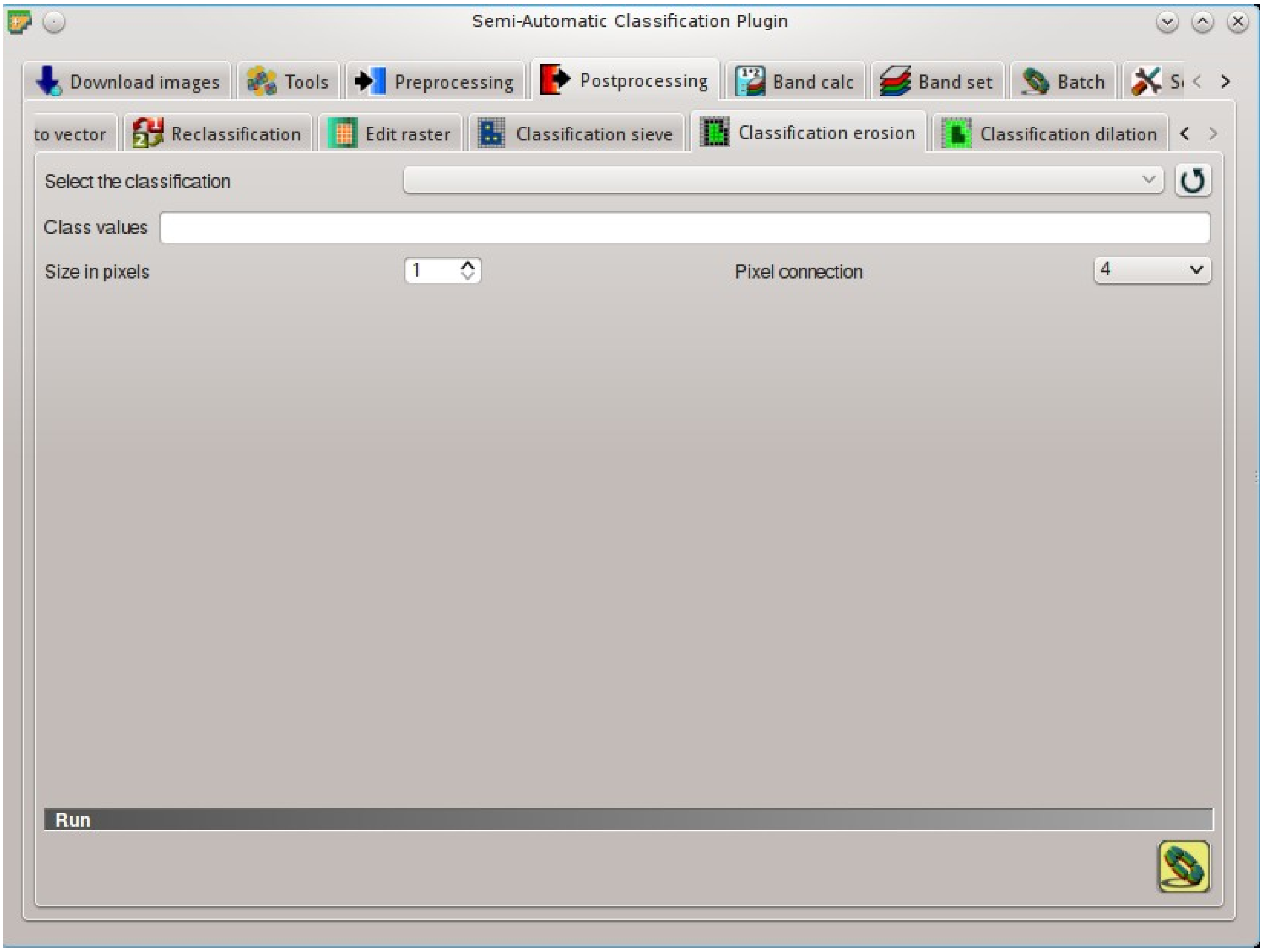


Fig. 10.33: *Classification erosion*

Classification erosion

This tab allows for removing the border of a class patch (erosion), defining the class values to be eroded and the number of pixels from the border. It is useful for classification refinement.

- *Select the classification* : select a raster (already loaded in QGIS);
- : refresh layer list;
- *Class values* : set the class values to be eroded; class values must be separated by `,` and `-` can be used to define a range of values (e.g. `1, 3-5, 8` will select classes 1, 3, 4, 5, 8); if the text is red then the expression contains errors;
- *Size in pixels* : number of pixels to be eroded from the border;
- ***Pixel connection* : select the type of pixel connection:**
  - *4*: in a 3x3 window, diagonal pixels are not considered connected;
  - *8*: in a 3x3 window, diagonal pixels are considered connected;

Run

- : choose the output destination and start the calculation;

Classification dilation

This tab allows for dilating the border of a class patch, defining the class values to be dilated and the number of pixels from the border. It is useful for classification refinement.

- *Select the classification* : select a raster (already loaded in QGIS);
- : refresh layer list;
- *Class values* : set the class values to be dilated; class values must be separated by `,` and `-` can be used to define a range of values (e.g. `1, 3-5, 8` will select classes 1, 3, 4, 5, 8); if the text is red then the expression contains errors;
- *Size in pixels* : number of pixels to be dilated from the border;
- ***Pixel connection* : select the type of pixel connection:**
  - *4*: in a 3x3 window, diagonal pixels are not considered connected;
  - *8*: in a 3x3 window, diagonal pixels are considered connected;

Run

- : choose the output destination and start the calculation;

Band calc

The `Band calc` allows for the **raster calculation for bands** (i.e. calculation of pixel values) using NumPy functions . Raster bands must be already loaded in QGIS. Input rasters must be in the same projection.

In addition, it is possible to calculate a raster using **decision rules**.

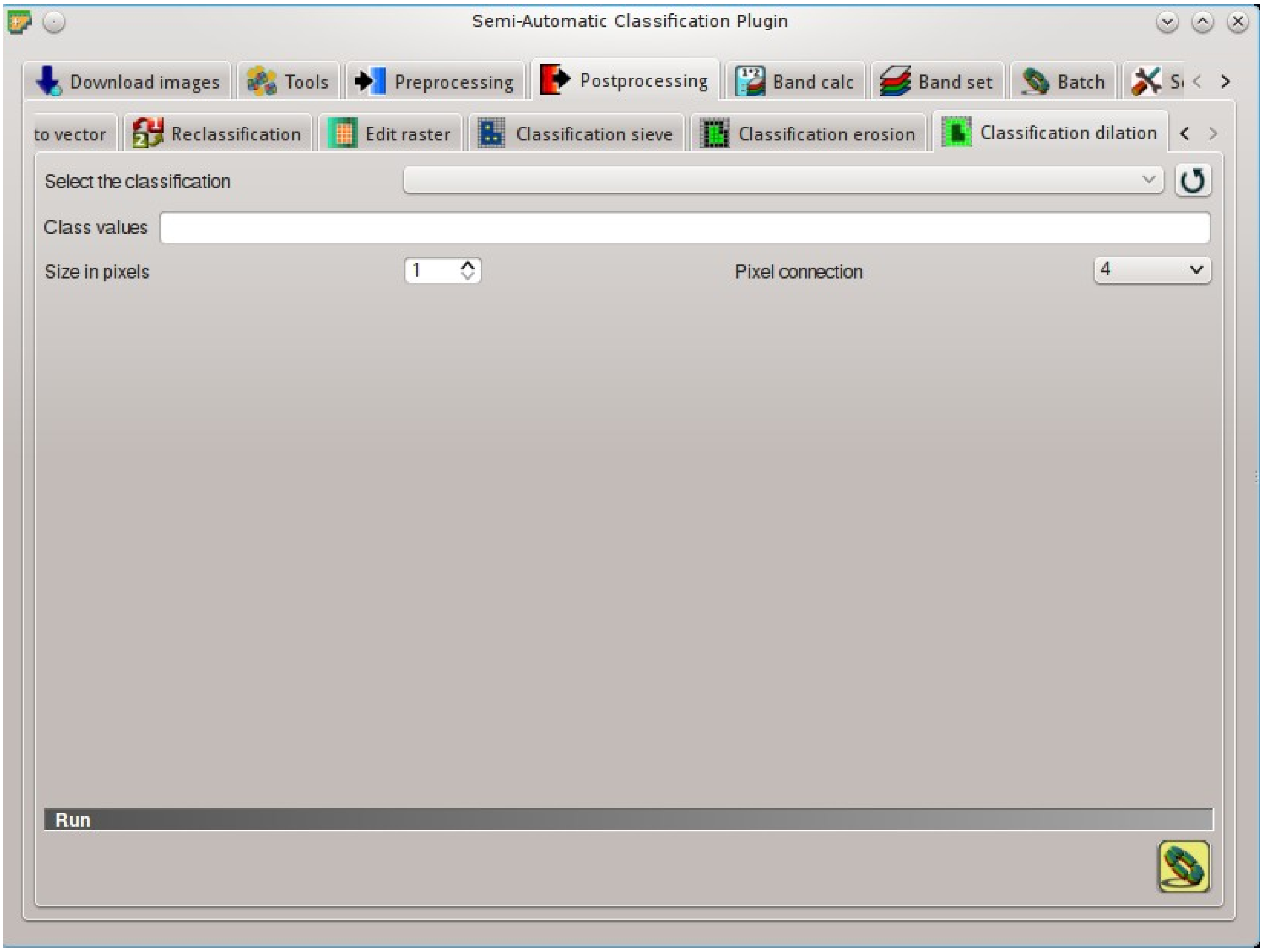


Fig. 10.34: *Classification dilation*

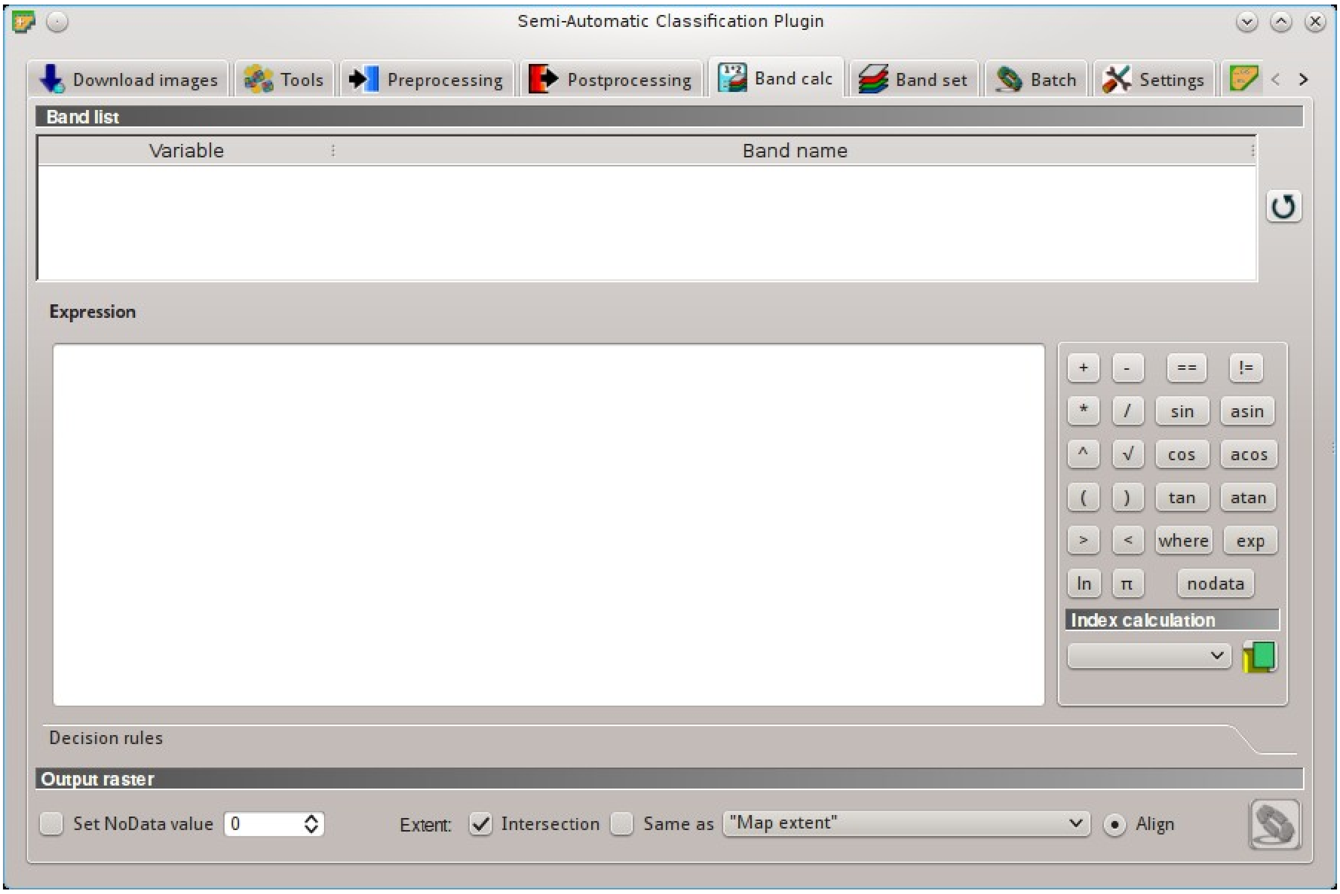


Fig. 10.35:  *Band calc*

Band list

- ***Band list*: table containing a list of single band rasters (already loaded in QGIS);**
  - *Variable*: variable name defined automatically for every band (e.g. raster1, raster2);
  - *Band name*: band name (i.e. the layer name in QGIS);
- : refresh image list;

Expression

Enter a mathematical expression for raster bands. In particular, NumPy functions can be used with the prefix *np.* (e.g. `np.log10(raster1)`). For a list of NumPy functions see the NumPy page .

The expression can work with both *Variable* and *Band name* (between double quotes). Also, bands in the *Band set* (pagina 110) can be referenced directly; for example `bandset#b1` refers to band 1 of the *Band set*. Double click on any item in the *Band list* (pagina 107) for adding its name to the expression. In addition, the following variables related to *Band set* (pagina 110) the are available:

- *"#BLUE#"*: the band with the center wavelength closest to 0.475 μm;
- *"#RED#"*: the band with the center wavelength closest to 0.65 μm;
- *"#NIR#"*: the band with the center wavelength closest to 0.85 μm;

Variables for output name are available:

- *#BANDSET#*: the name of the first band in the *Band set* (pagina 110);
- *#DATE#*: the current date and time (e.g. 20161110_113846527764);

If text in the *Expression* is green, then the syntax is correct; if text is red, then the syntax is incorrect and it is not possible to execute the calculation.

It is possible to enter multiple expressions separated by newlines such as the following example:

```
"raster1" + "raster2"

"raster3" - "raster4"
```

The above example calculates two new rasters in the output directory with the suffix `_1` (e.g. `calc_raster_1`) for the first expression and `_2` (e.g. `calc_raster_2`) for the second expression. Also, it is possible to define the output name using the symbol `@` followed by the name, such as the following example:

```
"raster1" + "raster2" @ calc_1

"raster3" - "raster4" @ calc_2
```

The following buttons are available:

- +: plus;
- -: minus;
- *: product;
- /: ratio;
- ^: power;
- *V*: square-root;
- *(*: open parenthesis;
- *)*: close parenthesis;
- >: greater then;

- <: less then;
- *ln*: natural logarithm;
- π: pi;
- ==: equal;
- *!*=: not equal;
- *sin*: sine;
- *asin*: inverse sine;
- *cos*: cosine;
- *acos*: inverse cosine;
- *tan*: tangent;
- *atan*: inverse tangent;
- *where*: conditional expression according to the syntax `where( condition , value if true, value if false)` (e.g. `where("raster1" == 1, 2, "raster1")`);
- *exp*: natural exponential;
- *nodata*: NoData value of raster (e.g. `nodata("raster1")`); it can be used as value in the expression (e.g. `where("raster1" == nodata("raster1"), 0, "raster1")`);

Index calculation

Index calculation allows for entering a spectral index expression (see *Spectral Indices* (pagina 149)).

- ***Index calculation*** **: list of spectral indices:**
  - *NDVI*: if selected, the NDVI calculation is entered in the *Expression* (`(( "#NIR#" - "#RED#") / ( "#NIR#" + "#RED#") @ NDVI)`);
  - *EVI*: if selected, the EVI calculation is entered in the *Expression* (`2.5 * ( "#NIR#" - "#RED#" ) / ( "#NIR#" + 6 * "#RED#" - 7.5 * "#BLUE#" + 1) @ EVI`);
- : open a text file (.txt) containing custom expressions to be listed in *Index calculation*; the text file must contain an expression for each line; each line must be in the form `expression_name; expression` (separated by `;`) where the `expression_name` is the expression name that is displayed in the *Index calculation*; if you open an empty text file, the default values are restored; following an example of text content:

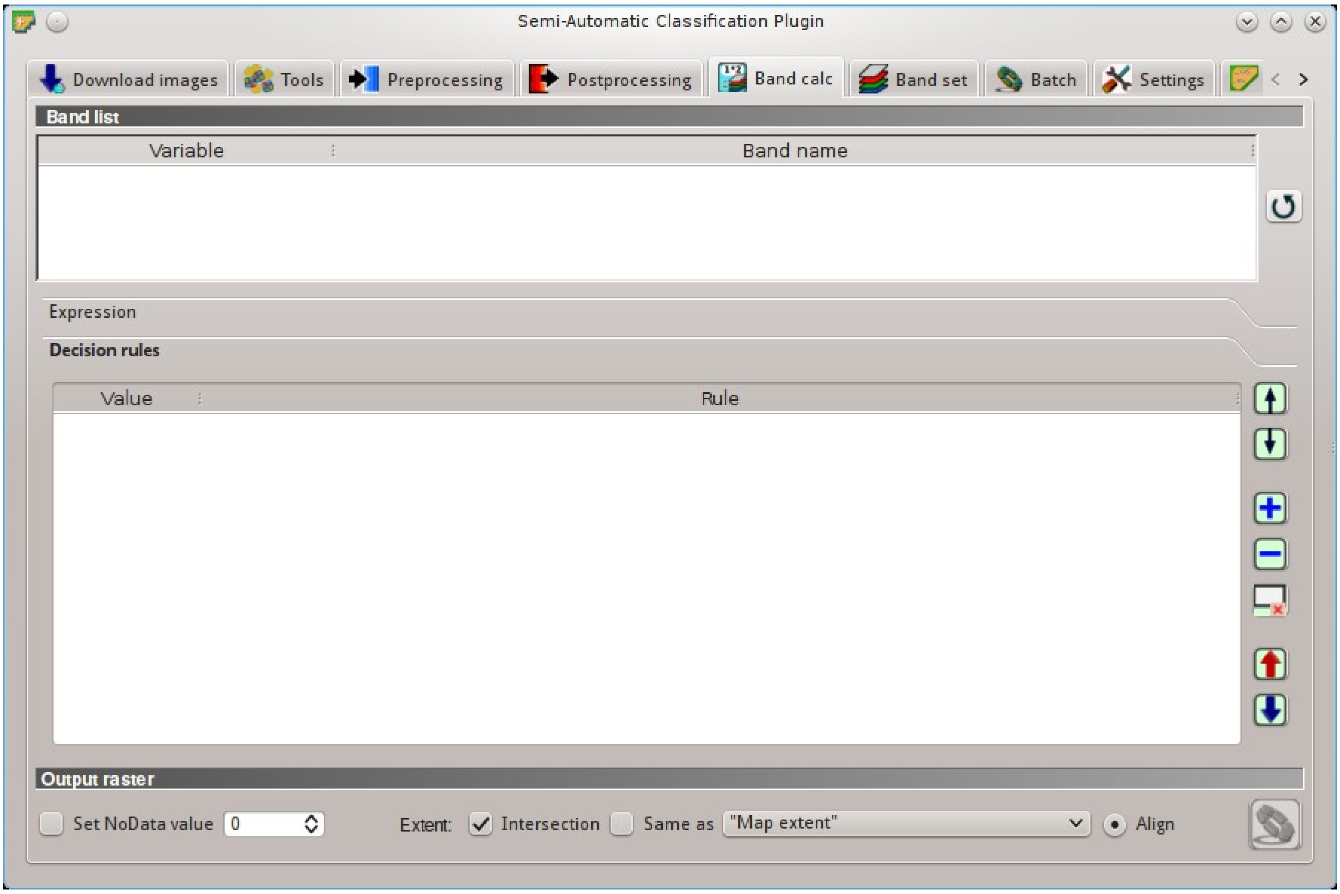
```
NDVI; ( "#NIR#" - "#RED#" ) / ( "#NIR#" + "#RED#" ) @NDVI
EVI; 2.5 * ( "#NIR#" - "#RED#" ) / ( "#NIR#" + 6 * "#RED#" - 7.5 * "#BLUE#" + 1) @EVI
SR; ( "#NIR#" / "#RED#" ) @SR
```

Decision rules

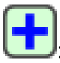
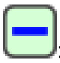
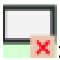
Decision rules allows for the calculation of an output raster based on rules. Rules are conditional statements based on other rasters; if the *Rule* is true, the corresponding *Value* is assigned to the output pixel.

Rules are verified from the first to the last row in the table; if the first *Rule* is false, the next *Rule* is verified for that pixel, until the last rule. If multiple rules are true for a certain pixel, the value of the first *Rule* is assigned to that pixel. The `NoData` value is assigned to those pixels where no *Rule* is true.

- ***Decision rules*****: table containing the following fields;**
  - *Value*: the value assigned to pixels if the *Rule* is true;



- *Rule*: the rule to be verified (e.g. `"raster1" > 0`); multiple conditional statements can be entered separated by `;` (e.g. `"raster1" > 0; "raster2" < 1` which means to set the *Value* where `raster1` > 0 and `raster2` < 1);

- : move highlighted rule up;
- : move highlighted rule down;
- : add a new row to the table;
- : delete the highlighted rows from the table;
- : clear the table;
- : export the rules to a text file that can be imported later;
- : import rules from a text file;

Output raster

The output raster is a .tif file, with the same spatial resolution and projection of input rasters; if input rasters have different spatial resolutions, then the highest resolution (i.e. minimum pixel size) is used for output raster.

-  *Use NoData value* : if checked, set the value of `NoData` pixels in output raster;

- **Extent: if the following options are unchecked, the output raster extent will include the extents of all input rasters;**
  - *Intersection*: if checked, the extent of output raster equals the intersection of input raster extents (i.e. minimum extent);
  - *Same as* : if checked, the extent of output raster equals the extent of *"Map extent"* (the extent of the map currently displayed) or a selected layer;
- *Align*: if checked, and *Same as* is checked selecting a raster, the calculation is performed using the same extent and pixel alignment of selected raster;
- : if `Expression` is active and text is green, choose the output destination and start the calculation based on `Expression`; if `Decision rules` is active and text is green, choose the output destination and start the calculation based on `Decision rules`;

Band set

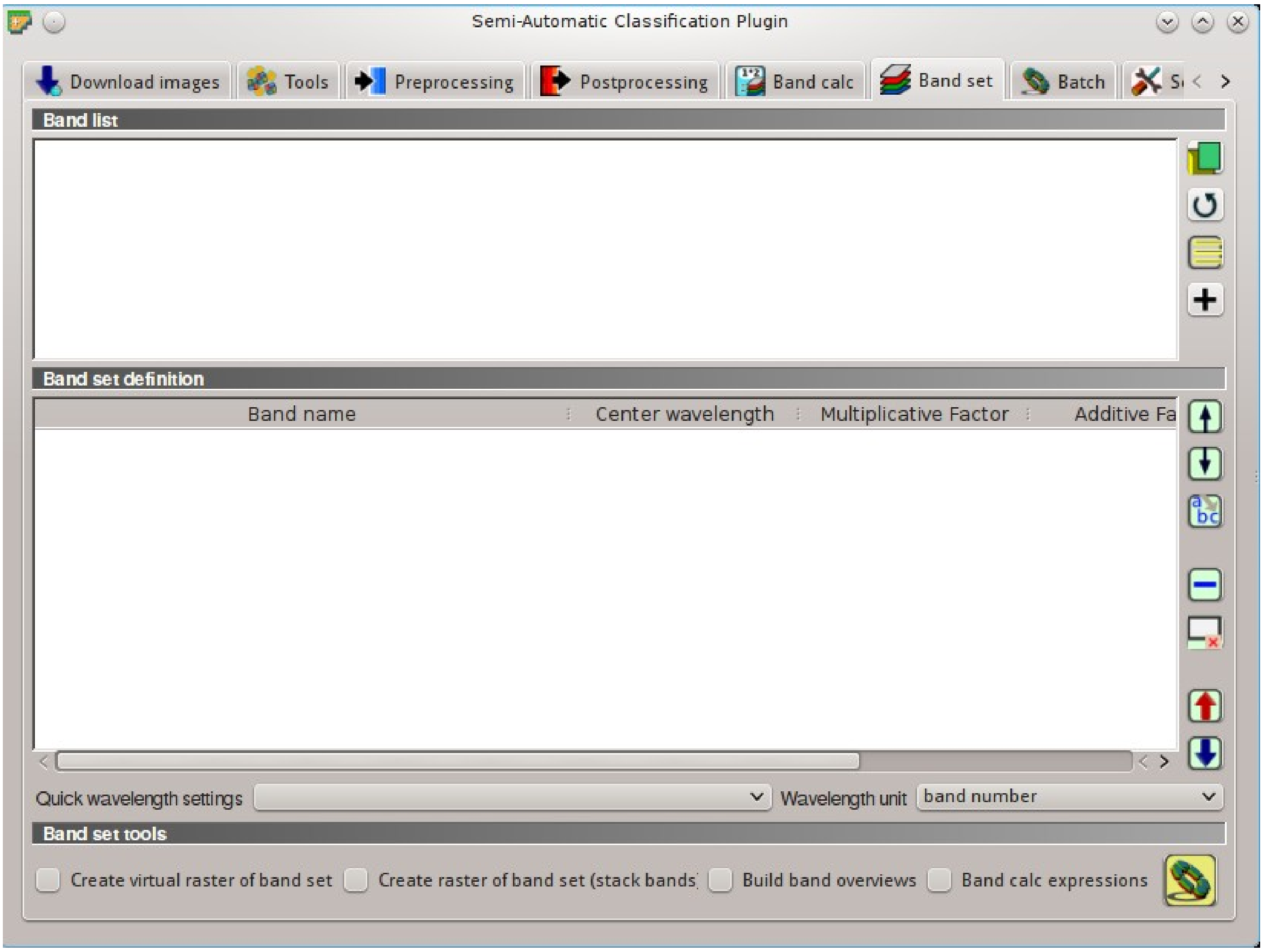


Fig. 10.36: *Band set*

This tab allows for the definition of a set of single band rasters (*Band set*) used as *Input image*. The `Center wavelength` of bands should be defined in order to use several functions of *SCP*.

If a *Band set* of single band rasters is defined, then the item `<< band set >>` will be listed in the *Working toolbar* (pagina 33) as *input image*.

The *Band set* definition is saved with the QGIS project.

Band list

List of single band rasters loaded in QGIS.

- : open one or more raster file (single band) which are added to the *Band set* and loaded in QGIS;
- : refresh list of raster bands loaded in QGIS;
- : select all raster bands;
- : add selected rasters to the *Band set*.

Band set definition

Definition of bands composing the *input image* .

If the *Center wavelength* of bands is not defined, the band number is used and some *SCP* tools will be disabled. It is possible to define a multiplicative rescaling factor and additive rescaling factor for each band (for instance using the values in Landsat metadata), which are used on the fly (i.e. `pixel value = original pixel value * multiplicative rescaling factor + additive rescaling factor`) during the processing.

- ***Band set definition*: table containing the following fields;**
  - *Band name* : name of the band; name cannot be edited;
  - *Center wavelength* : center of the wavelength of the band;
  - *Multiplicative Factor* : multiplicative rescaling factor;
  - *Additive Factor* : additive rescaling factor;
- : move highlighted bands upward;
- : move highlighted bands downward;
- : sort automatically bands by name, giving priority to the ending numbers of name;
- : remove highlighted bands from the *Band set*;
- : clear all bands from *Band set*;
- : export the *Band set* to a file;
- : import a previously saved *Band set* from file;

- ***Quick wavelength settings* : rapid definition of band center wavelength for the following satellite sensors:**
  - ASTER;
  - GeoEye-1;
  - Landsat 8 OLI;
  - Landsat 7 ETM+;
  - Landsat 5 TM;
  - Landsat 4 TM;
  - Landsat 1, 2, and 3 MSS;
  - MODIS;
  - Pleiades;
  - QuickBird;
  - RapidEye;
  - Sentinel-2;
  - SPOT 4;
  - SPOT 5;
  - SPOT 6;
  - WorldView-2 and WorldView-3;
- ***Wavelength unit* : select the wavelength unit among:**
  - *Band number*: no unit, only band number;
  - μm: micrometres;
  - *nm*: nanometres;

Band set tools

It is possible to perform several processes directly on *Band set*.

- *Create virtual raster of band set*: if checked, create a virtual raster of bands;
- *Create raster of band set (stack bands)*: if checked, stack all the bands and create a unique .tif raster;
- *Build band overviews*: if checked, build raster overviews (i.e. pyramids) for improving display performance; overview files are created in the same directory as bands;
- *Band calc expression*: if checked, calculate the *Expression* (pagina 107) entered in *Band calc* (pagina 104); it is recommended the use of *Band set* variables in the expression (e.g. `bandset#b1`);
- : choose the output destination and start the process;

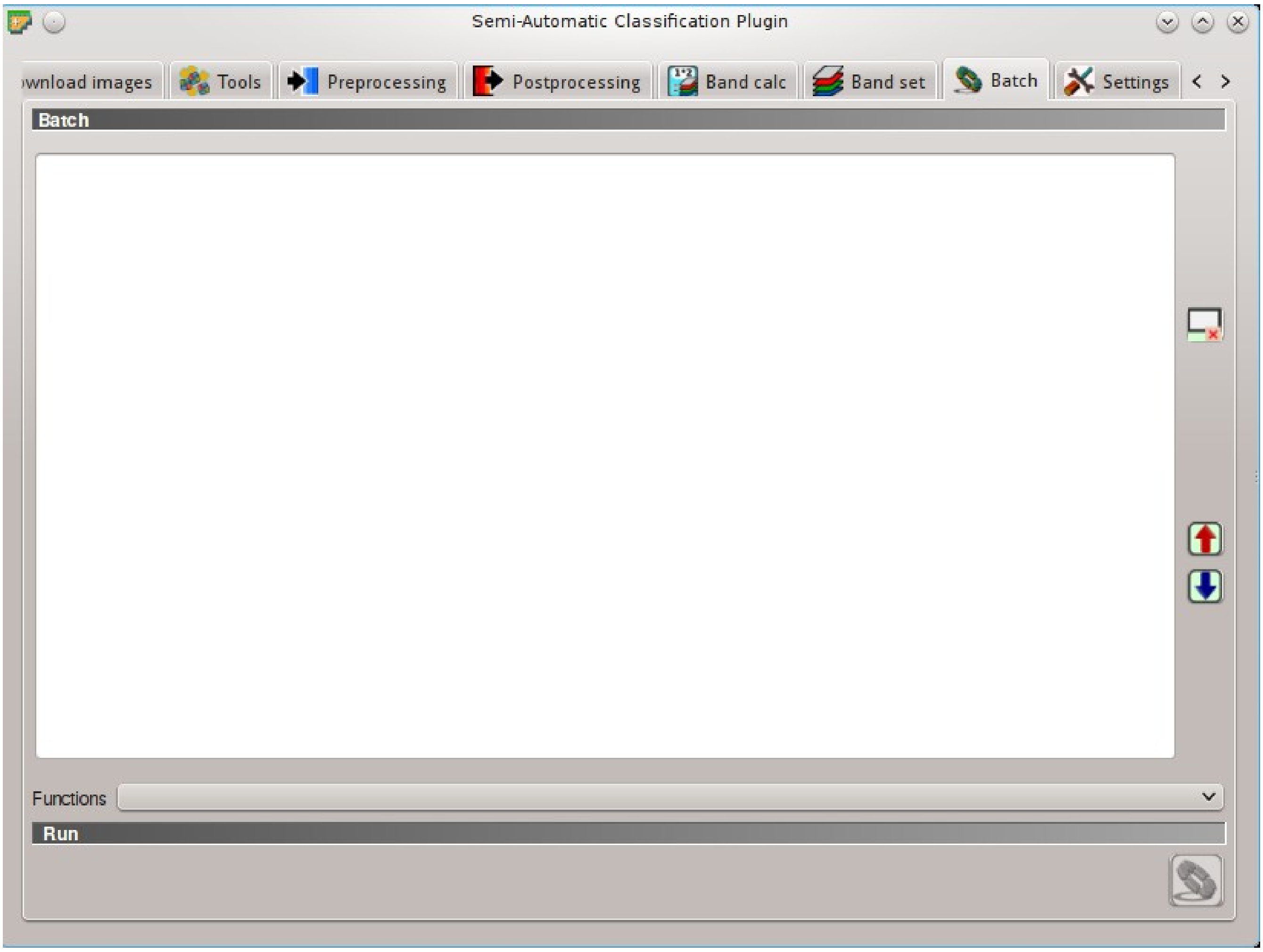


Fig. 10.37: *Batch*

Batch

This tab allows for the automatic execution (batch) of several *SCP* functions using a scripting interface.

Batch

Enter a batch expression; each function must be in a new line. Functions have the following structure:

`function name`; `function options`

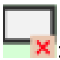
Each functions has options, identified by a name, with the following structure:

`option name`: `option argument`

Options must be separated by the character `;` . Each function option represents an option in the corresponding interface of *SCP*; option arguments of type text must be between the character `'` ; in case of checkboxes, the value 1 represents checked, while the value 0 represents unchecked. A new line beginning with # can be used for commenting.

According to the function, some of the options are mandatory while other options can be omitted from the expression. Option names that contain `path` require the full path to a file. Some options that require multiple arguments such as lists; lists must be separated by `,` .

If the expression contains errors, the text is red.

- : clear the expression;
- : export the batch expression to a file;
- : import a previously saved batch expression from file;

***Functions*: the following functions are available with the corresponding options;**

- *Accuracy* (pagina 91): calculate accuracy (`accuracy;classification_file_path : '';reference_file_path : '';shapefile_field_name : '';output_raster_path : ''`);
- *ASTER* (pagina 80): ASTER conversion (`aster_conversion;input_raster_path : '';celsius_temperature : 0;apply_dos1 : 0;use_nodata : 1;nodata_value : 0;create_bandset : 1;output_dir : ''`);
- *Band calc* (pagina 104): band calculation (`band_calc;expression : ''; output_raster_path : '';extent_same_as_raster_name : ''; extent_intersection : 1;set_nodata : 0;nodata_value : 0`);
- *Classification output* (pagina 46): perform classification (`classification; use_macroclass : 0;algorithm_name : 'Minimum Distance';use_lcs : 0;use_lcs_algorithm : 0;use_lcs_only_overlap : 0;apply_mask : 0;mask_file_path : '';vector_output : 0;classification_report : 0;save_algorithm_files : 0;output_classification_path : ''`);
- *Classification dilation* (pagina 104): dilation of a classification (`classification_dilation; input_raster_path : '';class_values : '';size_in_pixels : 1;pixel_connection : 4;output_raster_path : ''`);
- *Classification erosion* (pagina 104): erosion of a classification (`classification_erosion; input_raster_path : '';class_values : '';size_in_pixels : 1;pixel_connection : 4;output_raster_path : ''`);

- *Classification report* (pagina 94): report of a classification (`classification_report; input_raster_path : '';use_nodata : 0;nodata_value : 0;output_report_path : ''`);
- *Classification sieve* (pagina 101): classification sieve(`classification_sieve; input_raster_path : '';size_threshold : 2;pixel_connection : 4;output_raster_path : ''`);
- *Classification to vector* (pagina 96): convert classification to vector (`classification_to_vector;input_raster_path : ''; use_signature_list_code : 1;code_field : 'C_ID'; output_vector_path : ''`);
- *Clip multiple rasters* (pagina 84): clip multiple rasters (`clip_multiple_rasters; input_raster_path : '';output_dir : '';use_shapefile : 0; shapefile_path : '';ul_x : '';ul_y : '';lr_x : '';lr_y : '';nodata_value : 0;output_name_prefix : 'clip'`);
- *Cross classification* (pagina 95): cross classification (`cross_classification; classification_file_path : '';use_nodata : 0;nodata_value : 0;reference_file_path : '';shapefile_field_name : '';output_raster_path : ''`);
- *Edit raster* (pagina 99): edit raster values using a shapefile); (`edit_raster_using_shapefile;input_raster_path : ''; input_vector_path : '';vector_field_name : '';constant_value : 0;expression : 'where(raster == 1, 2, raster)'`);
- *Land cover change* (pagina 93): calculate land cover change (`land_cover_change;reference_raster_path : '';new_raster_path : '';output_raster_path : ''`);
- *Landsat* (pagina 77): Landsat conversion (`landsat_conversion;input_dir : ''; mtl_file_path : '';celsius_temperature : 0;apply_dos1 : 0; use_nodata : 1;nodata_value : 0;pansharpening : 0;create_bandset : 1;output_dir : ''`);
- *MODIS* (pagina 82): MODIS conversion (`modis_conversion;input_raster_path : '';reproject_wgs84 : 1;use_nodata : 1;nodata_value : -999;create_bandset : 1;output_dir : ''`);
- *PCA* (pagina 89): Principal Component Analysis (`pca;use_number_of_components : 0, number_of_components : 2;use_nodata : 1;nodata_value : 0;output_dir : ''`);
- *Reclassification* (pagina 96): raster reclassification (`reclassification; input_raster_path : '';value_list : 'oldVal-newVal; oldVal-newVal';use_signature_list_code : 1;code_field : 'MC_ID';output_raster_path : ''`);
- *Sentinel-2* (pagina 79): Sentinel-2 conversion (`sentinel_conversion;input_dir : '';mtd_safl1c_file_path : '';apply_dos1 : 0;use_nodata : 1;nodata_value : 0;create_bandset : 1;output_dir : ''`);
- *Split raster bands* (pagina 86): split raster to single bands (`split_raster_bands; input_raster_path : '';output_dir : '';output_name_prefix : 'split'`);
- *Stack raster bands* (pagina 86): stack rasters into a single file (`stack_raster_bands; input_raster_path : '';output_raster_path : ''`);
- *Vector to raster* (pagina 90): convert vector to raster (`vector_to_raster; vector_file_path : '';use_value_field : 1;vector_field_name : '';constant_value : 1;reference_raster_path : '';`

`type_of_conversion : 'Center of pixels';output_raster_path : '');`

In addition, the following functions are available:

- *Add raster to QGIS*: add a raster to QGIS (`add_raster;input_raster_path : '';input_raster_name : ''`);
- *Create Band set*: create a *Band set* (`create_bandset;raster_path_list : ''; center_wavelength : '';wavelength_unit : 1;multiplicative_factor : '';additive_factor : ''`);
- *Open training input*: open a training input file (`open_training_input; training_file_path : ''`);
- *Set working directory*: set a working directory (argument is the path to a directory) (`!working_dir!;''`);

If a working directory is defined, `!working_dir!` can be entered in other functions where a path is required (e.g. `add_raster;input_raster_path : '!working_dir!/raster1.tif'; input_raster_name : 'raster1.tif'`); An example of batch expression is:

```
!working_dir!; '/home/user/Desktop/temp/'
add_raster;input_raster_path : '!working_dir!/raster1.tif';input_raster_name :
↪'raster1.tif'
band_calc;expression : 'where("raster1.tif" > 1, 1,0)';output_raster_path : '!
↪working_dir!/calc1.tif';set_nodata : 1;nodata_value : 0
band_calc;expression : '"raster1.tif" * "calc1.tif"';output_raster_path : '!
↪working_dir!/calc2.tif';extent_intersection : 0
```

Run

- : if text in the batch expression is green, start the batch processes;

Settings

The tab *Settings* allows for the customization of *SCP*.

Interface

Customization of the interface.

Field names of training input

Set the names of fields in the *Training input* (pagina 40) . Changing field names should usually be avoided.

- *MC ID field* : name of the Macroclass ID field (default is `MC_ID`);
- *MC Info field* : name of the Macroclass Information field (default is `MC_info`);
- *C ID field* : name of the Class ID field (default is `C_ID`);
- *C Info field* : name of the Class Information field (default is `C_info`);

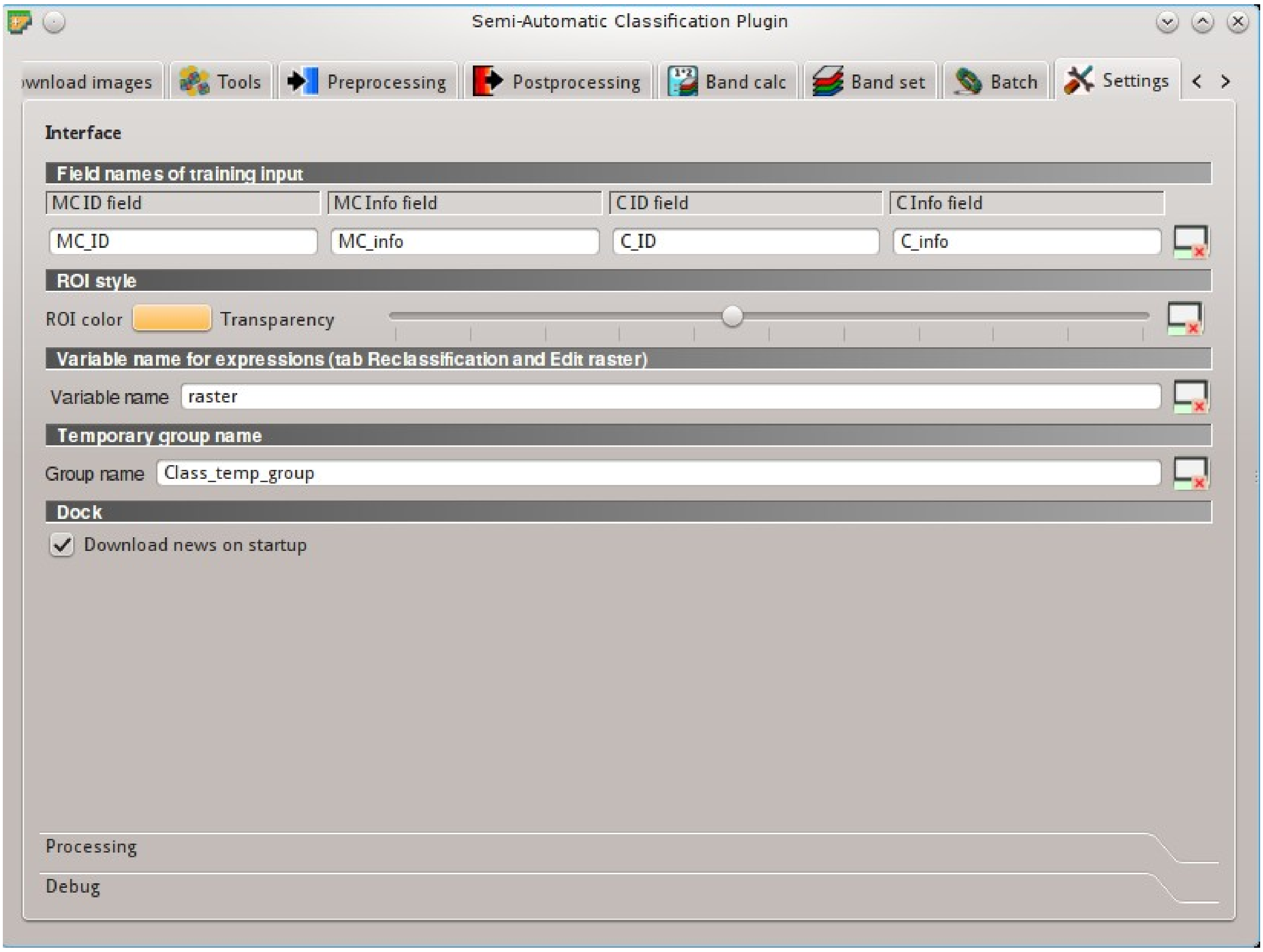


Fig. 10.38: *Interface*

- : reset field names to default;

ROI style

Change ROI color and transparency for a better visualization of temporary ROIs on the map.

- *ROI color* : button for changing ROI color;
- *Transparency* : change ROI transparency;
- : reset ROI color and transparency to default;

Variable name for expressions

Set the variable name used in expressions of the *Reclassification* (pagina 96) and *Edit raster* (pagina 99) .

- *Variable name* : set variable name (default is `raster`);
- : reset variable name to default;

Temporary group name

Set the temporary group name in QGIS Layers used for temporary layers .

- *Group name* : set group name (default is `Class_temp_group`);
- : reset group name to default;

Dock

- *Download news on startup*: if checked, news about the *SCP* and related services are downloaded on startup and displayed in *Dock*;

Processing

Classification process

- *Play sound when finished* : if checked, play a sound when the classification process is completed;
- *Use virtual rasters for temp files* : if checked, create virtual rasters for certain temporary files, instead of creating real rasters; it is useful for reducing disk space usage during calculations;
- *Raster compression* : if checked, a lossless compression (DEFLATE or PACKBITS) is applied to raster outputs in order to save disk space; it is recommended to check this option, however compressed files are sometimes larger than files without compression;

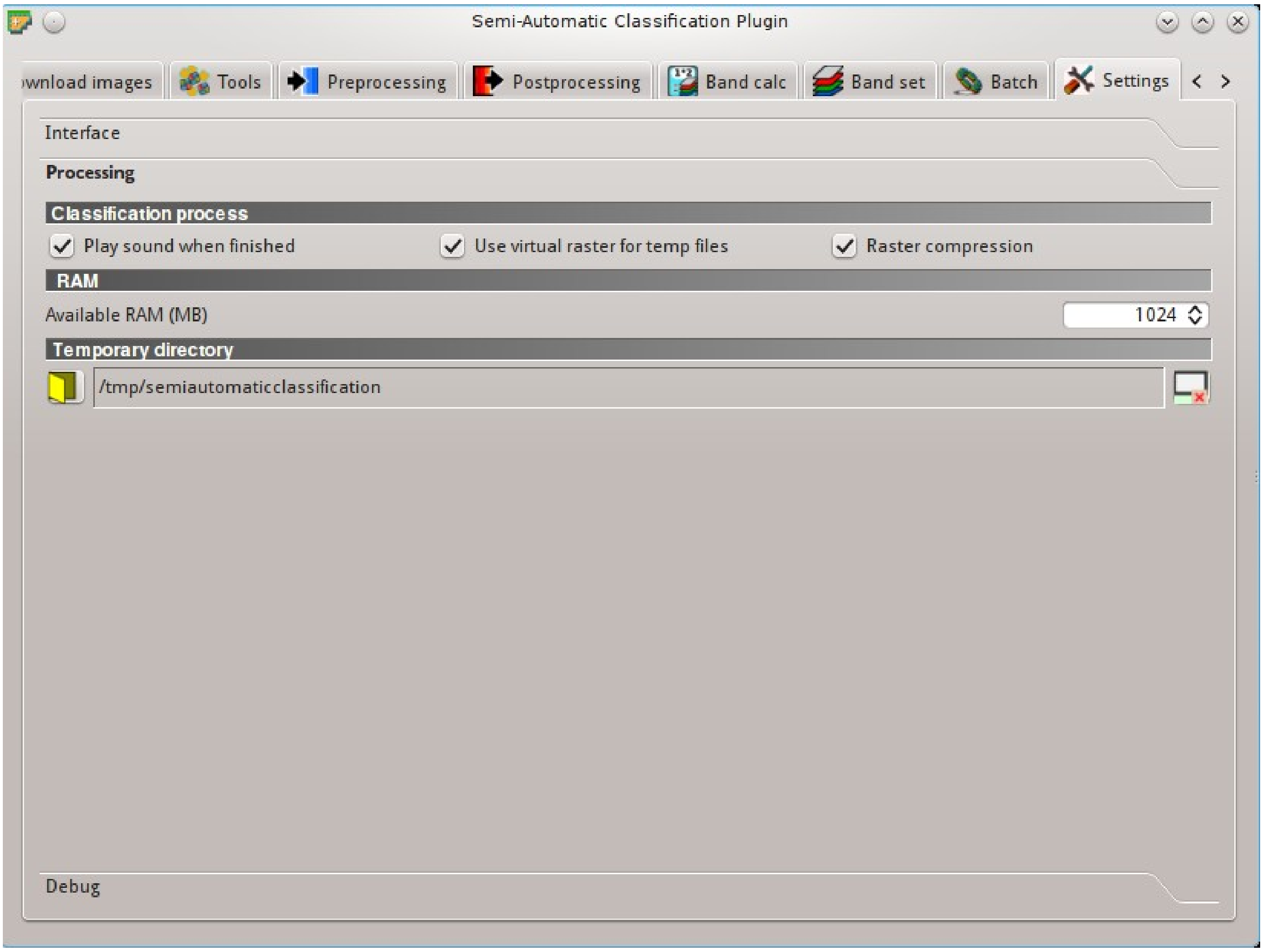


Fig. 10.39: *Processing*

RAM

- *Available RAM (MB)* : set the available RAM (in MB) that is used during the processes in order to improve the *SCP* performance; this value should be half of the system RAM (e.g. 1024MB if system has 2GB of RAM); in case of errors, set a value lower than 512MB;

Temporary directory

- : select a new temporary directory where temporary files are saved during processing; the path to the current temporary directory is displayed; default is a system temporary directory;
- : reset to default temporary directory;

Debug

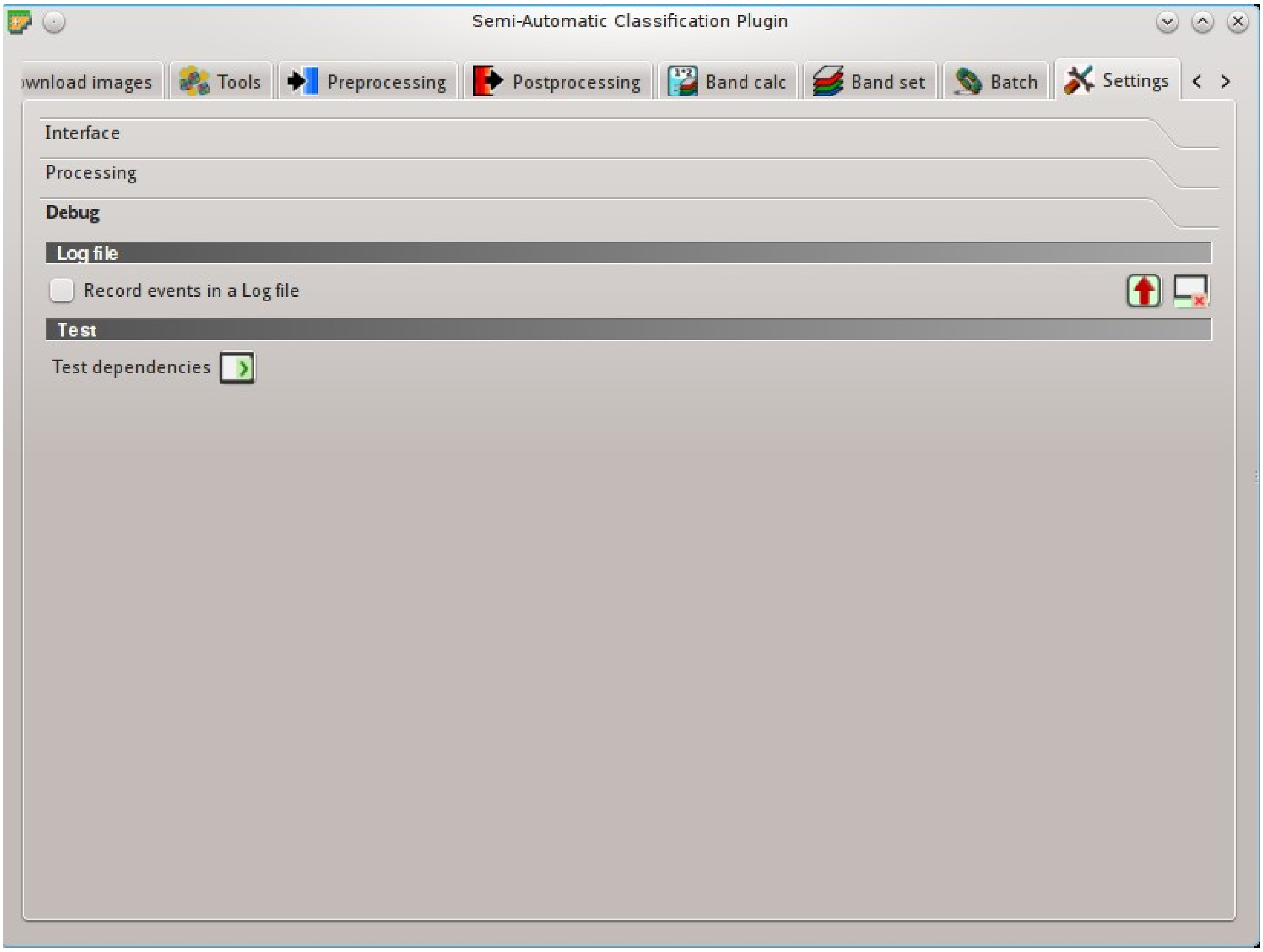


Fig. 10.40: *Debug*

Debugging utilities for the creation of a Log file (i.e. recording of *SCP* activities for reporting issues) and testing *SCP* dependencies.

If you found a plugin error, please read *How can I report an error?* (pagina 267) .

Log file

- *Records events in a log file* : if checked, start recording events in a Log file;
- : export the Log file (i.e. a .txt file);
- : clear the content of Log file;

Test

- *Test dependencies* : test *SCP* dependencies (GDAL, GDAL subprocess, NumPy, SciPy, Matplotlib, Internet connection); results are displayed in a window;

CAPITOLO 11

Spectral Signature Plot

The window *Spectral Signature Plot* includes several functions for displaying spectral signature values as a function of wavelength (defined in the *Band set* (pagina 110)). Signatures can be added to the `Spectral Signature Plot` through the *SCP dock* (pagina 37).

The window *Spectral Signature Plot* includes also some functions useful for the definition of value ranges used by the *Land Cover Signature Classification* (pagina 156) (see *LCS threshold* (pagina 73)).

Overlapping signatures (belonging to different classes or macroclasses) are highlighted in orange in the table *Plot Signature list* (pagina 123); the overlapping check is performed considering *MC ID* or *C ID* according to the setting *Use* *MC ID* *C ID* in *Classification algorithm* (pagina 44). Overlapping signatures sharing the same *ID* are not highlighted.

The functions are described in detail in the following paragraphs, using these conventions:

= Input date

= Input text

= List

= Input number

= Optional

= Configuration stored in the active project of QGIS

= Configuration stored in QGIS registry

= Slider

= Table

Plot Signature list

- ***Signature list*:**

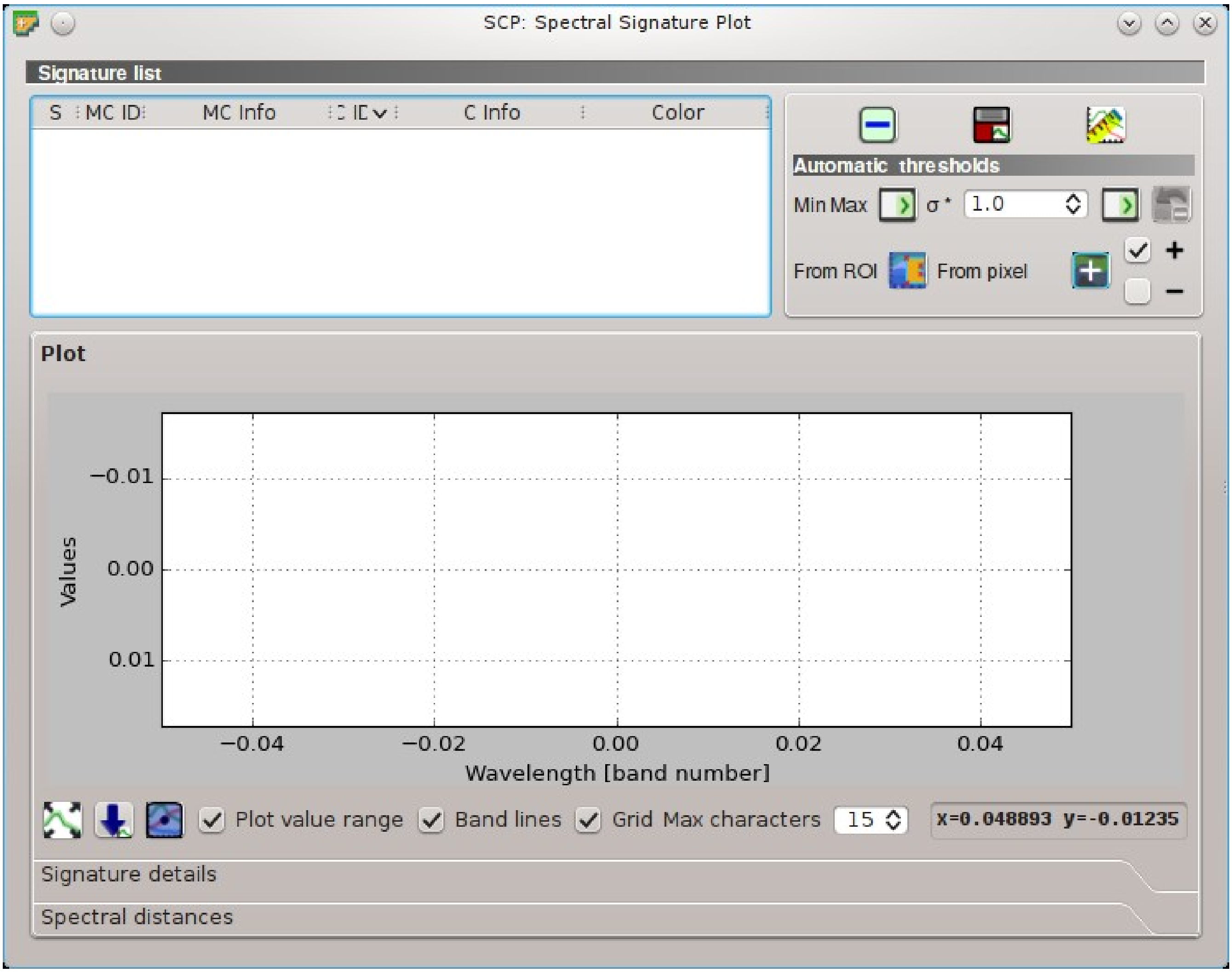


Fig. 11.1: *Spectral Signature Plot*

  - *S*: checkbox field; if checked, the spectral signature is displayed in the plot;
  - *MC ID*: signature Macroclass ID;
  - *MC Info*: signature Macroclass Information;
  - *C ID*: signature Class ID;
  - *C Info*: signature Class Information;
  - *Color [overlap MC_ID-C_ID]*: signature color; also, the combination *MC ID-C ID* is displayed in case of overlap with other signatures (see *Land Cover Signature Classification* (pagina 156));
  - *Min B* X: minimum value of band X; this value can be edited;
  - *Max B* X: maximum value of band X; this value can be edited;

- : remove highlighted signatures from this list;
- : add highlighted spectral signatures to *ROI Signature list* (pagina 41);
- : calculate the spectral distances of spectral signatures displayed in the plot; distances are reported in the tab *Spectral distances* (pagina 126);

Automatic thresholds

Set thresholds automatically for highlighted signatures in the table *Plot Signature list* (pagina 123); if no signature is highlighted, then the threshold is applied to all the signatures.

- *Min Max* : set the threshold based on the minimum and maximum of each band;
- σ * 1 : set an automatic threshold calculated as (band value + (σ * v)), where σ is the standard deviation of each band and v is the defined value;
- : undo the last automatic thresholds;
- ***From ROI* : set the threshold using the temporary ROI pixel values, according to the following checkboxes:**
  - +: if checked, signature threshold is extended to include pixel signature;
  - –: if checked, signature threshold is reduced to exclude pixel signature;
- ***From pixel* : set the threshold by clicking on a pixel, according to the following checkboxes:**
  - +: if checked, signature threshold is extended to include pixel signature;
  - –: if checked, signature threshold is reduced to exclude pixel signature;

Plottaggio

Left click and hold inside the plot to **move** the view of the plot. Use the **mouse wheel** to **zoom in and out** the view of the plot. **Right click** and hold inside the plot to **zoom in a specific area** of the plot. Legend inside the plot can be moved using the mouse.

Plot commands:

- : automatically fit the plot to data;
- : save the plot image to file (available formats are `.jpg`, `.png`, and `.pdf`);
- : activate the cursor for interactively changing the value range of highlighted signatures in the plot; click the plot to set the minimum or maximum value of a band (also for several signatures simultaneously); cursor is deactivated when moving outside the plot area;
- *Plot value range*: if checked, plot the value range for each signature (semi-transparent area);
- *Band lines*: if checked, display a vertical line for each band (center wavelength);
- *Grid*: if checked, display a grid;
- *Max characters* 1: set the maximum length of text in the legend;
- *x y*: display x y coordinates of mouse cursor inside the plot;

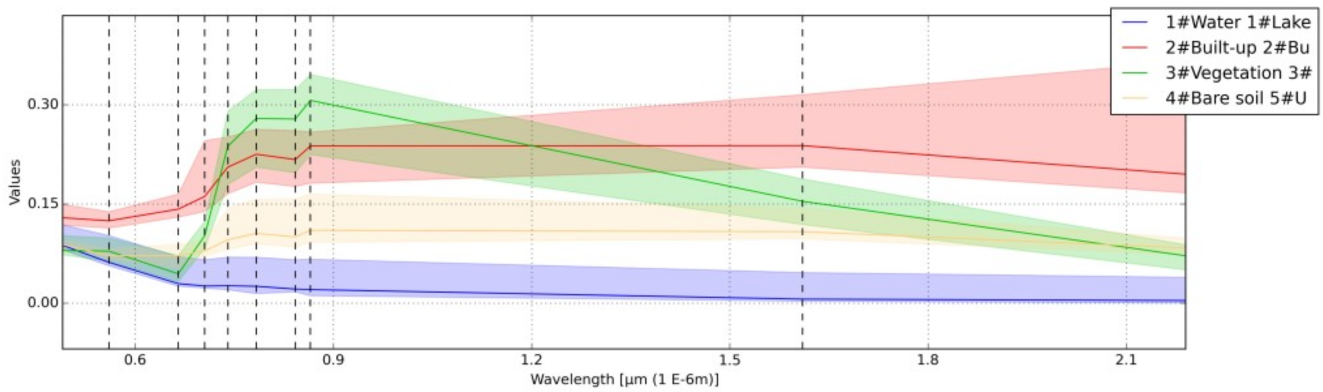


Fig. 11.2: *Spectral Signature: Example of spectral signature plot*

Signature details

Display the details about spectral signatures (i.e. Wavelength, Values, and Standard deviation). In case of signatures calculated from ROIs, the ROI size (number of pixels) is also displayed.

Spectral distances

Display spectral distances of signatures (see *Plot Signature list* (pagina 123)), which are useful for assessing ROI separability (see *Spectral Distance* (pagina 159)).

The following spectral distances are calculated :

- *Jeffries-Matusita Distance* (pagina 159): range [0 = identical, 2 = different]; useful in particular for *Maximum Likelihood* (pagina 154) classifications;
- *Spectral Angle* (pagina 159): range [0 = identical, 90 = different]; useful in particular for *Spectral Angle Mapping* (pagina 155) classifications;
- *Distanza euclidea* (pagina 159): useful in particular for *Minimum Distance* (pagina 154) classifications;
- *Bray-Curtis Similarity* (pagina 160): range [0 = different, 100 = identical]; useful in general;

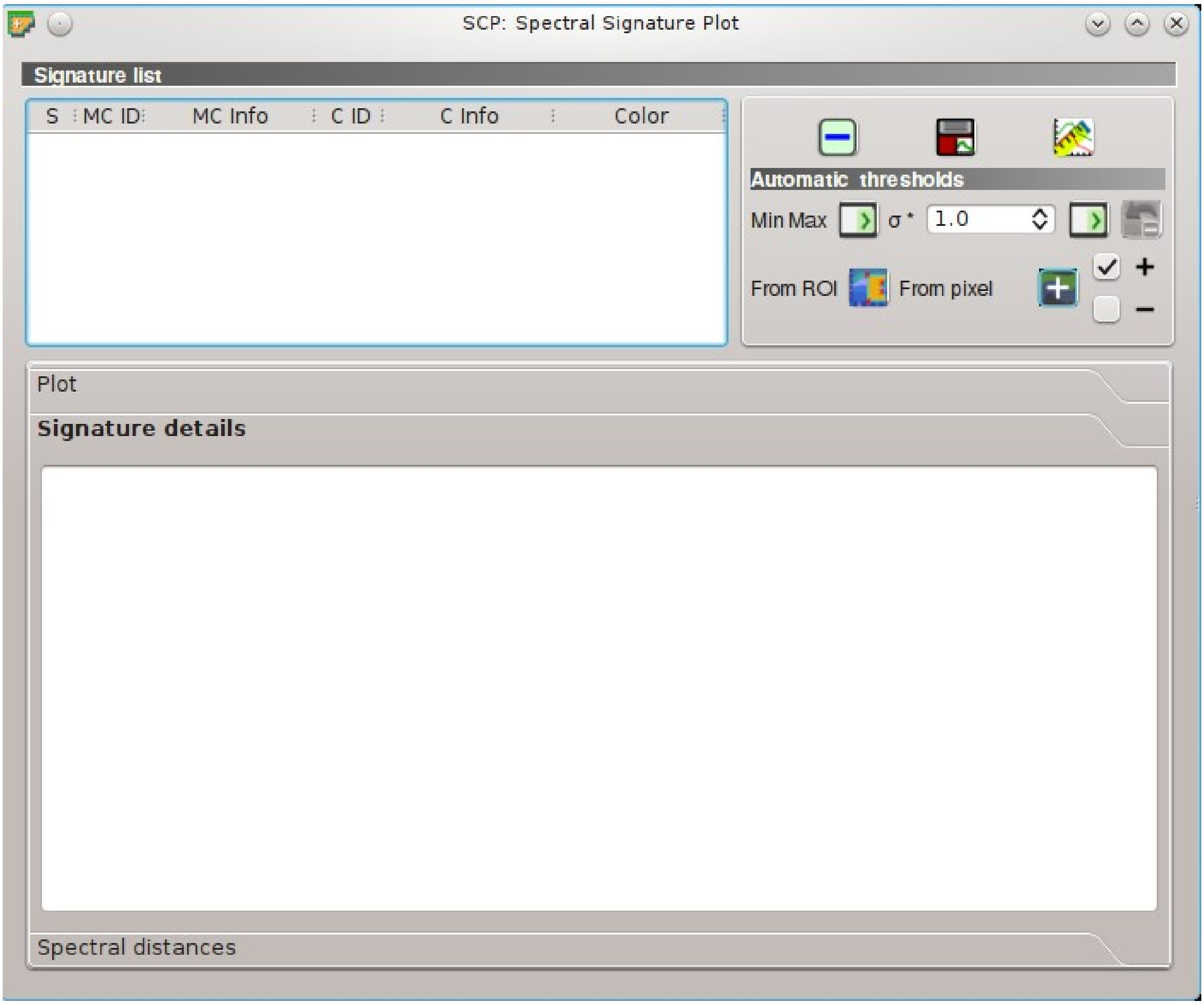
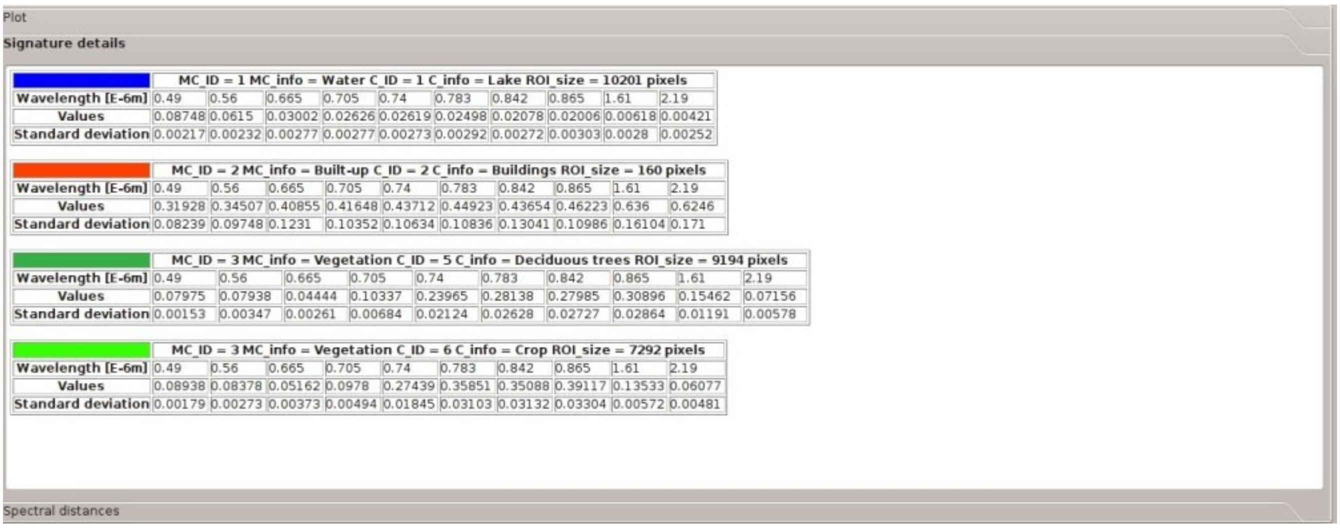


Fig. 11.3: *Spectral Signature: Signature details*



	MC_ID = 1 MC_info = Water C_ID = 1 C_info = Lake ROI_size = 10201 pixels									
Wavelength [E-6m]	0.49	0.56	0.665	0.705	0.74	0.783	0.842	0.865	1.61	2.19
Values	0.08748	0.0615	0.03002	0.02626	0.02619	0.02498	0.02078	0.02006	0.00618	0.00421
Standard deviation	0.00217	0.00232	0.00277	0.00277	0.00273	0.00292	0.00272	0.00303	0.0028	0.00252

	MC_ID = 2 MC_info = Built-up C_ID = 2 C_info = Buildings ROI_size = 160 pixels									
Wavelength [E-6m]	0.49	0.56	0.665	0.705	0.74	0.783	0.842	0.865	1.61	2.19
Values	0.31928	0.34507	0.40855	0.41648	0.43712	0.44923	0.43654	0.46223	0.636	0.6246
Standard deviation	0.08239	0.09748	0.1231	0.10352	0.10634	0.10836	0.13041	0.10986	0.16104	0.171

	MC_ID = 3 MC_info = Vegetation C_ID = 5 C_info = Deciduous trees ROI_size = 9194 pixels									
Wavelength [E-6m]	0.49	0.56	0.665	0.705	0.74	0.783	0.842	0.865	1.61	2.19
Values	0.07975	0.07938	0.04444	0.10337	0.23965	0.28138	0.27985	0.30896	0.15462	0.07156
Standard deviation	0.00153	0.00347	0.00261	0.00684	0.02124	0.02628	0.02727	0.02864	0.01191	0.00578

	MC_ID = 3 MC_info = Vegetation C_ID = 6 C_info = Crop ROI_size = 7292 pixels									
Wavelength [E-6m]	0.49	0.56	0.665	0.705	0.74	0.783	0.842	0.865	1.61	2.19
Values	0.08938	0.08378	0.05162	0.0978	0.27439	0.35851	0.35088	0.39117	0.13533	0.06077
Standard deviation	0.00179	0.00273	0.00373	0.00494	0.01845	0.03103	0.03132	0.03304	0.00572	0.00481

Fig. 11.4: *Spectral Signature: Example of signature details*

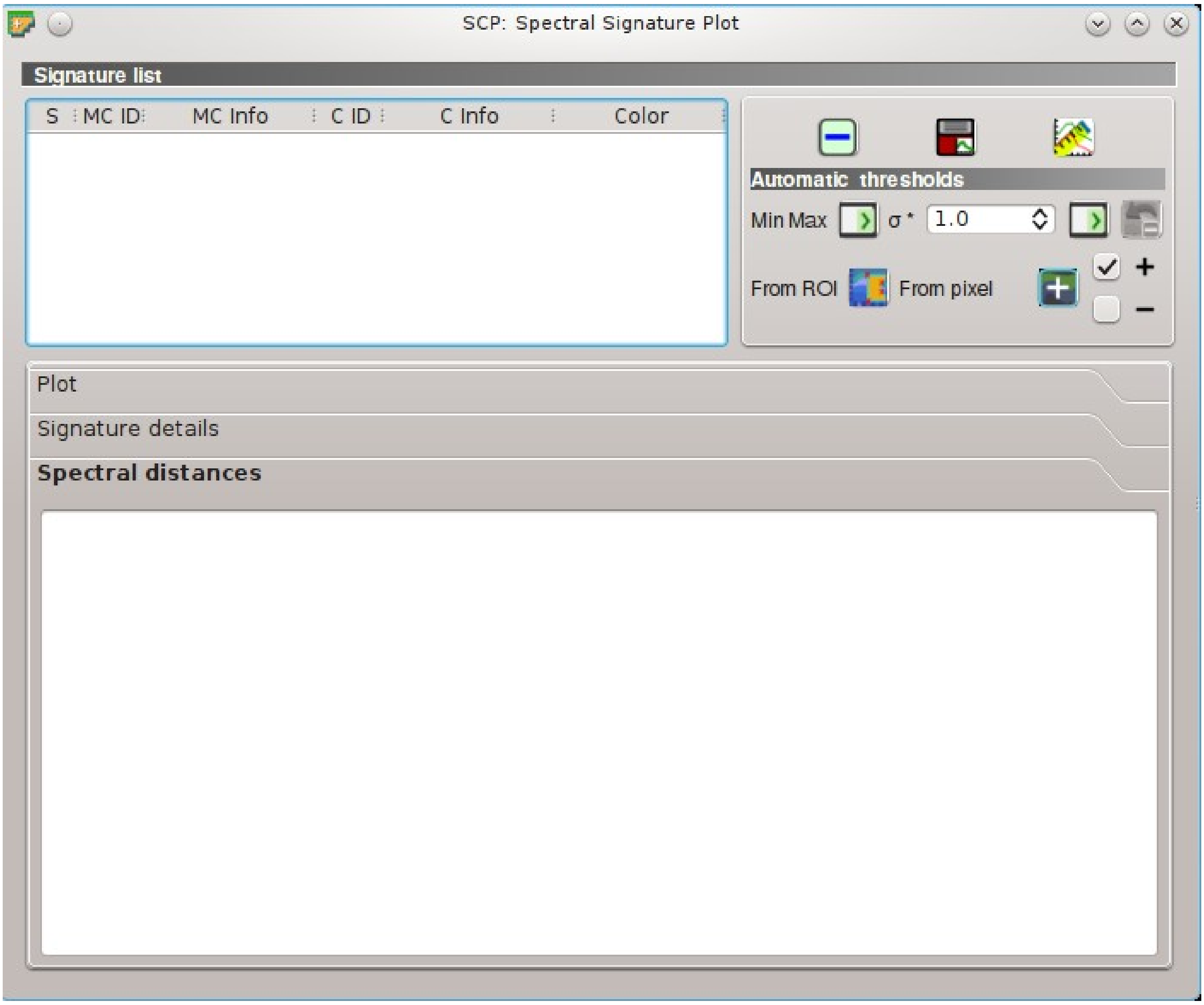


Fig. 11.5: *Spectral Signature: Spectral distances*

Values are displayed in red if signatures are particularly similar.

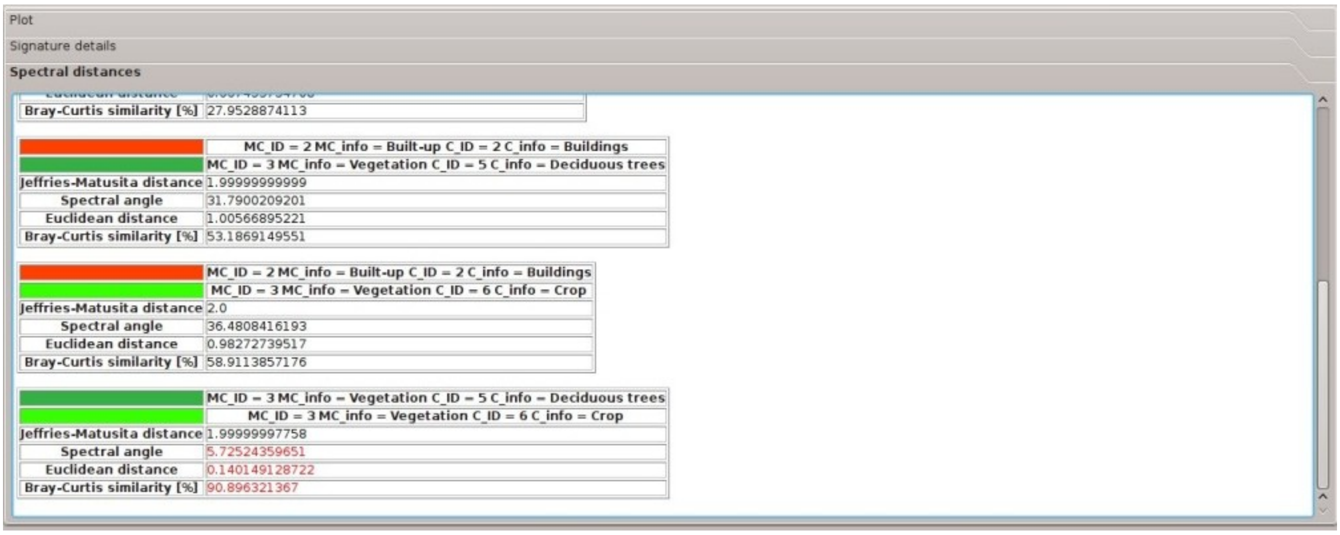


Fig. 11.6: *Spectral Signature: Example of spectral distances*

CAPITOLO 12

Scatter Plot

The window *Scatter plot* displays pixel values for two raster bands as points in the 2D space. Scatter plots are useful for assessing ROI separability between two bands.

The functions are described in detail in the following paragraphs, using these conventions:

= Input date

= Input text

= List

= Input number

= Optional

= Configuration stored in the active project of QGIS

= Configuration stored in QGIS registry

= Slider

= Table

Scatter list

- ***Scatter list*:**
  - *S*: checkbox field; if checked, the spectral signature is displayed in the plot;
  - *MC ID*: signature Macroclass ID;
  - *MC Info*: signature Macroclass Information;
  - *C ID*: signature Class ID;
  - *C Info*: signature Class Information;

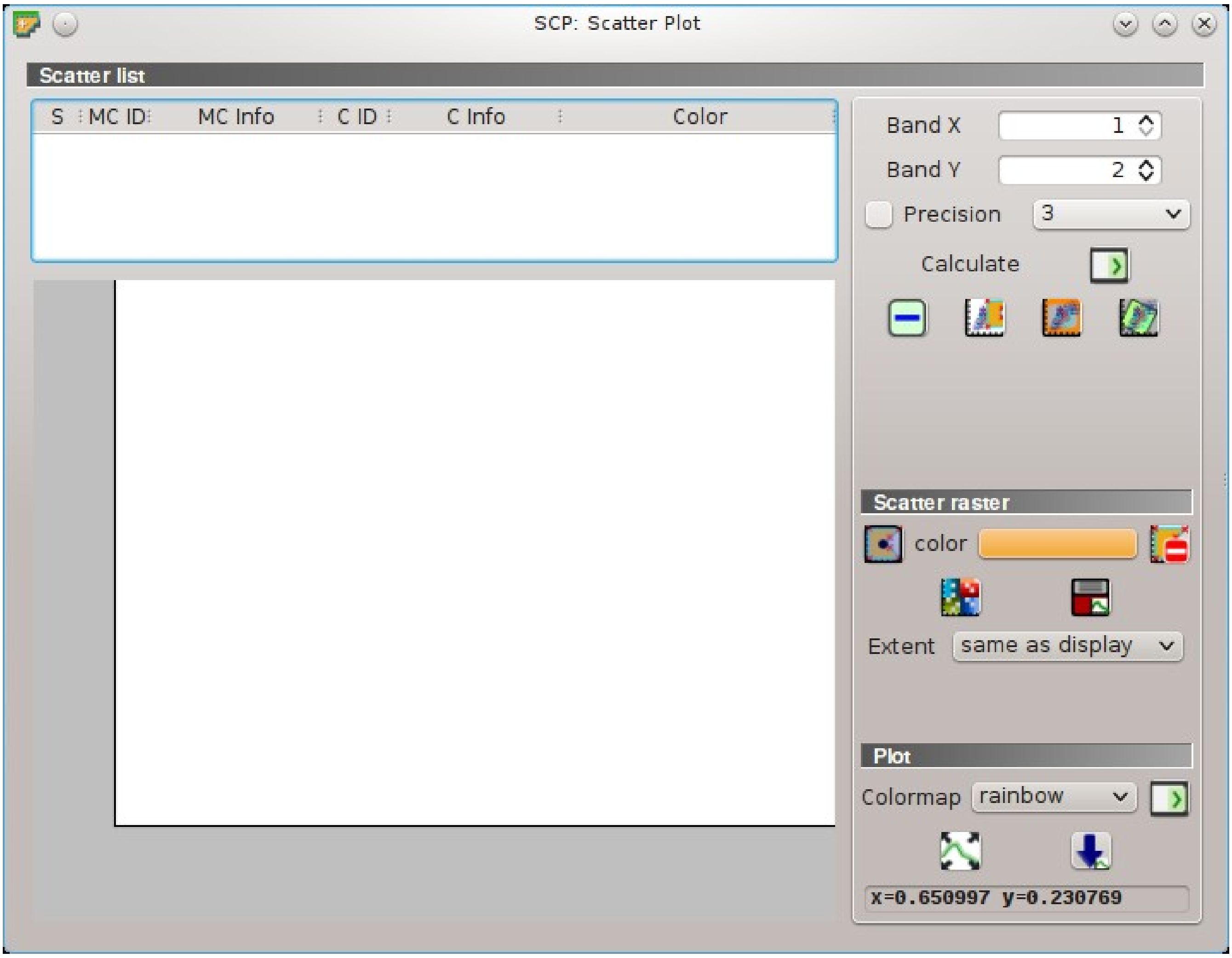


Fig. 12.1: *Scatter Plot*

  - *Color*: color field; double click to select a color for the plot;

- *Band X* : X band of the plot;
- *Band Y* : Y band of the plot;
- ***Precision*** **: use custom precision for calculation (precision should be selected according to pixel values):**

  - 4 = 10^{-4}
  - 3 = 10^{-3}
  - 2 = 10^{-2}
  - 1 = 10^{-1}
  - 0 = 1
  - -1 = 10
  - -2 = 10^{2}
  - -3 = 10^{3}

- *Calculate* : calculate the scatter plot for the ROIs checked in the list;
- : remove highlighted signatures from this list;
- : add a temporary scatter plot to the list (as `MC Info = tempScatter`) and start the plot calculation of the last temporary ROI (see *Working toolbar* (pagina 33));
- : add a temporary scatter plot to the list (as `MC Info = tempScatter`) and start the plot calculation of pixels in current display extent;
- : add a temporary scatter plot to the list (as `MC Info = tempScatter`) and start the plot calculation of the entire image;

  WARNING: Using a precision value that is too high can result in slow calculation or failure.

Scatter raster

This tool allows for the drawing of selection polygons inside the scatter plot; these selection polygons are used for creating a *Scatter raster* that is a temporary raster classified according to the intersection of scatter plots and drawn polygons.

Pixels of the *Input image* (pagina 38) are classified, according to scatter plot bands, if pixel values are in the range of intersection between scatter plots and selection polygons (polygons should not overlap). The value assigned to the *Scatter raster* pixels is the sequential number of selection polygon; also the raster color is derived from the selection polygon.

After the creation of a new *Scatter raster*, old rasters are placed in QGIS Layers inside a layer group named `Class_temp_group` (custom name can be defined in *Temporary group name* (pagina 118)) and are deleted when the QGIS session is closed.

- : activate the cursor for interactively drawing a polygon in the plot; left click on the plot to define the vertices and right click to define the last vertex closing the polygon;
- *color*: select the color of polygon (which is used also in the *Scatter raster*);

- : remove all the selection polygons from the plot;
- : calculate the *Scatter raster* and display it in the map;
- : calculate the spectral signature of the *Scatter raster* (considering all the classified pixels) using the *Input image* (pagina 38), and save the signature to the *ROI Signature list* (pagina 41);
- ***Extent*** **: extent of the *Scatter raster*; available options are:**
  - *Same as display*: extent is the same as map display;
  - *Same as image*: extent is the same as the whole image;

Plottaggio

Left click and hold inside the plot to **move** the view of the plot. Use the **mouse wheel** to **zoom in and out** the view of the plot. **Right click** and hold inside the plot to **zoom in a specific area** of the plot.

- *Colormap* : select a colormap that is applied to highlighted scatter plots in the list when is clicked; if no scatter plot is highlighted then the colormap is applied to all the scatter plots;
- : automatically fit the plot to data;
- : save the plot image to file (available formats are `.jpg`, `.png`, and `.pdf`);
- *x y*: display x y coordinates of mouse cursor inside the plot;

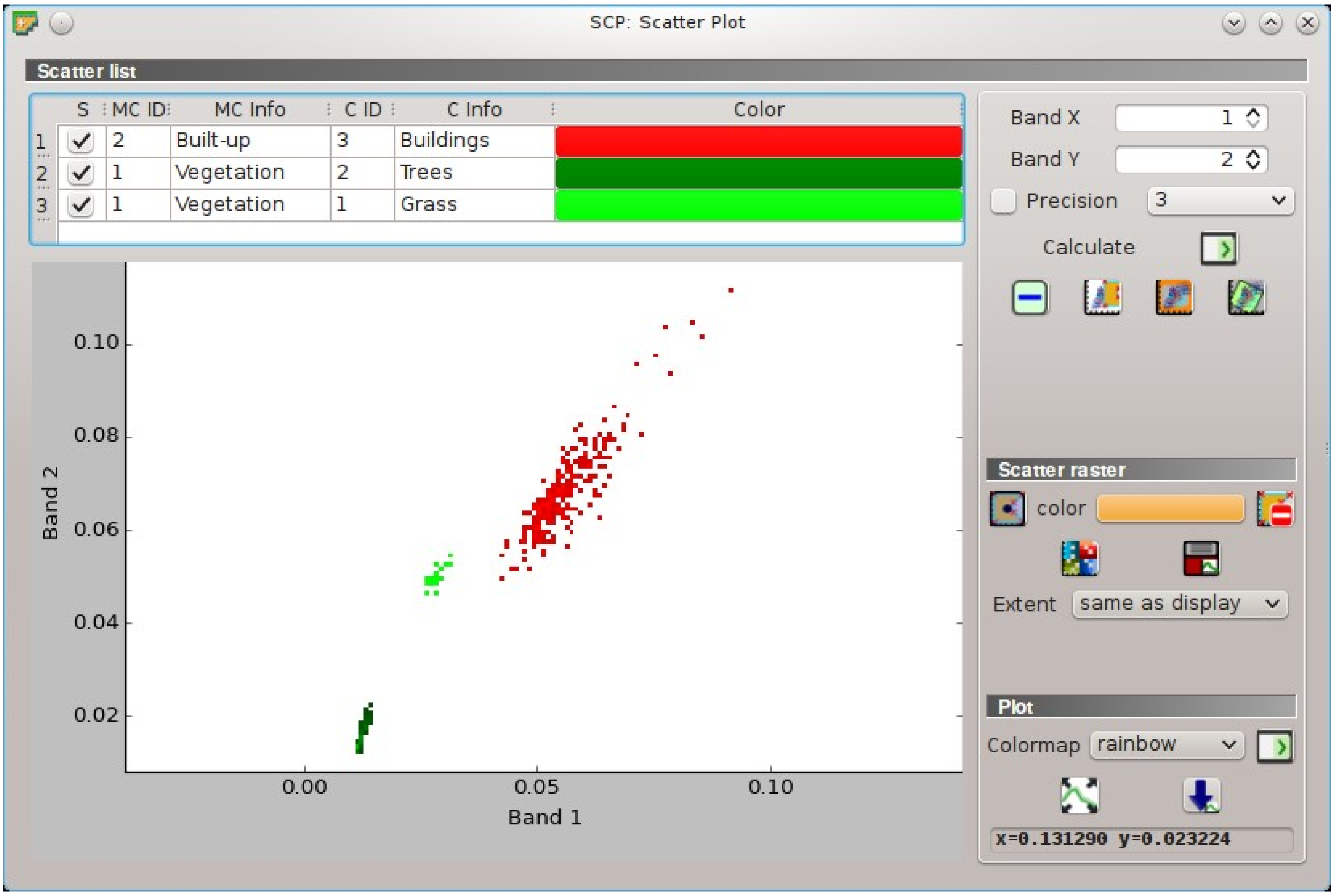


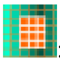
Fig. 12.2: *Example Scatter Plot*

CAPITOLO 13

SCP Edit Toolbar

Fig. 13.1: *SCP Tools*

The *SCP Edit Toolbar* allows for the direct editing of pixel values in the input raster defined in *Edit raster* (pagina 99) using ROI polygons. Only pixels beneath ROI polygons are edited.

- : open the tool *SCP Edit Toolbar* for selecting the input raster;
- : edit the raster using the selected constant value;
- : edit the raster using the selected constant value;
- : edit the raster using the selected constant value;
- : undo the last raster edit (available only when using ROI polygons);

Parte IV

Breve Introduzione al Telerilevamento (Remote Sensing)

CAPITOLO 14

Definizioni Base

This chapter provides basic definitions about GIS and remote sensing. For other useful resources see *Free and valuable resources about remote sensing and GIS* (pagina 272).

GIS definizione

Esistono diverse definizioni di ** ** GIS (Geographic Information Systems), che non è semplicemente un programma. In generale, i GIS sono sistemi che consentono l'utilizzo di informazioni geografiche (dati che hanno coordinate spaziali). In particolare, i GIS permettono la visualizzazione, l'interrogazione, il calcolo e l'analisi dei dati spaziali, che principalmente si distinguono in raster e vettori. I Vettori sono oggetti di tipo puntuale o lineare o poligonale, e ogni oggetto può avere uno o più valori di attributi; un raster è una griglia (o immagine) in cui ogni cella ha un valore di attributo (Fisher Unwin, 2005). Le applicazioni GIS utilizzano immagini raster che sono derivati da telerilevamento.

Telerilevamento definizione

Una definizione generale di ** ** Remote Sensing è: "la scienza e la tecnologia con la quale le caratteristiche degli oggetti di interesse possono essere identificate, misurate e analizzate senza contatto diretto" (JARS, 1993).

Solitamente, il telerilevamento misura l'energia che viene emanata dalla superficie terrestre. Se la sorgente dell'energia misurata è il sole, allora si chiama ** telerilevamento passivo **, e il risultato di questa misurazione può essere un'immagine digitale (Richards e Jia, 2006). Se l'energia misurata non viene emessa dal Sole, ma da un sensore artificiale allora è definito come ** telerilevamento attivo **, come i radar stellite che operano nel campo delle microonde (Richards e Jia, 2006) radar.

Lo **spettro elettromagnetico** è "il sistema che classifica, secondo la lunghezza d'onda, tutta l'energia (da breve a lungo cosmica radio) che si muove, armonicamente, alla velocità costante di luce" (NASA, 2013). I sensori passivi misurano l'energia dalle regioni ottiche dello spettro elettromagnetico: visibile, vicino infrarosso (NIR), infrarosso a onde corte (SWIR) e infrarosso termico (TM) (vedi Figura: ref: *figEM*).

L'interazione tra energia solare e materiali dipende dalla lunghezza d'onda; energia solare va dal Sole alla Terra e poi al sensore. Lungo questo percorso, **l'energia solare ** è (NASA, 2013):

- ** Trasmesso ** - L'energia passa da un mezzo a un altro venendo rifratta come determinato dall'indice di rifrazione dei due mezzi in questione.
- ** Assorbita ** - L'energia è assorbita da un oggetto attraverso reazioni di elettroni o molecolari.

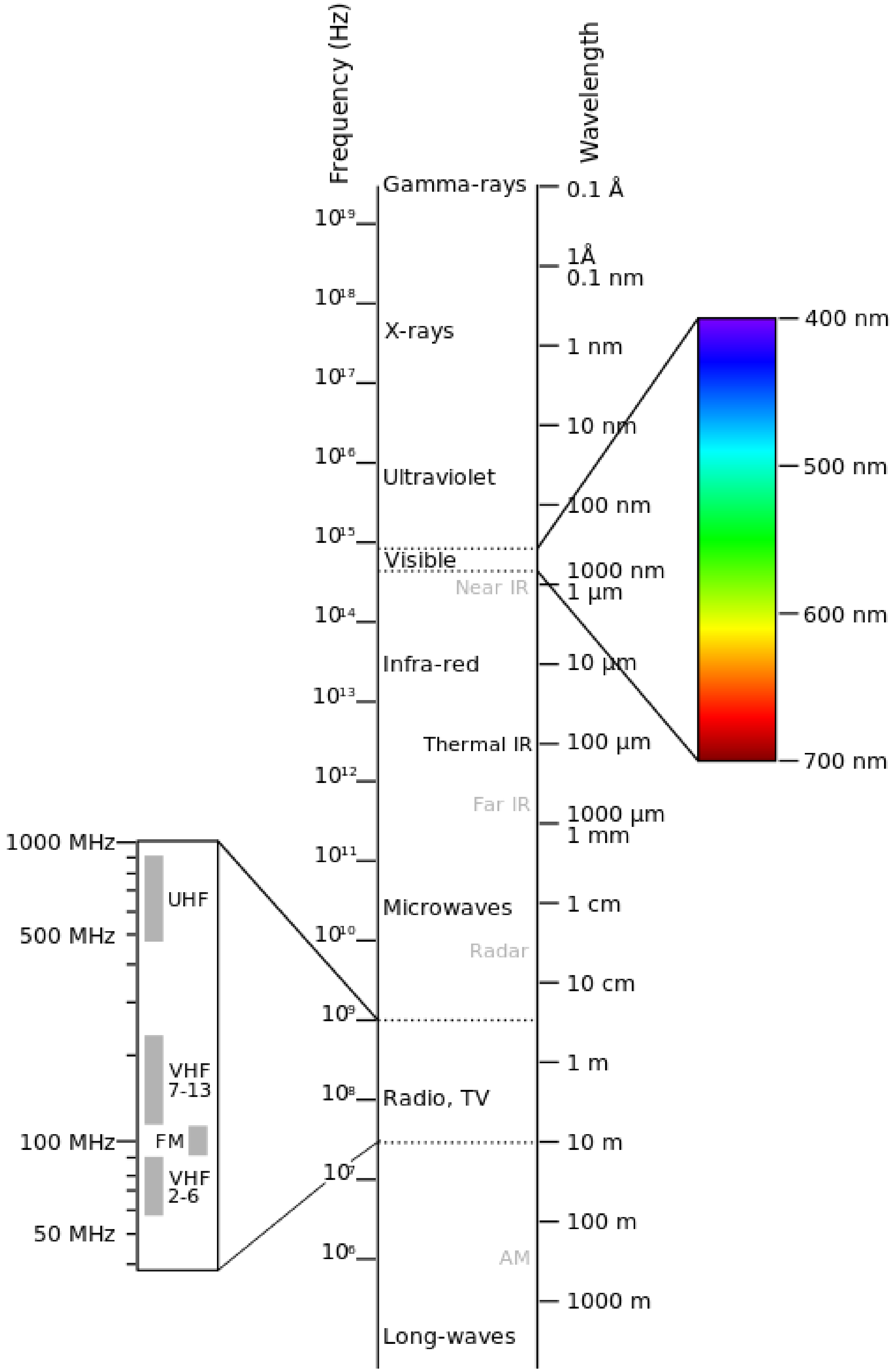


Fig. 14.1: *Spettro-Elettromagnetico*

by Victor Blacus (SVG version of File:Electromagnetic-Spectrum.png) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)] via Wikimedia Commons http://commons.wikimedia.org/wiki/File%3AElectromagnetic-Spectrum.svg

- ** Riflessa ** - L'energia viene restituito invariato con un angolo di incidenza uguale all'angolo di riflessione. La riflettanza è il rapporto tra l'energia riflessa a quella incidente su un corpo. La lunghezza d'onda riflessa (non assorbita) determina il colore di un oggetto.
- **Dispersa** - La direzione di propagazione dell'energia è cambia in modo casuale. Rayleigh e Mie sono i due più importanti tipi di dispersione in atmosfera.
- ** Emessa** - In realtà, l'energia viene prima assorbita, poi ri-emessa, di solito a lunghezze d'onda maggiori. L'oggetto si riscalda.

Sensori

** I sensori ** possono essere a bordo di aerei o a bordo di satelliti, per misurare la radiazione elettromagnetica a intervalli specifici (generalmente chiamati bande). Come risultato, le misure sono quantizzate e convertite in un'immagine digitale, in cui ogni elemento di immagine (pixel) ha un valore discreto in unità di Digital Number (DN) (NASA, 2013). Le immagini risultanti hanno caratteristiche diverse (risoluzioni) a seconda del sensore. Ci sono diversi tipi di **risoluzioni**:

- **La risoluzione spaziale**, di solito misurata in dimensione dei pixel, "è il potere di risoluzione di uno strumento necessario per la discriminazione delle caratteristiche e si basa sulla dimensione del sensore, distanza focale, e altitudine del sensore " (NASA, 2013); risoluzione spaziale è indicata anche come risoluzione geometrica o IFOV;
- **Risoluzione spettrale** , è il numero e la posizione nello spettro elettromagnetico (definito da due lunghezze d'onda) delle bande spettrali (NASA, 2013) in sensori multispettrali, per ogni banda corrisponde un'immagine;
- ** Risoluzione radiometrica **, solitamente misurata in bit (cifre binarie), è la gamma di valori di luminosità disponibili, che nell'immagine corrispondono alla portata massima dei DN; per esempio, un'immagine con risoluzione di 8 bit dispone di 256 livelli di luminosità (Richards e Jia, 2006);
- Per i sensori satellitari, si misura anche la **risoluzione temporale**, che è il tempo necessario per rivisitare la stessa area della Terra (NASA, 2013).

Radianza e Riflettanza

I sensori misurano la **radianza**, che corrisponde alla luminosità in una certa direzione verso il sensore; inoltre è utile definire la **riflettanza** come il rapporto tra l'energia riflessa e l'energia totale.

Firma Spettrale

The **spectral signature** is the reflectance as a function of wavelength (see Figure *: guilabel: curva di riflettanza spettrale di quattro diversi oggetti* (pagina 144)); each material has a unique signature, therefore it can be used for material classification (NASA, 2013).

Satellite Landsat

Landsat è un insieme di satelliti multispettrali sviluppato dalla NASA (National Aeronautics and Space Administration degli Stati Uniti), sin dagli inizi del 1970.

Le immagini Landsat sono molto utilizzate per la ricerca ambientale. Le risoluzioni dei sensori Landsat 4 e Landsat 5 sono riportate nella seguente tabella (da http://landsat.usgs.gov/band_designations_landsat_satellites.php); Inoltre, risoluzione temporale Landsat è di 16 giorni (NASA, 2013).

Landsat 4 and Landsat 5 Bands

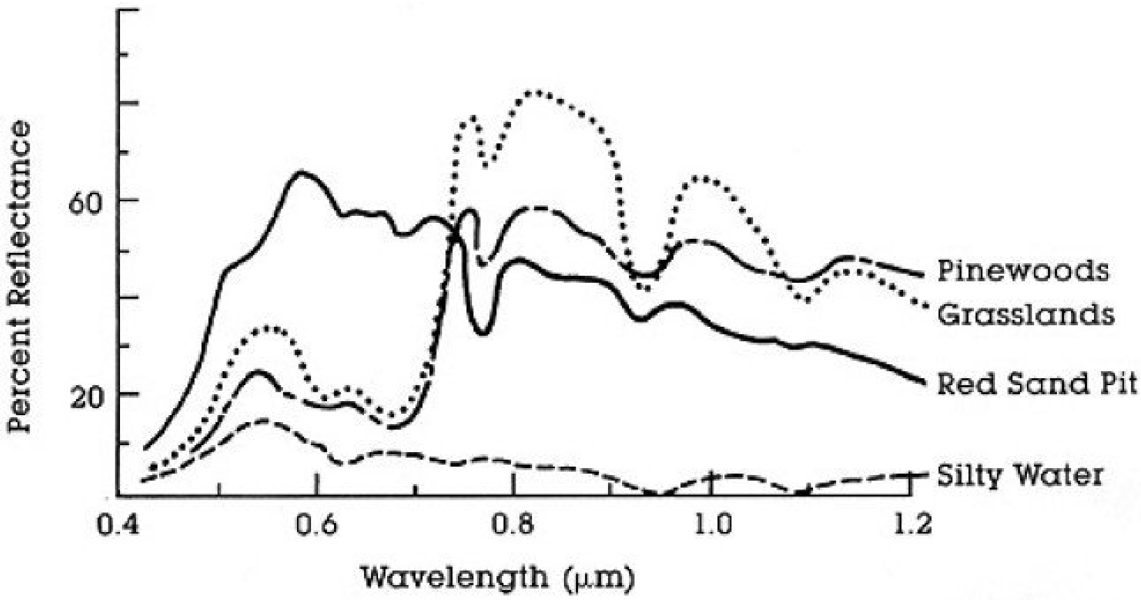


Fig. 14.2: : guilabel: *curva di riflettanza spettrale di quattro diversi oggetti (NASA, 2013)*‘

Bande Landsat 4, Landsat 5	Lunghezza d'onda [micrometri]	Risoluzione [metri]
Banda 1 - Blu	0.45 - 0.52	30
Banda 2 - Verde	0.52 - 0.60	30
Banda 3 - Rosso	0.63 - 0.69	30
Banda 4 - Vicino Infrarosso (NIR)	0.76 - 0.90	30
Banda 5 - Onde corte Infrarosso (SWIR)	1.55 - 1.75	30
Banda 6 - Infrarosso termico (TI)	10.40 - 12.50	120 (ricampionata a 30)
Banda 7 - SWIR	2.08 - 2.35	30

Le risoluzioni del sensore Landsat 7 sono riportate nella seguente tabella (da http://landsat.usgs.gov/band_designations_landsat_satellites.php); Inoltre, la risoluzione temporale Landsat è di 16 giorni (NASA, 2013).

Landsat 7 Bands

Landsat 7 Bands	Lunghezza d'onda [micrometri]	Risoluzione [metri]
Banda 1 - Blu	0.45 - 0.52	30
Banda 2 - Verde	0.52 - 0.60	30
Banda 3 - Rosso	0.63 - 0.69	30
Banda 4 - Vicino Infrarosso (NIR)	0.77 - 0.90	30
Banda 5 - Onde corte Infrarosso (SWIR)	1.57 - 1.75	30
Banda 6 - Infrarosso termico (TI)	10.40 - 12.50	60 (ricampionate a 30)
Banda 7 - SWIR	2.09 - 2.35	30
Band 8 - Panchromatica	0.52 - 0.90	15

Le risoluzioni del sensore Landsat 8 sono riportate nella seguente tabella (da http://landsat.usgs.gov/band_designations_landsat_satellites.php); Inoltre, la risoluzione temporale Landsat è di 16 giorni (NASA, 2013)

Landsat 8 Bands

Bande Landsat 8	Lunghezza d'onda [micrometri]	Risoluzione [metri]
Banda 1 - Aerosol costiero	0.43 - 0.45	30
Band 2 - Blue	0.45 - 0.51	30
Banda 3 - Verde	0.53 - 0.59	30
Banda 4 - Rosso	0.64 - 0.67	30
Band 5 - Infrarosso Vicino (NIR)	0.85 - 0.88	30
Band 6 - SWIR 1	1.57 - 1.65	30
Band 7 - SWIR 2	2.11 - 2.29	30
Band 8 - Panchromatica	0.50 - 0.68	15
Band 9 - Cirro	1.36 - 1.38	30
Band 10 - Infrarosso Termico (TIRS) 1	10.60 - 11.19	100 (resampled to 30)
Band 11 - Infrarosso Termico (TIRS) 2	11.50 - 12.51	100 (resampled to 30)

A vast archive of images is freely available from the U.S. Geological Survey . For more information about how to freely download Landsat images read this .

Images are identified with the paths and rows of the WRS (Worldwide Reference System for Landsat).

Sentinel-2 Satellite

Sentinel-2 è un satellite multispettrale sviluppato dall'Agenzia Spaziale Europea (ESA) nel quadro di Copernicus land monitoring services. Sentinel-2 acquisisce 13 bande spettrali con la risoluzione spaziale di 10m, 20m e 60m a seconda della fascia, come illustrato nella seguente tabella (ESA, 2015).

Sentinel-2 Bands

Sentinel-2 Bande	Central Wavelength [micrometers]	Risoluzione [metri]
Banda 1 - Aerosol costiero	0.443	60
Band 2 - Blue	0.490	10
Banda 3 - Verde	0.560	10
Banda 4 - Rosso	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

Le immagini Sentinel-2 sono liberamente disponibili sul sito web dell'ESA https://scihub.esa.int/dhus/.

ASTER Satellite

The **ASTER** (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite was launched in 1999 by a collaboration between the Japanese Ministry of International Trade and Industry (MITI) and the NASA. ASTER has 14 bands whose spatial resolution varies with wavelength: 15m in the visible and near-infrared, 30m in the short wave infrared, and 90m in the thermal infrared (USGS, 2015). ASTER bands are illustrated in the following table (due to a sensor failure **SWIR data acquired since April 1, 2008 is not available**). An additional band 3B (backwardlooking near-infrared) provides stereo coverage.

ASTER Bands

ASTER Bands	Lunghezza d'onda [micrometri]	Risoluzione [metri]
Band 1 - Green	0.52 - 0.60	15
Band 2 - Red	0.63 - 0.69	15
Band 3N - Near Infrared (NIR)	0.78 - 0.86	15
Band 4 - SWIR 1	1.60 - 1.70	30
Band 5 - SWIR 2	2.145 - 2.185	30
Band 6 - SWIR 3	2.185 - 2.225	30
Band 7 - SWIR 4	2.235 - 2.285	30
Band 8 - SWIR 5	2.295 - 2.365	30
Band 9 - SWIR 6	2.360 - 2.430	30
Band 10 - TIR 1	8.125 - 8.475	90
Band 11 - TIR 2	8.475 - 8.825	90
Band 12 - TIR 3	8.925 - 9.275	90
Band 13 - TIR 4	10.25 - 10.95	90
Band 14 - TIR 5	10.95 - 11.65	90

MODIS Products

The **MODIS** (Moderate Resolution Imaging Spectroradiometer) is an instrument operating on the Terra and Aqua satellites launched by NASA in 1999 and 2002 respectively. Its temporal resolutions allows for viewing the entire Earth surface every one to two days, with a swath width of 2,330. Its sensors measure 36 spectral bands at three spatial resolutions: 250m, 500m, and 1,000m (see https://lpdaac.usgs.gov/dataset_discovery/modis).

Several products are available, such as surface reflectance and vegetation indices. In this manual we are considering the surface reflectance bands available at 250m and 500m spatial resolution (Vermote, Roger, & Ray, 2015).

MODIS Bands

MODIS Bands	Lunghezza d'onda [micrometri]	Risoluzione [metri]
Band 1 - Red	0.62 - 0.67	250 - 500
Band 2 - Near Infrared (NIR)	0.841 - 0.876	250 - 500
Band 3 - Blue	0.459 - 0.479	500
Band 4 - Green	0.545 - 0.565	500
Band 5 - SWIR 1	1.230 - 1.250	500
Band 6 - SWIR 2	1.628 - 1.652	500
Band 7 - SWIR 3	2.105 - 2.155	500

The following products (Version 6, see https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table) are available for download (Vermote, Roger, & Ray, 2015):

- MOD09GQ: daily reflectance at 250m spatial resolution from Terra MODIS;
- MYD09GQ: daily reflectance at 250m spatial resolution from Aqua MODIS;
- MOD09GA: daily reflectance at 500m spatial resolution from Terra MODIS;
- MYD09GA: daily reflectance at 500m spatial resolution from Aqua MODIS;
- MOD09Q1: reflectance at 250m spatial resolution, which is a composite of MOD09GQ (each pixel contains the best possible observation during an 8-day period);
- MYD09Q1: reflectance at 250m spatial resolution, which is a composite of MYD09GQ (each pixel contains the best possible observation during an 8-day period);
- MOD09A1: reflectance at 250m spatial resolution, which is a composite of MOD09GA (each pixel contains the best possible observation during an 8-day period);
- MYD09A1: reflectance at 250m spatial resolution, which is a composite of MYD09GA (each pixel contains the best possible observation during an 8-day period);

Colore Composito

Spesso, una combinazione viene creata da tre immagini monocromatiche individuali, in cui a ciascuna è assegnato un dato colore; questa è definita ** color composite ** ed è utile per la fotointerpretazione (NASA, 2013). Le color composite sono di solito espresse come:

"R G B = Br Bg Bb"

where:

- R sta per rosso;
- G sta per verde;
- B sta per Blue;
- Br è il numero di banda associato al colore rosso;
- Bg è il numero di banda associato al colore verde;
- Bb è il numero di banda associato al colore blu.

The following Figure *: guilabel: Colore composito di un immagine Landsat8* (pagina 147) shows a color composite "R G B = 4 3 2" of a Landsat 8 image (for Landsat 7 the same color composite is R G B = 3 2 1; for Sentinel-2 is R G B = 4 3 2) and a color composite "R G B = 5 4 3" (for Landsat 7 the same color composite is R G B = 4 3 2; for Sentinel-2 is R G B = 8 4 3). The composite "R G B = 5 4 3" is useful for the interpretation of the image because vegetation pixels appear red (healthy vegetation reflects a large part of the incident light in the near-infrared wavelength, resulting in higher reflectance values for band 5, thus higher values for the associated color red).

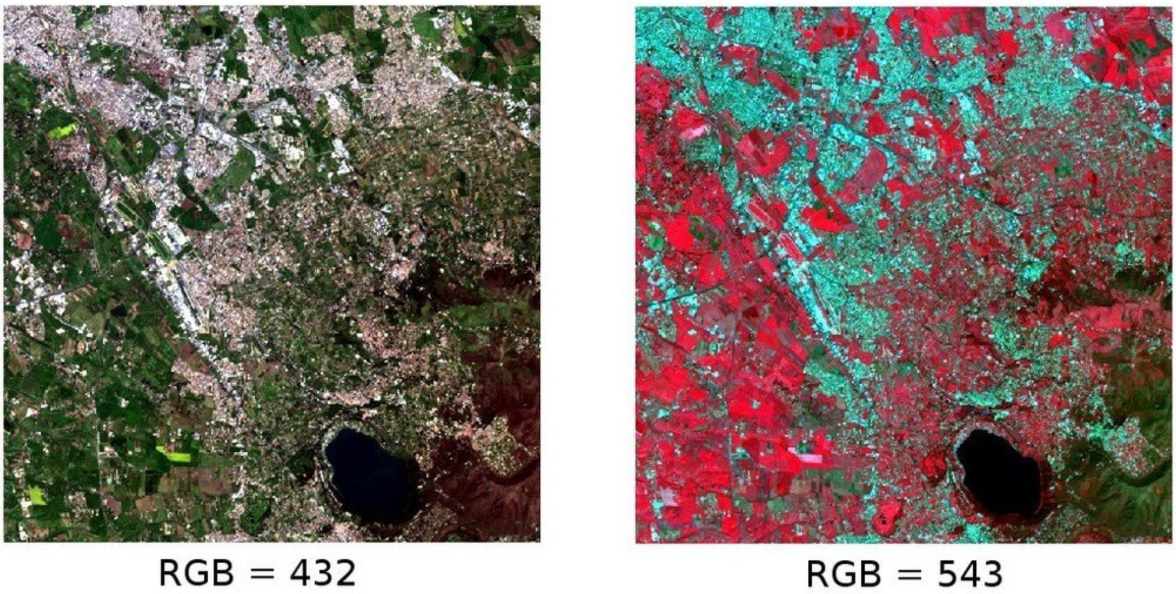


Fig. 14.3: : guilabel: *Colore composito di un immagine Landsat8*
`I dati disponibili da U.S. Geological Survey`

Principal Component Analysis

Principal Component Analysis (PCA) is a method for reducing the dimensions of measured variables (bands) to the principal components (JARS, 1993).

Th principal component transformation provides a new set of bands (principal components) having the following characteristic: principal components are uncorrelated; each component has variance less than the previous component. Therefore, this is an efficient method for extracting information and data compression (Ready and Wintz, 1973).

Given an image with N spectral bands, the principal components are obtained by matrix calculation (Ready and Wintz, 1973; Richards and Jia, 2006):

$$Y = D^t X$$

where:

- Y = vector of principal components
- D = matrix of eigenvectors of the covariance matrix C_x in X space
- t denotes vector transpose

And X is calculated as:

$$X = P - M$$

- P = vector of spectral values associated with each pixel
- M = vector of the mean associated with each band

Thus, the mean of X associated with each band is 0. D is formed by the eigenvectors (of the covariance matrix C_x) ordered as the eigenvalues from maximum to minimum, in order to have the maximum variance in the first component. This way, the principal components are uncorrelated and each component has variance less than the previous component(Ready and Wintz, 1973).

Usually the first two components contain more than the 90% of the variance. For example, the first principal components can be displayed in a *Colore Composito* (pagina 147) for highlighting *Land Cover* (pagina 151) classes, or used as input for *Supervised Classification* (pagina 151).

Pan-sharpening

Pan-sharpening is the combination of the spectral information of multispectral bands (MS), which have lower spatial resolution (for Landsat bands, spatial resolution is 30m), with the spatial resolution of a panchromatic band (PAN), which for Landsat 7 and 8 it is 15m. The result is a multispectral image with the spatial resolution of the panchromatic band (e.g. 15m). In *SCP*, a Brovey Transform is applied, where the pan-sharpened values of each multispectral band are calculated as (Johnson, Tateishi and Hoan, 2012):

$$MSpan = MS * PAN/I$$

dove:: I è intensità, che è una funzione di bande multispettrali.

The following weights for I are defined, basing on several tests performed using the *SCP*. For Landsat 8, Intensity is calculated as:

$$I = (0.42 * Blue + 0.98 * Green + 0.6 * Red)/2$$

Per Landsat 7, l' Intensità è così calcolata:

$$I = (0.42 * Blue + 0.98 * Green + 0.6 * Red + NIR)/3$$

Fig. 14.4: *Esempio di pan-sharpening di un'immagine Landsat 8. Sinistra, bande multispettrali originali (30m); a destra, pan-sharpened (15m)*

`I dati disponibili da U.S. Geological Survey`

Spectral Indices

Spectral indices are operations between spectral bands that are useful for extracting information such as vegetation cover (JARS, 1993). One of the most popular spectral indices is the **Normalized Difference Vegetation Index** (NDVI), defined as (JARS, 1993):

$$NDVI = (NIR - Red)/(NIR + Red)$$

NDVI values range from -1 to 1. Dense and healthy vegetation show higher values, while non-vegetated areas show low NDVI values.

Another index is the **Enhanced Vegetation Index** (EVI) which attempts to account for atmospheric effects such as path radiance calculating the difference between the blue and the red bands (Didan,et al., 2015). EVI is defined as:

$$EVI = G(NIR - Red)/(NIR + C_1 Red - C_2 Blue + L)$$

where: G is a scaling factor, C_1 and C_2 are coefficients for the atmospheric effects, and L is a factor for accounting the differential NIR and Red radiant transfer through the canopy. Typical coefficient values are: $G = 2.5$, $L = 1$, $C_1 = 6$, $C_2 = 7.5$ (Didan,et al., 2015).

CAPITOLO 15

Supervised Classification Definizioni

Questo capitolo fornisce le definizioni di base riguardoa alla supervised classifications.

Land Cover

Land cover è il materiale a terra, come il suolo, la vegetazione, l'acqua, asfalto, ecc (Fisher e Unwin, 2005). In base alle risoluzione del sensore, il numero e il tipo di classi di copertura del suolo che può possono essere identificata nell'immagine possono variare significativamente.

Supervised Classification

Una **classificazione semiautomatica** (supervised classification) è una tecnica di elaborazione di immagini che permette l'identificazione di materiali in un'immagine, in base alle loro firme spettrali. Ci sono diversi tipi di algoritmi di classificazione, ma lo scopo generale è quello di produrre una mappa tematica della copertura del suolo.

Il processamento di immagini e le analisi spaziali richiedono specifici software come il Semi-Automatic Classification Plugin per QGIS

Training Areas

Di solito, le supervised classifications richiedono all'utente di selezionare uno o più regioni di interesse (ROI, o Training Areas) per ogni classe di copertura del suolo identificato nell'immagine. ** ROI** sono poligoni disegnati su aree omogenee dell'immagine che includoni pixel appartenenti alla stessa classe di copertura del suolo.

Region Growing Algorithm

The Region Growing Algorithm allows to select pixels similar to a seed one, considering the **spectral similarity** (i.e. spectral distance) of adjacent pixels. In *SCP* the Region Growing Algorithm is available for the training area creation. The parameter **distance** is related to the similarity of pixel values (the lower the value, the more similar are selected pixels) to the seed one (i.e. selected clicking on a pixel). An additional parameter is the **maximum**

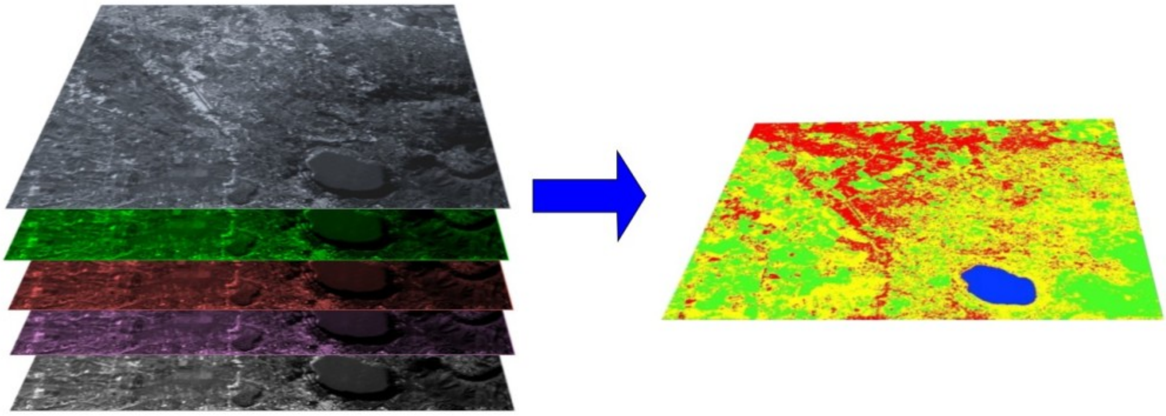


Fig. 15.1: *A multispectral image processed to produce a land cover classification*
`(Landsat image provided by USGS)`

width, which is the side length of a square, centred at the seed pixel, which inscribes the training area (if all the pixels had the same value, the training area would be this square). The **minimum size** is used a constraint (for every single band), selecting at least the pixels that are more similar to the seed one until the number of selected pixels equals the minimum size.

In figure *Region growing example* (pagina 152) the central pixel is used as seed (image a) for the region growing of one band (image b) with the parameter spectral distance = 0.1; similar pixels are selected to create the training area (image c and image d).

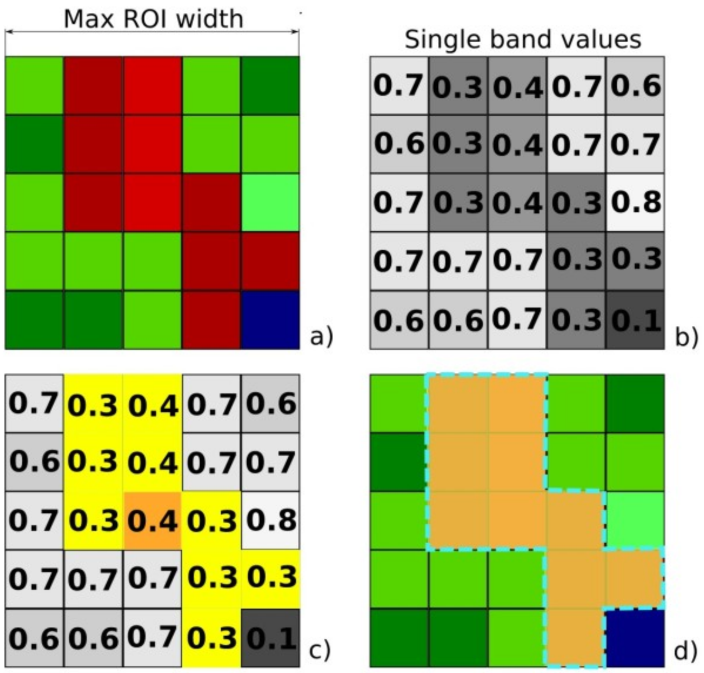


Fig. 15.2: *Region growing example*

Classi e Macroclassi

Land cover classes are identified with an arbitrary ID code (i.e. Identifier). *SCP* allows for the definition of **Macroclass ID** (i.e. MC ID) and **Class ID** (i.e. C ID), which are the identification codes of land cover classes. A **Macroclass** is a group of ROIs having different Class ID, which is useful when one needs to classify materials that have different spectral signatures in the same land cover class. For instance, one can identify grass (e.g. `ID class = 1` and `Macroclass ID = 1`) and trees (e.g. `ID class = 2` and `Macroclass ID = 1`) as vegetation class (e.g. `Macroclass ID = 1`). Multiple Class IDs can be assigned to the same Macroclass ID, but the same Class ID cannot be assigned to multiple Macroclass IDs, as shown in the following table.

Example of Macroclasses

Macroclass name	Macroclass ID	Class name	Class ID
Vegetazione	1	Erba	1
Vegetazione	1	Alberi	2
Costruito	2	Buildings	3
Costruito	2	Roads	4

Pertanto, Le classi sono sottoinsiemi di un macroclasse come illustrato nella figura *Macroclass esempio* (pagina 153).

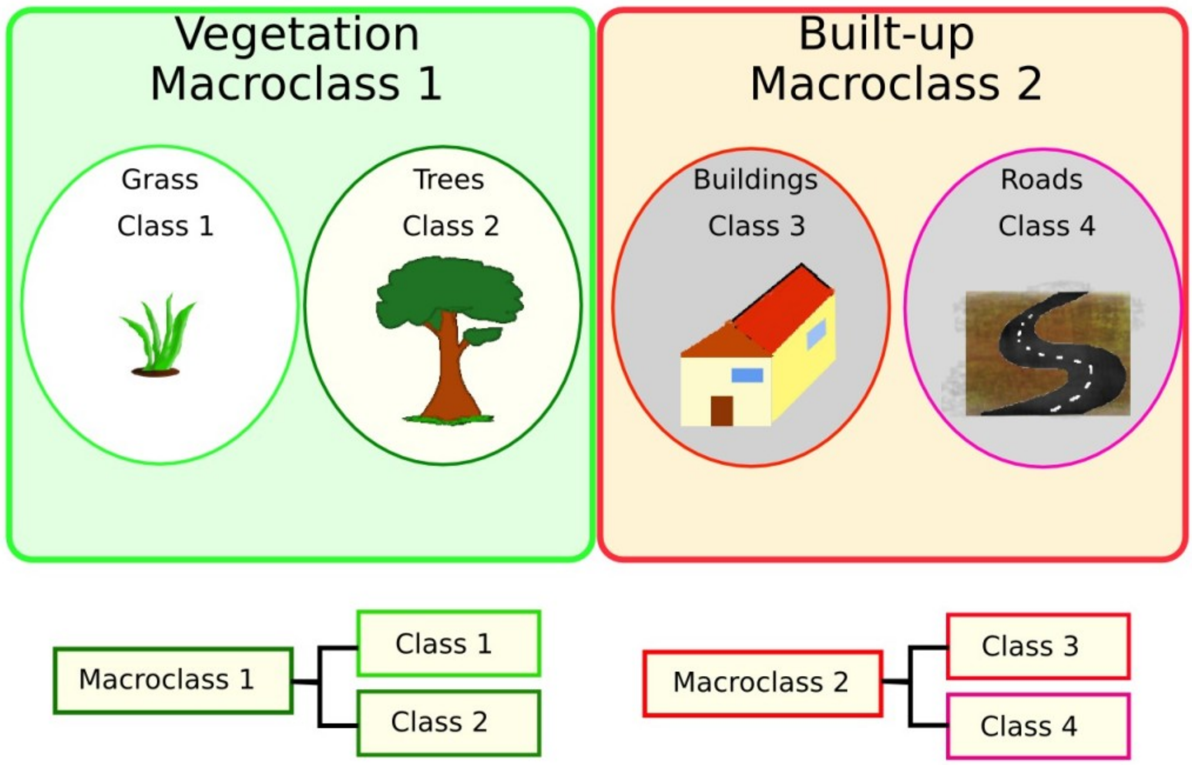


Fig. 15.3: *Macroclass esempio*

Se per lo scopo dello studio non è richiesto l'uso della macroclasse, allora per tutte le ROIs può essere definito lo stesso ID di macroclasse (e.g. Macroclass ID = 1) e tutti i valori di macroclasse vengono ignorati durante la classificazione.

Classification Algorithms

The **spectral signatures** (spectral characteristics) of reference land cover classes are calculated considering the values of pixels under each ROI having the same Class ID (or Macroclass ID). Therefore, the classification algorithm classifies the whole image by comparing the spectral characteristics of each pixel to the spectral characteristics of reference land cover classes. *SCP* implements the following classification algorithms.

Minimum Distance

L'algoritmo Minimum Distance calcola la distanza euclidea: matematica: *d (x, y)* tra firme spettrali dei pixel dell'immagine e le firme spettrali delle ROI secondo la seguente equazione:

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

where:

- x = firma spettrale vettoriale di un pixel dell immagine;
- y = firma spettrale vettoriale della training area;
- n = numero di bande nell immagine.

Pertanto, la distanza è calcolata per ogni pixel nell'immagine, assegnandgli la classe della firma spettrale che gli è più vicina, secondo la seguente funzione discriminante (adattato da Richards e Jia, 2006):

$$x \in C_k \iff d(x,y_k) < d(x,y_j) \forall k \neq j$$

where:

- C_k = land cover class k;
- y_k = firma spettrale della classe k;
- y_j = firma spettrale della classe j.

È possibile definire una soglia:math:*T_i* per escludere pixel sotto di questo valore dalla classificazione:

$$\begin{aligned} x \in C_k \iff d(x,y_k) < d(x,y_j) \forall k \neq j \\ and \\ d(x,y_k) < T_i \end{aligned}$$

Maximum Likelihood

L'algoritmo Maximum Likelihood calcola le distribuzioni di probabilità per le classi, relative al teorema di Bayes, stimando se un pixel appartiene a una classe di copertura del suolo. In particolare, le distribuzioni di probabilità per le classi si assumono la forma di modelli multivariati normali (Richards e Jia, 2006). Per utilizzare questo algoritmo, è necessario un numero sufficiente di pixel per ciascuna area di formazione consentendo il calcolo della matrice di covarianza. La funzione discriminante, descritta da Richards e Jia (2006), è calcolato per ogni pixel come

$$g_k(x) = \ln p(C_k) - \frac{1}{2}\ln|\Sigma_k| - \frac{1}{2}(x-y_k)^t \Sigma_k^{-1}(x-y_k)$$

where:

- C_k = land cover class k;
- x = firma spettrale vettoriale di un pixel dell immagine;
- $p(C_k)$ =probabilità che la classe sia corretta C_k;

- $|\Sigma_k|$ =determinante della matrice di covarianza dei dati nella classe:math:*C_k*;
- Σ_k^{-1} = inverso della matrice di covarianza;
- y_k = firma spettrale vettoriale della classe k.

Dunque

$$x \in C_k \iff g_k(x) > g_j(x) \forall k \neq j$$

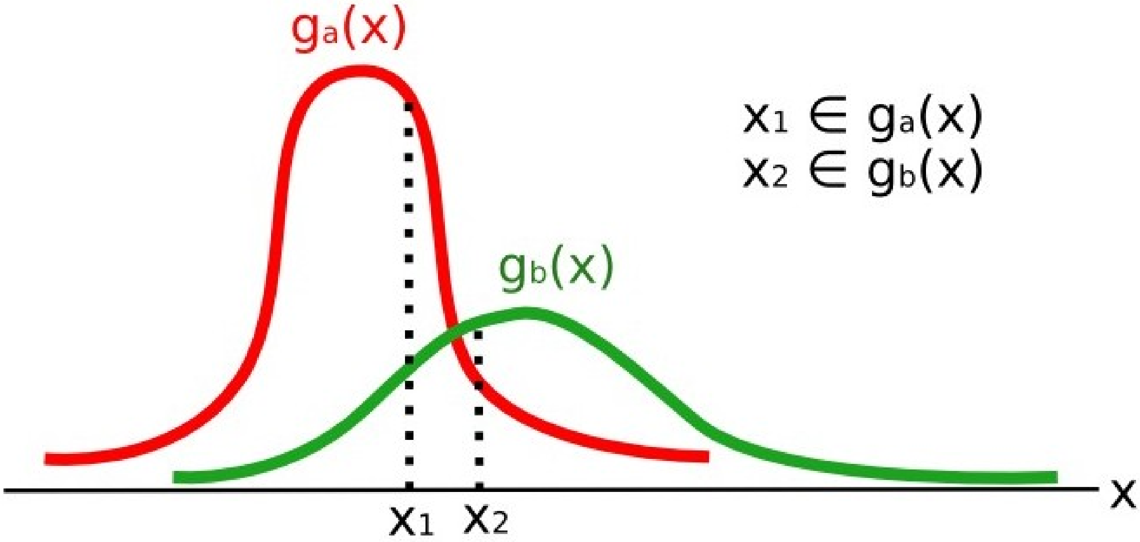


Fig. 15.4: *Maximum Likelihood example*

inoltre, è possibile definire una soglia per la funzione discriminante per escludere pixel sotto di questo valore dalla classificazione. Considerando una soglia T_i la condizione di classificazione diventa:

$$\begin{aligned} x \in C_k \iff g_k(x) > g_j(x) \forall k \neq j \\ and \\ g_k(x) > T_i \end{aligned}$$

Maximum likelihood è una delle classificazioni supervisionate più comuni, ma il processo di classificazione può essere più lento di: ref: *minimum_distance_algorithm*.

Spectral Angle Mapping

L'algoritmo Spectral Angle Mapping calcola l'angolo spettrale tra le firme spettrali dei pixel e le firme spettrali di riferimento. L'angolo spettrale: matematica: *theta* è definita come (Kruse et al., 1993):

$$\theta(x, y) = \cos^{-1}\left(\frac{\sum_{i=1}^{n} x_i y_i}{\left(\sum_{i=1}^{n} x_i^2\right)^{\frac{1}{2}} * \left(\sum_{i=1}^{n} y_i^2\right)^{\frac{1}{2}}}\right)$$

Dove:

- x = firma spettrale vettoriale di un pixel dell immagine;
- y = firma spettrale vettoriale della training area;
- n = numero di bande nell immagine.

Perciò un pixel appartiene alla classe avente l'angolo più piccolo, cioè:

$$x \in C_k \iff \theta(x, y_k) < \theta(x, y_j) \forall k \neq j$$

where:

- C_k = land cover class k;
- y_k = firma spettrale della classe k;
- y_j = firma spettrale della classe j.

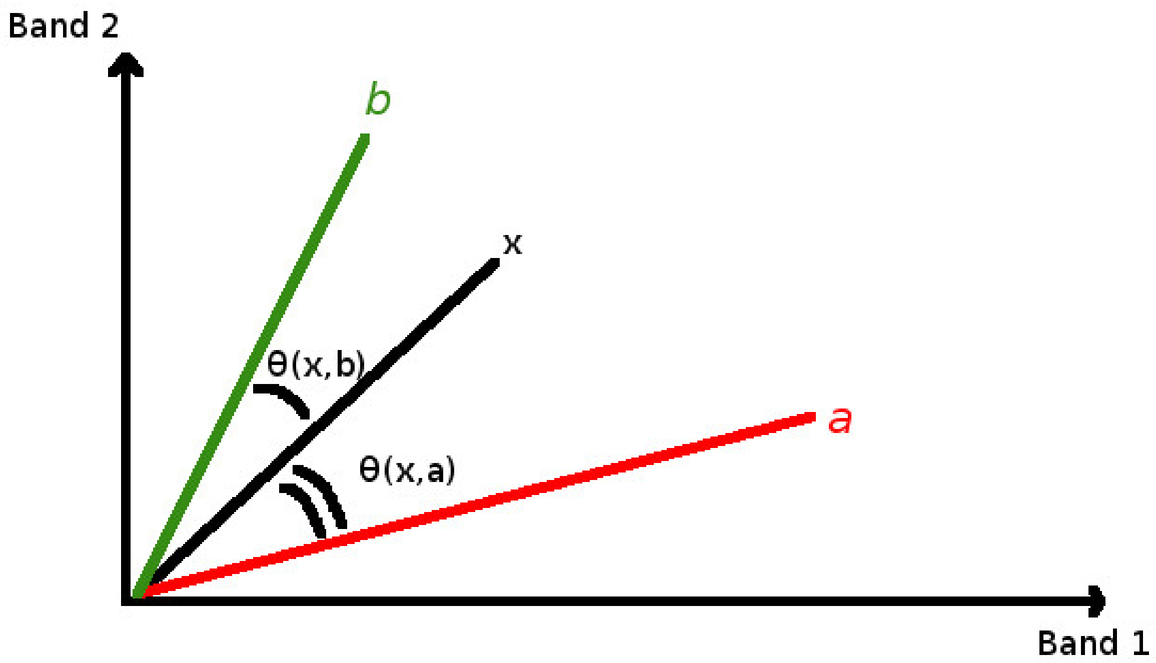


Fig. 15.5: *Spectral Angle Mapping example*

Per escludere pixel sotto questo valore dalla classificazione è possibile definire una soglia: matematica: *T_i*:

$$x \in C_k \iff \theta(x, y_k) < \theta(x, y_j) \forall k \neq j$$
$$and$$
$$\theta(x, y_k) < T_i$$

Spectral Angle Mapping è largamente utilizzato, soprattutto con i dati iperspettrali.

Parallelepiped Classification

Parallelepiped classification is an algorithm that considers a range of values for each band, forming a multidimensional parallelepiped that defines a land cover class. A pixel is classified if the values thereof are inside a parallelepiped. One of the major drawbacks is that pixels whose signatures lie in the overlapping area of two or more parallelepipeds cannot be classified (Richards and Jia, 2006).

Land Cover Signature Classification

Land Cover Signature Classification is available in *SCP* (see *Land Cover Signature Classification* (pagina 46)). This classification allows for the definition of spectral thresholds for each training input signature (a minimum value and a maximum value for each band). The thresholds of each training input signature define a spectral region belonging to a certain land cover class.

Spectral signatures of image pixels are compared to the training spectral signatures; a pixel belongs to `class X` if pixel spectral signature is completely contained in the spectral region defined by `class X`. In case of pixels falling inside overlapping regions or outside any spectral region, it is possible to use additional classification algorithms (i.e. *Minimum Distance* (pagina 154), *Maximum Likelihood* (pagina 154), *Spectral Angle Mapping* (pagina 155)) considering the spectral characteristics of the original input signature.

In the following image, a scheme illustrates the *Land Cover Signature Classification* for a simple case of two spectral bands x and y. User defined spectral regions define three classes (g_a, g_b, and g_c). Point p_1 belongs to class g_a and point p_2 belongs to class g_b. However, point p_3 is inside the spectral regions of both classes g_b and g_c (overlapping regions); in this case, point p_3 will be unclassified or classified according to an additional classification algorithm. Point p_4 is outside any spectral region, therefore it will be unclassified or classified according to an additional classification algorithm. Given that point p_4 belongs to class g_c, the spectral region thereof could be extended to include point p_4 .

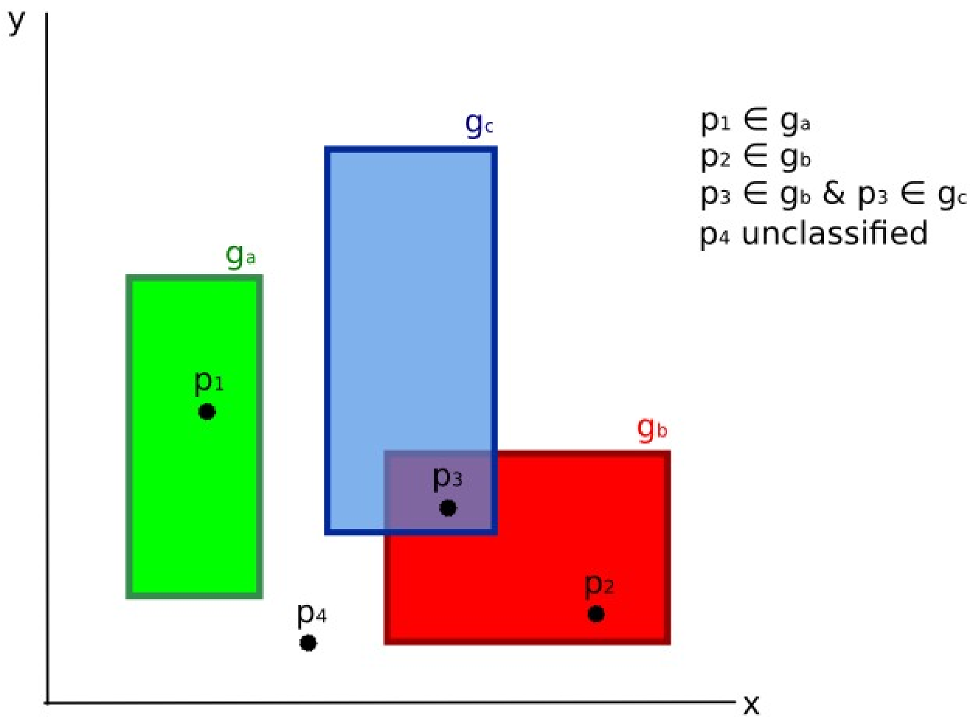


Fig. 15.6: *Land cover signature classification*

This is similar to *Parallelepiped Classification* (pagina 156), with the exception that spectral regions are defined by user, and can be assigned independently for the upper and lower bounds. One can imagine spectral regions as the set of all the spectral signatures of pixels belonging to one class.

In figure *Plot of spectral ranges* (pagina 158) the spectral ranges of three classes (g_a, g_b, and g_c) are displayed; the colored lines inside the ranges (i.e. semi-transparent area) represent the spectral signatures of pixels that defined the upper and lower bounds of the respective ranges. Pixel p_1 (dotted line) belongs to class g_b because the spectral signature thereof is completely inside the range of class g_b (in the upper limit); pixel p_2 (dashed line) is unclassified because the spectral signature does not fall completely inside any range; pixel p_3 (dotted line) belongs to class g_a.

It is worth noticing that these spectral thresholds can be applied to any spectral signature, regardless of spectral characteristics thereof; this function can be very useful for separating similar spectral signatures that differ only in one band, defining thresholds that include or exclude specific signatures. In fact, classes are correctly separated if the spectral ranges thereof are not overlapping at least in one band. Of course, even if spectral regions are overlapping, chances are that no pixel will fall inside the overlapping region and be misclassified; which is the

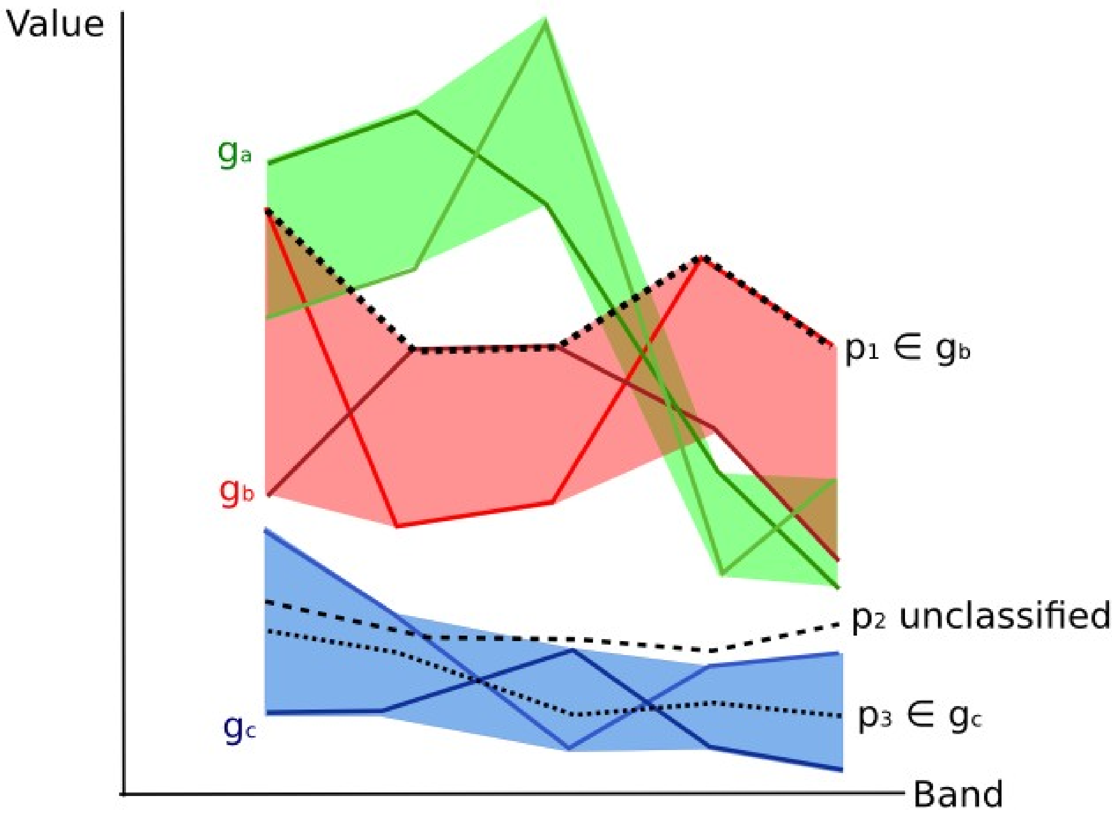


Fig. 15.7: *Plot of spectral ranges*

upper (or lower) bound of a range do not imply the existence, in the image, of any spectral signature having the maximum (or minimum) range values for all the bands (for instance pixel p_1 of figure *Plot of spectral ranges* (pagina 158) could not exist).

One of the main benefit of the *Land Cover Signature Classification* is that it is possible to select pixels and and include the signature thereof in a spectral range; therefore, the classification should be the direct representation of the class expected for every spectral signature. This is very suitable for the classification of a single land cover class (defined by specific spectral thresholds), and leave unclassified the rest of the image that is of no interest for the purpose of the classification.

Algorithm raster

An algorithm raster represents the "distance" (according to the definition of the classification algorithm) of an image pixel to a specific spectral signature.

In general, an algorithm raster is produced for every spectral signature used as training input. The value of every pixel is the result of the algorithm calculation for a specific spectral signature. Therefore, a pixel belongs to `class X` if the value of the algorithm raster corresponding to `class X` is the lowest in case of *Minimum Distance* (pagina 154) or *Spectral Angle Mapping* (pagina 155) (or highest in case of *Maximum Likelihood* (pagina 154)).

Given a classification, a combination of algorithm rasters can be produced, in order to create a raster with the lowest "distances" (i.e. pixels have the value of the algorithm raster corresponding to the class they belong in the classification). Therefore, this raster can be useful to identify pixels that require the collection of more similar spectral signatures (see *Classification preview* (pagina 35)).

Spectral Distance

It is useful to evaluate the spectral distance (or separability) between training signatures or pixels, in order to assess if different classes that are too similar could cause classification errors. The *SCP* implements the following algorithms for assessing similarity of spectral signatures.

Jeffries-Matusita Distance

Jeffries-Matusita Distance calcola la separabilità di un paio di distribuzioni di probabilità. Questo può essere particolarmente significativo per valutare i risultati di: ref: *classificazioni max_likelihood_algorithm*.

Il Jeffries-Matusita Distance: matematica: *J_ {xy}* viene calcolato come (Richards e Jia, 2006):

$$J_{xy} = 2\left(1 - e^{-B}\right)$$

where:

$$B = \frac{1}{8}(x-y)^t\left(\frac{\Sigma_x + \Sigma_y}{2}\right)^{-1}(x-y) + \frac{1}{2}\ln\left(\frac{|\frac{\Sigma_x+\Sigma_y}{2}|}{|\Sigma_x|^{\frac{1}{2}}|\Sigma_y|^{\frac{1}{2}}}\right)$$

where:

- x = prima firma spettrale;
- y = second firma spettrale;
- Σ_x =matrice di covarianza x;
- Σ_y = matrice di covarianza y;

Il Jeffries-Matusita Distance tende a 2 quando le firme sono completamente diverse, e tende a 0 quando le firme sono identiche.

Spectral Angle

The Spectral Angle è il più appropriato per valutare l'algoritmo: ref: *algoritmo spectra_angle_mapping_algorithm*. Il spettrale angolo di: matematica: *theta* è definita come (Kruse et al., 1993):

$$\theta(x,y) = \cos^{-1}\left(\frac{\sum_{i=1}^{n} x_i y_i}{\left(\sum_{i=1}^{n} x_i^2\right)^{\frac{1}{2}} * \left(\sum_{i=1}^{n} y_i^2\right)^{\frac{1}{2}}}\right)$$

Dove:

- x = firma spettrale vettoriale di un pixel dell immagine;
- y = firma spettrale vettoriale della training area;
- n = numero di bande nell immagine.

Lo Spectral angle varia da 0 quando le firme sono identiche a 90 quando le firme sono completamente differenti.

Distanza euclidea

La distanza euclidea è particolarmente utile per la valutazione del risultato di classificazione: ref: *minimum_distance_algorithm*. Infatti, la distanza è definita come:

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

where:

- x = prima firma spettrale;
- y = second firma spettrale;
- n = numero di bande nell immagine.

La distanza euclidea è 0 quando le firme sono identiche e tende ad aumentare con la distanza spettrale tra le firme.

Bray-Curtis Similarity

Bray-Curtis Similarity è una statistica usata per valutare la relazione tra due campioni (*leggere questo <http://en.wikipedia.org/wiki/Bray%E2%80%93Curtis_dissimilarity>* _). E' utile, in generale, per valutare la somiglianza delle firme spettrali, e Bray-Curtis Similarity: matematica: *S (x, y)* viene calcolato come:

$$S(x, y) = 100 - \left(\frac{\sum_{i=1}^{n} |(x_i - y_i)|}{\sum_{i=1}^{n} x_i + \sum_{i=1}^{n} y_i} \right) * 100$$

where:

- x = prima firma spettrale;
- y = second firma spettrale;
- n = numero di bande nell immagine.

Bray-Curtis Similarity viene calcolata come percentuale e varia da 0 quando firme sono completamente diverse a 100 quando le firme spettrali sono identiche.

Risultato di Classificazione

Il risultato del processo di classificazione è un raster (vedere un esempio di classificazione Landsat in figura: ref: *figLC*), dove i valori dei pixel corrispondono all'ID della classe e ogni colore rappresenta una classe di copertura del suolo.

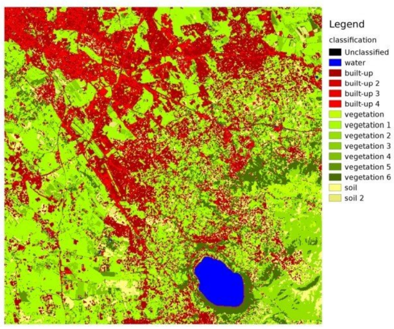


Fig. 15.8: *Landsat classification*

`I dati disponibili da U.S. Geological Survey`

Una certa quantità di errori si può verificare nella classificazione della copertura del suolo (ad esempio alcuni pixel possono essere assegnati a una classe di copertura suolo sbagliata), a causa della somiglianza spettrale tra le classi, o per una definizione sbagliata della classe durante la raccolta ROI.

Valutazione dell'Accuratezza

Dopo il processo di classificazione, è utile valutare la precisione della classificazione copertura del suolo, al fine di identificare e misurare l'errore della mappa risultante. Solitamente, la **valutazione dell'accuratezza** è effettuata con il calcolo di una matrice di errore, che è una tabella che mette a confronto i dati di mappa con i dati di riferimento (ad esempio dati di verità a terra) per un certo numero di aree campione (Congalton e Green, 2009).

La seguente tabella è una matrice degli errori, dove k è il numero di classi identificate nella classificazione copertura del suolo, ed n è il numero totale di unità di campionamento raccolte. Le voci nella diagonale (aii) sono il numero di elementi correttamente classificati, mentre gli altri elementi sono errori di classificazione.

Scheme of Error Matrix

	Ground truth 1	Ground truth 2	...	Ground truth k	Total
Class 1	a_{11}	a_{12}	...	a_{1k}	a_{1+}
Class 2	a_{21}	a_{22}	...	a_{2k}	a_{2+}
...	...	...	...	...	...
Class k	a_{k1}	a_{k2}	...	a_{kk}	a_{k+}
Total	a_{+1}	a_{+2}	...	a_{+k}	n

Pertanto, è possibile calcolare la precisione complessiva come rapporto tra il numero di campioni correttamente classificate (la somma della diagonale maggiore), e il numero totale di unità di campionamento n (Congalton e Green, 2009).

Per ulteriori informazioni, sono disponibili liberamente i seguenti documenti: Landsat 7 Science Data User's Handbook, Remote Sensing Note , or Wikipedia.

CAPITOLO 16

Image conversion to reflectance

This chapter provides information about the conversion to reflectance implemented in *SCP*.

Radianza al Sensore

Radianzaè il "flusso di energia (principalmente irradiante o energia incidente) per angolo solido emesso da una superficie unitaria in una data direzione", "Radiance è ciò che viene misurato sul sensore ed è in qualche modo dipendente dalla riflettanza" (NASA, 2011, p. 47).

Images such as Landsat or Sentinel-2 are composed of several bands and a metadata file which contains information required for the conversion to reflectance.

Landsat images are provided in radiance, scaled prior to output. for Landsat images **Spectral Radiance at the sensor's aperture** (L_λ, measured in [watts/(meter squared * ster * μm)]) is given by (https://landsat.usgs.gov/Landsat8_Using_Product.php):

$$L_\lambda = M_L * Q_{cal} + A_L$$

where:

- M_L = fattore moltiplicativo Banda-specifico dai metadati Landsat (RADIANCE_MULT_BAND_x, dove x è il numero di banda)
- A_L = fattore additivo Banda-specifico dai metadati Landsat (RADIANCE_ADD_BAND_x, dove x è il numero della banda)
- Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Sentinel-2 images (Level-1C) are already provided in *Top Of Atmosphere (TOA) Reflectance* (pagina 163), scaled prior to output (ESA, 2015).

Top Of Atmosphere (TOA) Reflectance

Images in radiance can be converted to Top Of Atmosphere (TOA) Reflectance (combined surface and atmospheric reflectance) in order to reduce the in between-scene variability through a normalization for solar irradiance. This

TOA reflectance (ρ_p), which is the unitless ratio of reflected versus total power energy (NASA, 2011), is calculated by:

$$\rho_p = (\pi * L_\lambda * d^2)/(ESUN_\lambda * cos\theta_s)$$

where:

- L_λ = Radianza spettrale al sensore (at-satellite radiance)
- d = Earth-Sun distance in astronomical units (provided with Landsat 8 metadata file, and an excel file is available from http://landsathandbook.gsfc.nasa.gov/excel_docs/d.xls)
- $ESUN_\lambda$ =Media della irradianza exo-atmosferica
- θ_s = Angolo zenitale solare in gradi, che è uguale a θ_s = 90° - θ_e dove θ_e is the Sun elevation

It is worth pointing out that Landsat 8 images are provided with band-specific rescaling factors that allow for the direct conversion from DN to TOA reflectance.

Sentinel-2 images are already provided in scaled TOA reflectance, which can be converted to TOA reflectance with a simple calculation using the Quantification Value provided in the metadata (see https://sentinel.esa.int/documents/247904/349490/S2_MSI_Product_Specification.pdf).

Surface Reflectance

The effects of the atmosphere (i.e. a disturbance on the reflectance that varies with the wavelength) should be considered in order to measure the reflectance at the ground.

Come descritto da Moran et al. (1992), the **riflettanza della superfice terrestre** (ρ) is:

$$\rho = [\pi * (L_\lambda - L_p) * d^2]/[T_v * ((ESUN_\lambda * cos\theta_s * T_z) + E_{down})]$$

where:

- L_p è la radinaza diffusa
- T_v è la trasmittanza atmosferica nella direzione di osservazione
- T_z è la trasmittanza atmosferica nella direzione di illuminazione
- E_{down} is the downwelling diffuse irradiance

Therefore, we need several atmospheric measurements in order to calculate ρ (physically-based corrections). Alternatively, it is possible to use **image-based techniques** for the calculation of these parameters, without in-situ measurements during image acquisition. It is worth mentioning that **Landsat Surface Reflectance High Level Data Products** for Landsat 8 are available (for more information read http://landsat.usgs.gov/CDR_LSR.php).

Correzione DOS1

The **Dark Object Subtraction** (DOS) è una famiglia di correzioni atmosferiche basati su immagini. Chavez (1996) spiega che "l'assunto di base è che nell'immagine alcuni pixel sono in completa ombra e loro radianza ricevuta satellite è dovuta a dispersione atmosferica (path radiance). Questa ipotesi è combinato con il fatto che pochissimi obiettivi sulla la superficie terrestre sono il nero assoluto, così l'ipotesi di uno percento come riflettanza minima è meglio di zero". vale la pena di sottolineare che la precisione delle tecniche di image-based è in genere inferiore a correzioni basate fisicamente, ma sono molto utili quando misurazioni atmosferiche non sono disponibili e possono migliorare la stima di riflettanza della superficie terrestre The **path radiance** è data da (Sobrino, et al., 2004):

$$L_p = L_{min} - L_{DO1\%}$$

where:

- :
- $L_{DO1\%}$ = radianza del Dark Object, assunto avere riflettanza 0.01

In particular for Landsat images:

$$L_{min} = M_L * DN_{min} + A_L$$

Sentinel-2 images are converted to radiance prior to DOS1 calculation.

La**radianza del Dark Object** è data da (Sobrino, et al., 2004):

$$L_{DO1\%} = 0.01 * [(ESUN_\lambda * cos\theta_s * T_z) + E_{down}] * T_v/(\pi * d^2)$$

Pertanto la **radianza diffusa** è:

$$L_p = M_L * DN_{min} + A_L - 0.01 * [(ESUN_\lambda * cos\theta_s * T_z) + E_{down}] * T_v/(\pi * d^2)$$

Esistono varie tecniche DOS (e.g. DOS1, DOS2, DOS3, DOS4), basate su differenti assunzioni: math:*T_{v}*, T_z , and E_{down} . La tecnica più semplice è il **DOS1**, dove sono fatte le seguenti ipotesi (Moran et al., 1992):

- T_v = 1
- T_z = 1
- E_{down} = 0

Pertanto la **radianza diffusa** è:

$$L_p = M_L * DN_{min} + A_L - 0.01 * ESUN_\lambda * cos\theta_s/(\pi * d^2)$$

E la risultante **riflettanza superficiale terrestre** è data da:

$$\rho = [\pi * (L_\lambda - L_p) * d^2]/(ESUN_\lambda * cos\theta_s)$$

ESUN [W /(m2 * μm)] i valori per Landsat sono forniti dalla seguente tabella.

ESUN values for Landsat bands

Banda	Landsat 1 MSS*	Landsat 2 MSS*	Landsat 3 MSS*	Landsat 4 TM*	Landsat 5 TM*	Landsat 7 ETM+**
1				1983	1983	1970
2				1795	1796	1842
3				1539	1536	1547
4	1823	1829	1839	1028	1031	1044
5	1559	1539	1555	219.8	220	225.7
6	1276	1268	1291			
7	880.1	886.6	887.9	83.49	83.44	82.06
8						1369

* from Chander, Markham, & Helder (2009)

** from http://landsathandbook.gsfc.nasa.gov/data_prod/prog_sect11_3.html

For **Landsat 8**, $ESUN$ can be calculated as (from http://grass.osgeo.org/grass65/manuals/i.landsat.toar.html):

$$ESUN = (\pi * d^2) * RADIANCE\_MAXIMUM/REFLECTANCE\_MAXIMUM$$

dove RADIANCE_MAXIMUM e REFLECTANCE_MAXIMUM sono forniti.

ESUN [W /(m2 * μm)] values for **Sentinel-2** sensor (provided in image metadata) are illustrated in the following table.

ESUN values for Sentinel-2 bands

Banda	Sentinel-2
1	1913.57
2	1941.63
3	1822.61
4	1512.79
5	1425.56
6	1288.32
7	1163.19
8	1036.39
8A	955.19
9	813.04
10	367.15
11	245.59
12	85.25

ESUN [W /(m2 * μm)] values for **ASTER** sensor are illustrated in the following table (from Finn, et al., 2012).

ESUN values for ASTER bands

Banda	ASTER
1	1848
2	1549
3	1114
4	225.4
5	86.63
6	81.85
7	74.85
8	66.49
9	59.85

Un esempio di confronto tra riflettanza TOA, riflettanza corretta con DOS1 e una Landsat Surface Reflectance High Level Data Products (ground truth) in Figure *Firme spettrali di un pixel di costruito* (pagina 166).

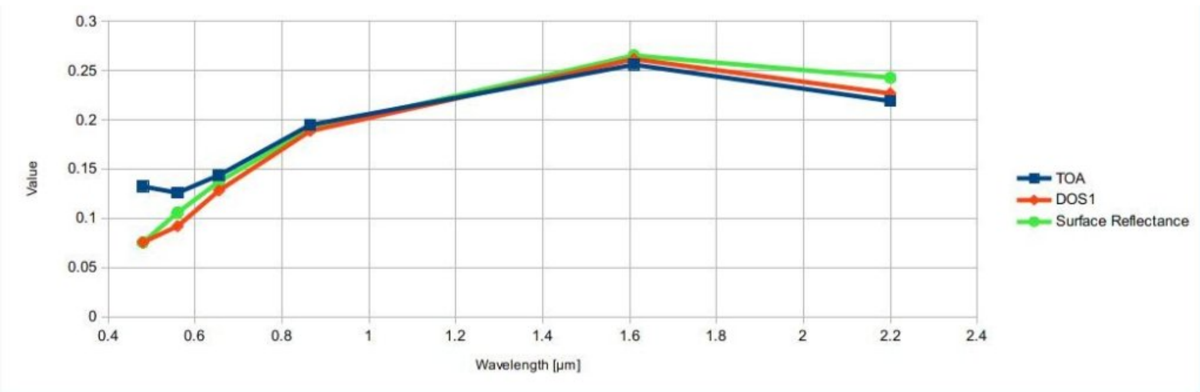


Fig. 16.1: *Firme spettrali di un pixel di costruito*

`confronto tra riflettanza TOA, riflettanza corretta con DOS1 e Landsat Surface Reflectance High Level Data Products`

CAPITOLO 17

Conversion to Temperature

This chapter provides the basic information about the conversion to **At-Satellite Brightness Temperature** implemented in *SCP* and the estimation of **Land Surface Temperature**.

Conversione At-Satellite Brightness Temperature

For thermal bands, the conversion of DN to At-Satellite Brightness Temperature is given by (from https://landsat.usgs.gov/Landsat8_Using_Product.php):

$$T_B = K_2 / ln[(K_1/L_\lambda) + 1]$$

where:

- K_1 = Banda-specifica costante di conversione termica (in watts/meter squared * ster * μm)
- K_2 = Banda-specifica costante di conversione termica (in kelvin)

and L_λ is the Spectral Radiance at the sensor's aperture, measured in watts/(meter squared * ster * μm).

The K_1 and K_2 constants for Landsat sensors are provided in the following table.

Thermal Conversion Constants for Landsat

Costante	Landsat 4*	Landsat 5*	Landsat 7**
K_1	671.62	607.76	666.09
K_2	1284.30	1260.56	1282.71

* from Chander & Markham (2003)

** from NASA (2011)

For **Landsat 8**, the K_1 and K_2 values are provided in the image metadata file.

K_1 and K_2 are calculated as (Jimenez-Munoz & Sobrino, 2010):

$$K_1 = c_1/\lambda^5$$

$$K_2 = c_2/\lambda$$

where (Mohr, Newell, & Taylor, 2015):

- c_1 = first radiation constant = $1.191 * 10^{-16} W m^2 sr^{-1}$

- c_2 = second radiation constant = $1.4388 * 10^{-2} mK$

Therefore, for ASTER bands K_1 and K_2 are provided in the following table.

Thermal Conversion Constants for ASTER

Costante	Band 10	Band 11	Band 12	Band 13	Band 14
K_1	$3.024 * 10^3$	$2.460 * 10^3$	$1.909 * 10^3$	$8.900 * 10^2$	$6.464 * 10^2$
K_2	$1.733 * 10^3$	$1.663 * 10^3$	$1.581 * 10^3$	$1.357 * 10^3$	$1.273 * 10^3$

Estimation of Land Surface Temperature

Several studies have described the estimation of Land Surface Temperature. Land Surface Temperature can be calculated from At-Satellite Brightness Temperature T_B as (Weng, et al. 2004):

$$T = T_B/[1 + (\lambda * T_B/c_2) * ln(e)]$$

where:

- λ = wavelength of emitted radiance
- $c_2 = h * c/s = 1.4388 * 10^{-2}$ m K
- h = Planck's constant = $6.626 * 10^{-34}$ J s
- s = Boltzmann constant = $1.38 * 10^{-23}$ J/K
- c = velocity of light = $2.998 * 10^8$ m/s

The values of λ for the thermal bands of Landsat and ASTER satellites can be calculated from the tables in *Satellite Landsat* (pagina 143) and *ASTER Satellite* (pagina 145).

Several studies used NDVI for the estimation of land surface emissivity (Sobrino, et al., 2004); other studies used a land cover classification for the definition of the land surface emissivity of each class (Weng, et al. 2004). For instance, the emissivity (e) values of various land cover types are provided in the following table (from Mallick, et al. 2012).

Emissivity values

Land surface	Emissivity e
Soil	0.928
Erba	0.982
Asphalt	0.942
Concrete	0.937

CAPITOLO 18

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Parte V

Tutorials di Base

The following are very basic tutorials for land cover classification using the Semi-Automatic Classification Plugin (*SCP*). It is assumed that you have a basic knowledge of QGIS (you can find a guide to QGIS interface at this page).

CAPITOLO 19

Tutorial 1

The following is very basic tutorials for land cover classification using the Semi-Automatic Classification Plugin (*SCP*). It is assumed that you have a basic knowledge of QGIS.

Tutorial 1: Your First Land Cover Classification

This is a basic tutorial about the use of *SCP* for the classification of a multi-spectral image. It is recommended to read the *Breve Introduzione al Telerilevamento (Remote Sensing)* (pagina 139) before this tutorial.

The purpose of the classification is to identify the following land cover classes:

1. Water;
2. Built-up;
3. Vegetation;
4. Bare soil.

Following the video of this tutorial.

http://www.youtube.com/watch?v=GFrDgQ6Nzqs

Data

Download the image from this archive (data available from the U.S. Geological Survey) and **unzip** the downloaded file.

The downloaded file is actually a *Satellite Landsat* (pagina 143) image (pan-sharpened) including the following bands:

1. Blue;
2. Green;
3. Red;
4. Near-Infrared;
5. Short Wavelength Infrared 1;
6. Short Wavelength Infrared 2.

In this tutorial we pretend this dataset is a generic multi-spectral raster in order to focus on the classification process (in the next tutorial we are going to use an image whose bands are single rasters).

Set the Input Image in SCP

Start QGIS. In the *SCP input it* (pagina 38) click the button of the *Input image* (pagina 38), in order to select the file `sample_image.tif`. Once selected, `sample_image.tif` is set as *Input image*, the image is displayed in the map and bands are loaded in the *Band set* (pagina 110).

We can display a *Colore Composito* (pagina 147) of bands: Near-Infrared, Red, and Green: in the *Working toolbar* (pagina 33), click the list *RGB=* and select the item `4-3-2` (corresponding to the band numbers in *Band set* (pagina 110)). You can see that image colors in the map change according to the selected bands, and vegetation is highlighted in red (if the item `3-2-1` was selected, natural colors would be displayed).

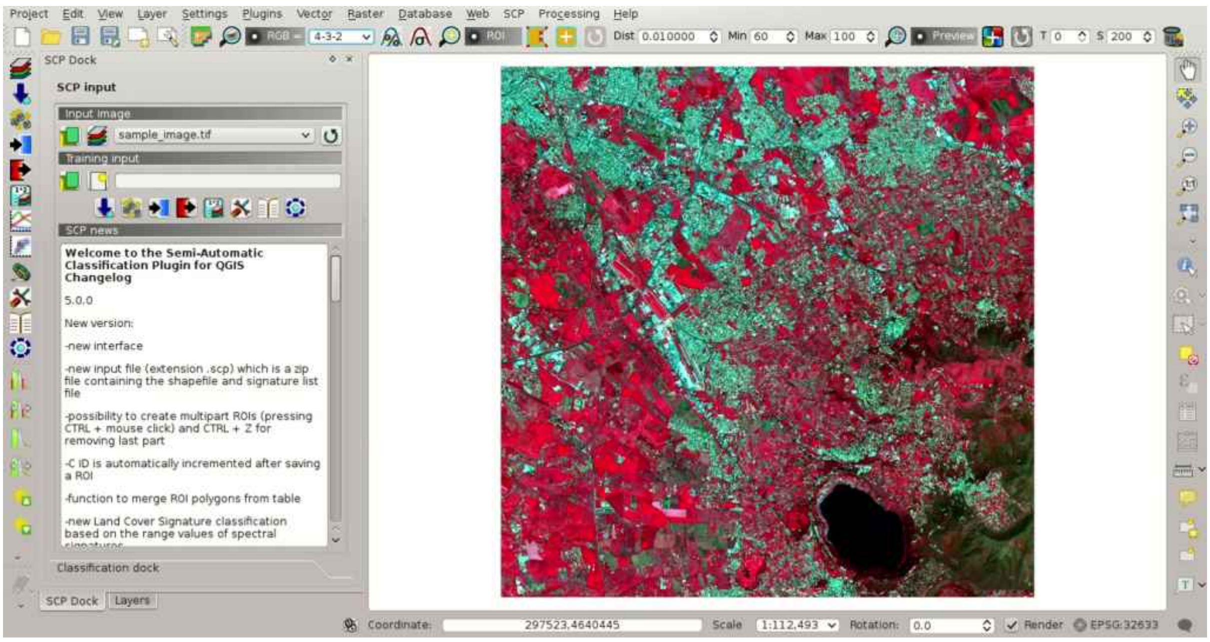


Fig. 19.1: *Color composite RGB=4-3-2*

Create the Training Input File

Now we need to create the *Training input* (pagina 40) in order to collect *Training Areas* (pagina 151) (ROIs) and calculate the *Firma Spettrale* (pagina 143) thereof (which are used in classification).

In the *SCP dock* (pagina 37) click the button and define a name (e.g. `training.scp`) in order to create the *Training input*. The path of the file is displayed in *Training input*. A vector is added to QGIS layers with the same name as the `Training input` (in order to prevent data loss, you should not edit this layer using QGIS functions).

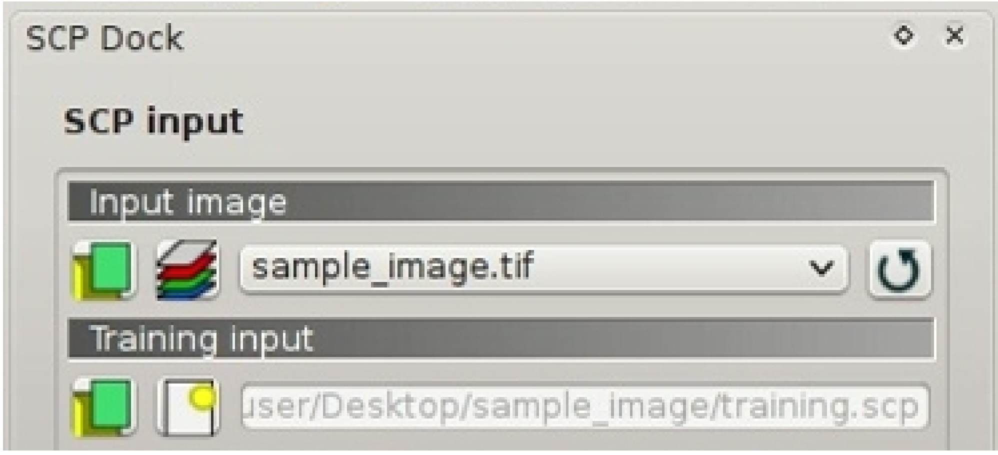


Fig. 19.2: *Definition of Training input in SCP*

Create the ROIs

We are going to create ROIs defining the *Classi e Macroclassi* (pagina 153). Each ROI identifies a land cover class through a Class ID. The Class ID codes used in this tutorial are illustrated in the following table (for now we assign the same code to Class ID and Macroclass ID).

Macroclasses

Class name	Class ID
Water	1
Built-up	2
Vegetation	3
Bare soil	4

ROIs can be created by manually drawing a polygon or with an automatic region growing algorithm.

Zoom in the map over the dark area (it is a lake) in the lower right region of the image. In order to create manually a ROI inside the dark area, click the button in the *Working toolbar* (pagina 33) (you can ignore a message about wavelength unit not provided). Left click on the map to define the ROI vertices and right click to define the last vertex closing the polygon. An orange semi-transparent polygon is displayed over the image, which is a temporary polygon (i.e. it is not saved in the *Training input*).

> **TIP** : You can draw temporary polygons (the previous one will be overridden) until the shape covers the intended area.

If the shape of the temporary polygon is good we can save it to the *Training input*.

Open the *Dock di classificazione* (pagina 40) to define the *Classi e Macroclassi* (pagina 153) . In the *Creazione ROI* (pagina 42) set *MC ID* = 1 and *MC Info* = `Water`; also set *C ID* = 1 and *C Info* = `Lake`. Now click to save the ROI in the *Training input*.

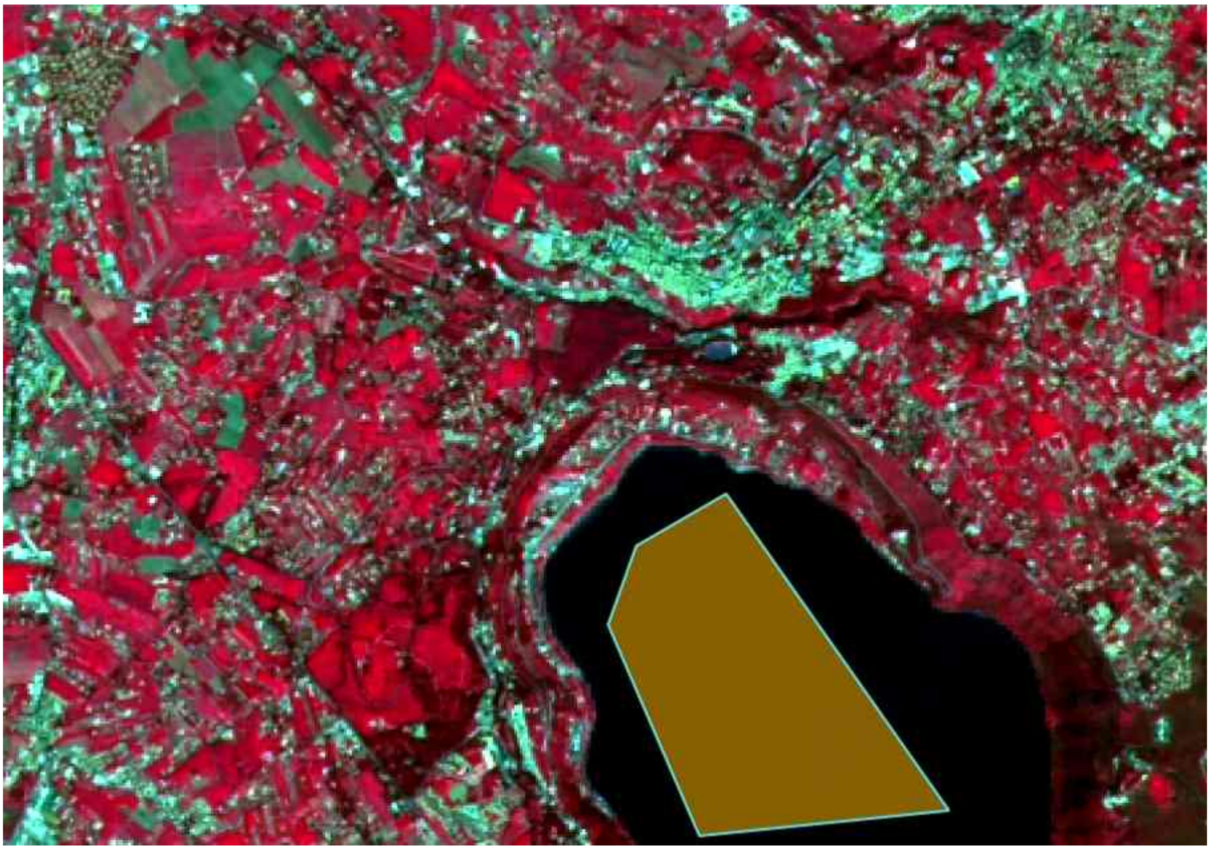


Fig. 19.3: *A temporary ROI created manually*

After a few seconds, the ROI is listed in the *ROI Signature list* (pagina 41) and the spectral signature is calculated (because *Calculate sig.* was checked).

As you can see, the *C ID* in *Creazione ROI* (pagina 42) is automatically increased by 1. Saved ROI is displayed as a dark polygon in the map and the temporary ROI is removed. Also, in the *ROI Signature list* (pagina 41) you can notice that the *Type* is *B*, meaning that the ROI spectral signature was calculated and saved in the *Training input*.

Now we are going to create a second ROI for the built-up class using the automatic region growing algorithm. Zoom in the map over the blue area in the upper left region of the image.

In *Working toolbar* (pagina 33) set the *Dist* value to 0.08 . Click the button in the *Working toolbar* (pagina 33) and click over the blue area of the map. After a while the orange semi-transparent polygon is displayed over the image.

> **TIP** : *Dist* value should be set according to the range of pixel values; in general, increasing this value creates larger ROIs.

In the *Creazione ROI* (pagina 42) set *MC ID* = 2 and *MC Info* = `Built-up` ; also set *C ID* = 2 (it should be already set) and *C Info* = `Buildings`.

Again, the *C ID* in *Creazione ROI* (pagina 42) is automatically increased by 1.

Create a ROI for the class `Vegetation` (red pixels in color composite `RGB=4-3-2`) and a ROI for the class `Bare soil` (green pixels in color composite `RGB=4-3-2`) following the same steps described previously. The following images show a few examples of these classes identified in the map.

The following examples display a few RGB color composites of Landsat images.

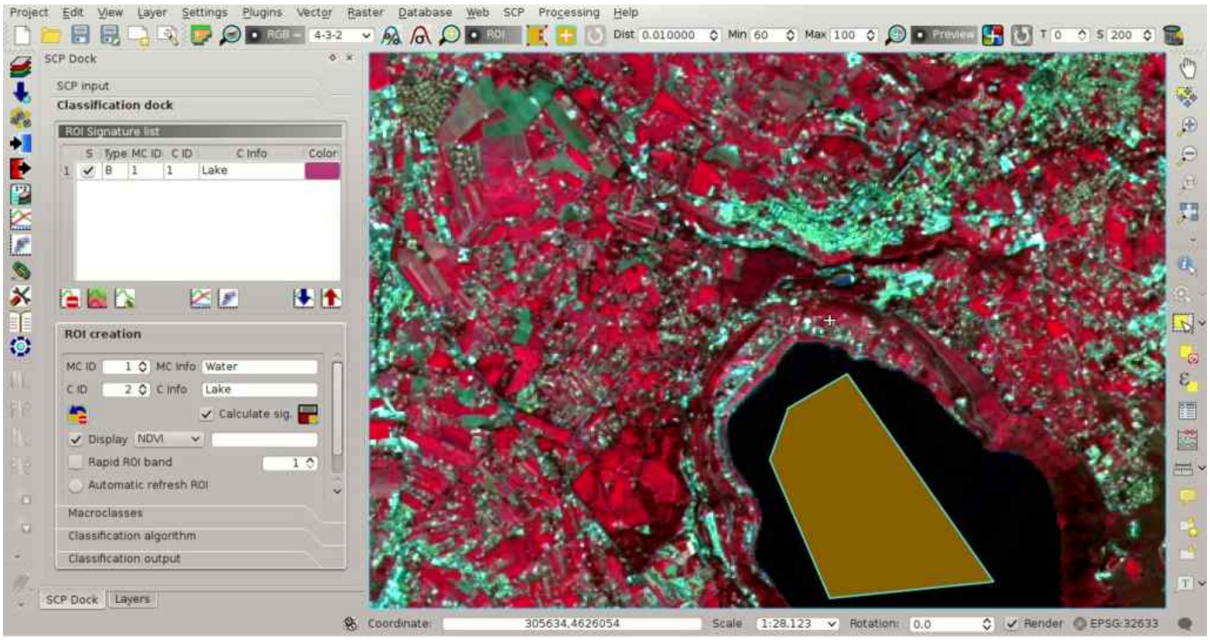


Fig. 19.4: *The ROI saved in the Training input*

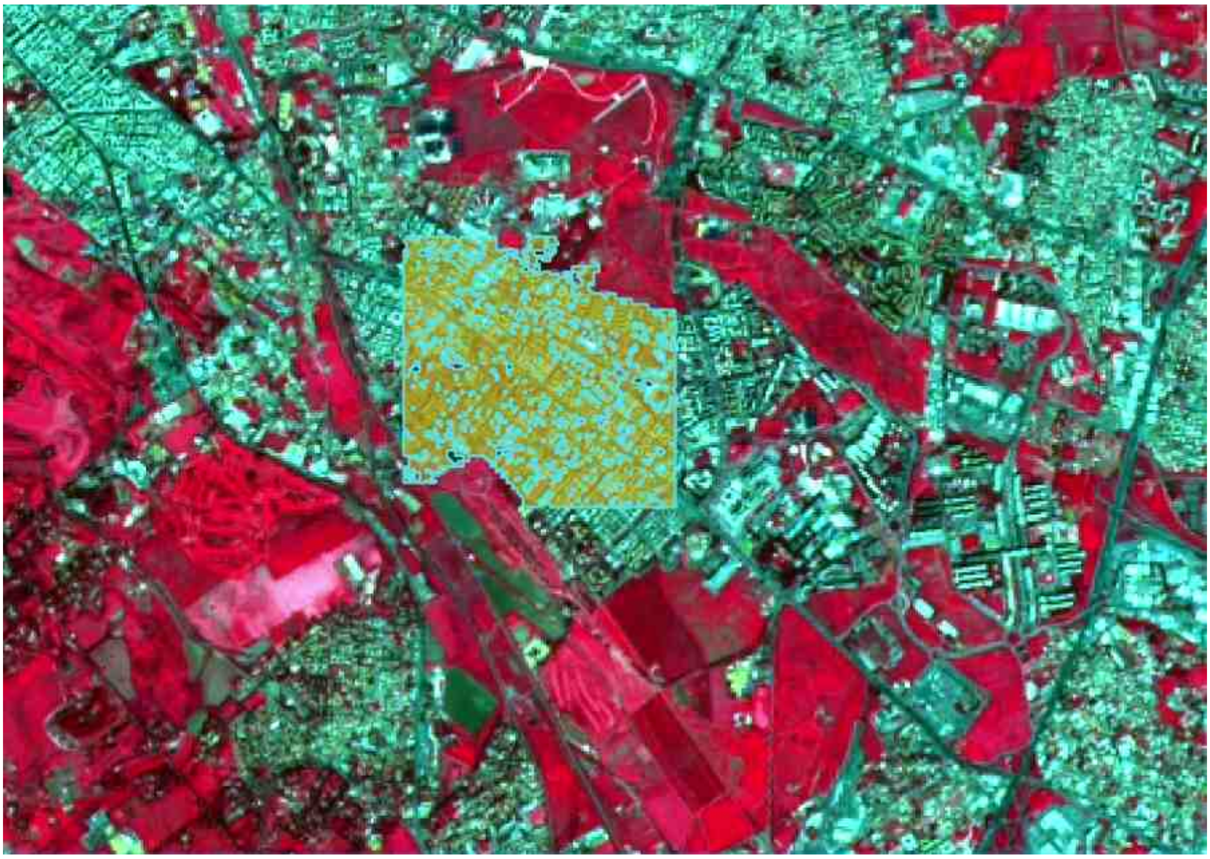


Fig. 19.5: *A temporary ROI created with the automatic region growing algorithm*

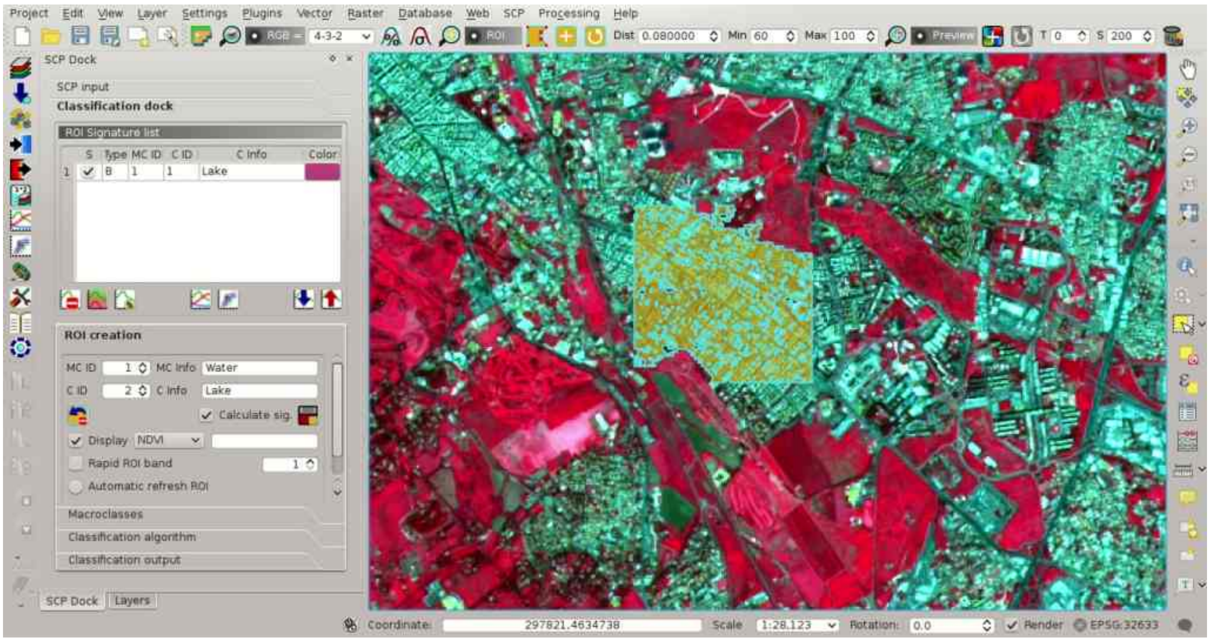


Fig. 19.6: *The ROI saved in the Training input*

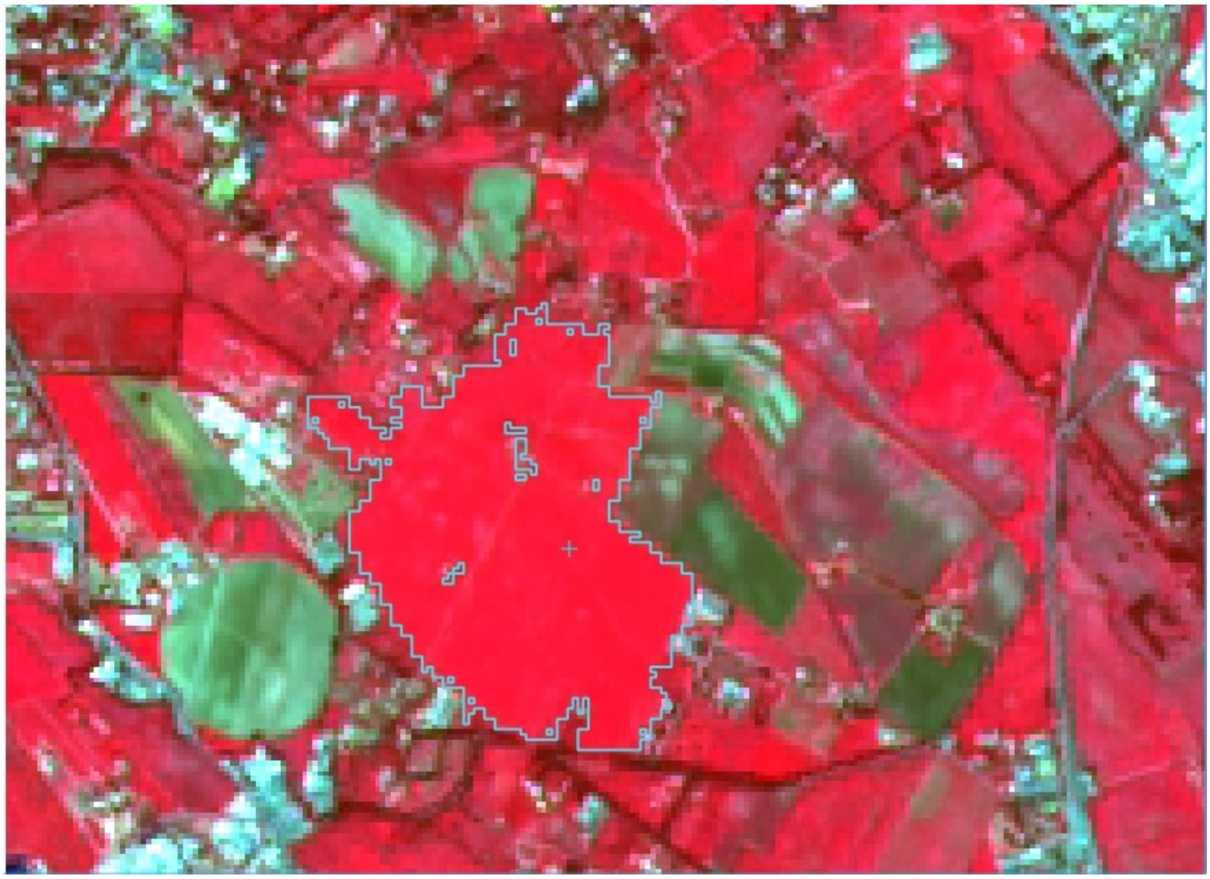


Fig. 19.7: *Vegetation*

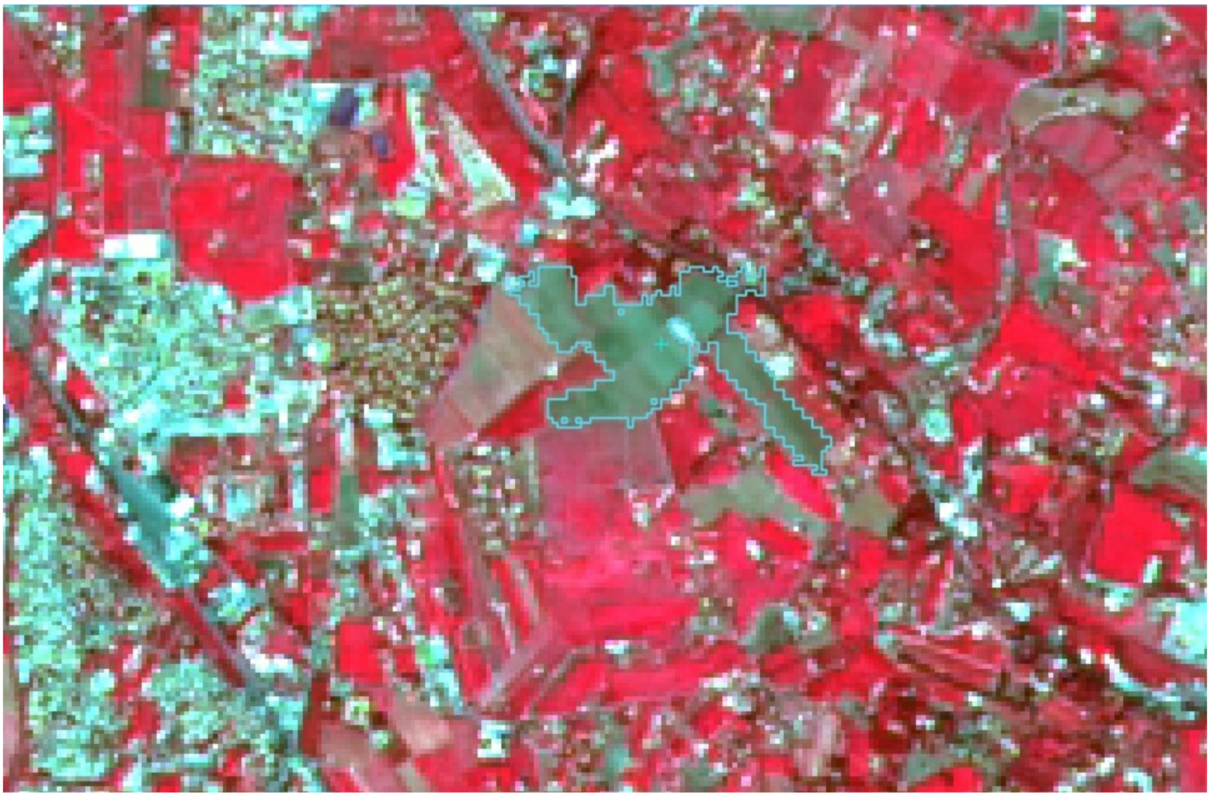


Fig. 19.8: *Bare soil*

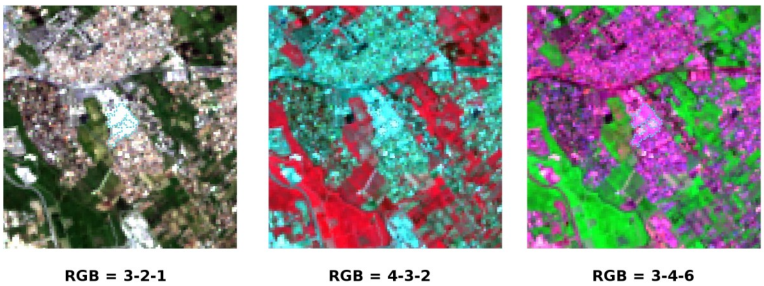


Fig. 19.9: *Built-up ROI: large buildings*

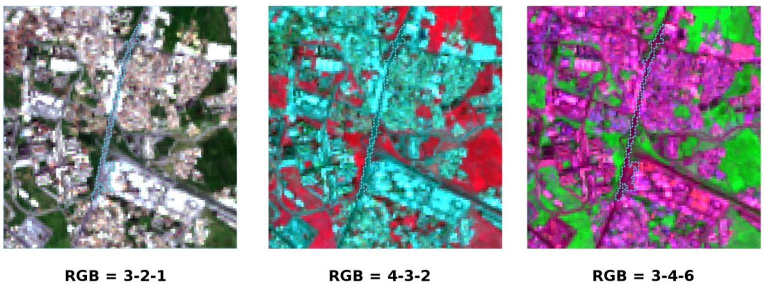


Fig. 19.10: *Built-up ROI: road*

Fig. 19.11: *Built-up ROI: buildings and narrow roads*

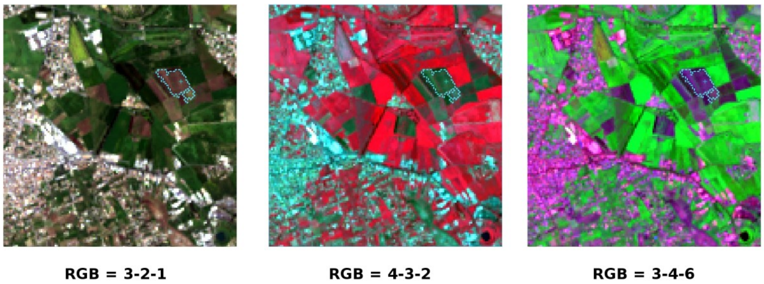


Fig. 19.12: *Bare soil ROI: uncultivated land*

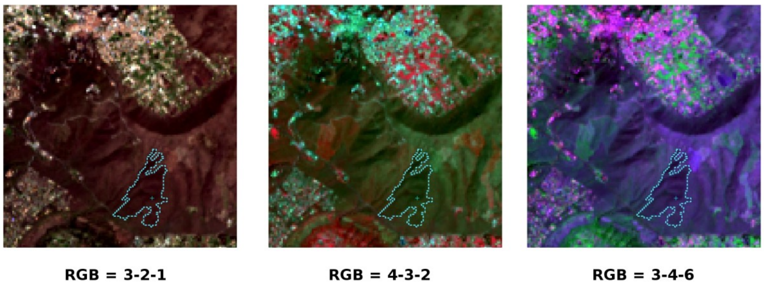


Fig. 19.13: *Vegetation ROI: deciduous trees*

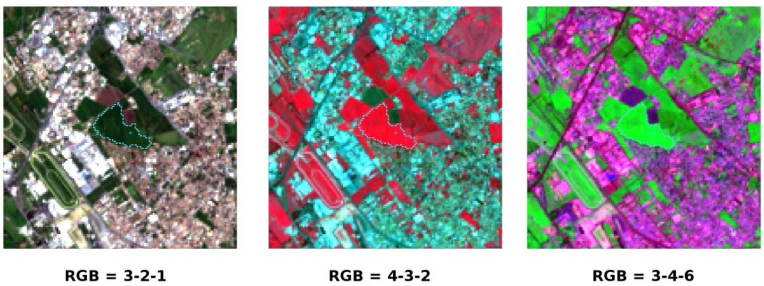


Fig. 19.14: *Vegetation ROI: crop*

Create a Classification Preview

The classification process is based on collected ROIs (and spectral signatures thereof). It is useful to create a *Classification preview* (pagina 35) in order to assess the results (influenced by spectral signatures) before the final classification. In case the results are not good, we can collect more ROIs to better classify land cover.

Before running a classification (or a preview), set the color of land cover classes that will be displayed in the classification raster. In the *ROI Signature list* (pagina 41), double click the color (in the column *Color*) of each ROI to choose a representative color of each class.

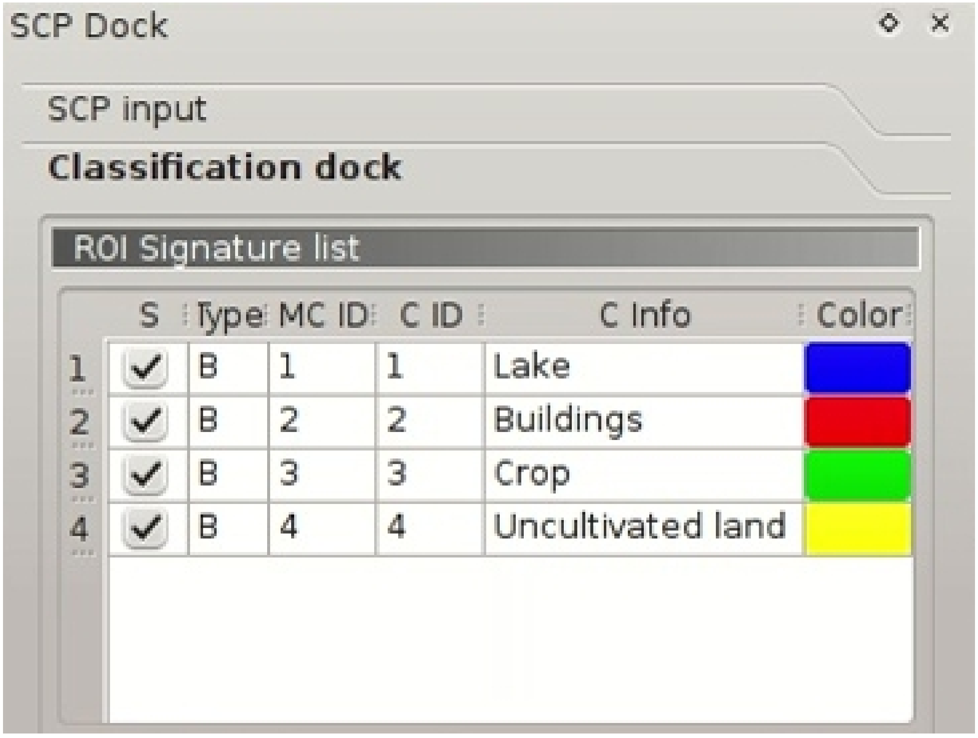


Fig. 19.15: *Definition of class colors*

Now we need to select the classification algorithm. In this tutorial we are going to select the *Spectral Angle Mapping* (pagina 155).

In *Classification algorithm* (pagina 44) select the *Spectral Angle Mapping Algorithm* (pagina 45). In *Classification preview* (pagina 35) set *Size* = 500; click the button  and then left click a point of the image in the map. The classification process should be rapid, and the result is a classified square centered in clicked point.

Previews are temporary rasters (deleted after QGIS is closed) placed in a group named *Class_temp_group* in the QGIS panel Layers.

> **TIP** : When loading a previously saved QGIS project, a message could ask to handle missing layers, which are temporary layers that SCP creates during each session and are deleted afterwards; you can click *Cancel* and ignore these layers.

In general, it is good to perform a classification preview every time a ROI (or a spectral signature) is added to the *ROI Signature list* (pagina 41). Therefore, the phases *Create the ROIs* (pagina 177) and *Create a Classification Preview* (pagina 183) should be iterative and concurrent processes.

Create the Classification Output

Assuming that the results of classification previews were good (i.e. pixels are assigned to the correct class defined in the *ROI Signature list* (pagina 41)), we can perform the actual land cover classification of the whole image.

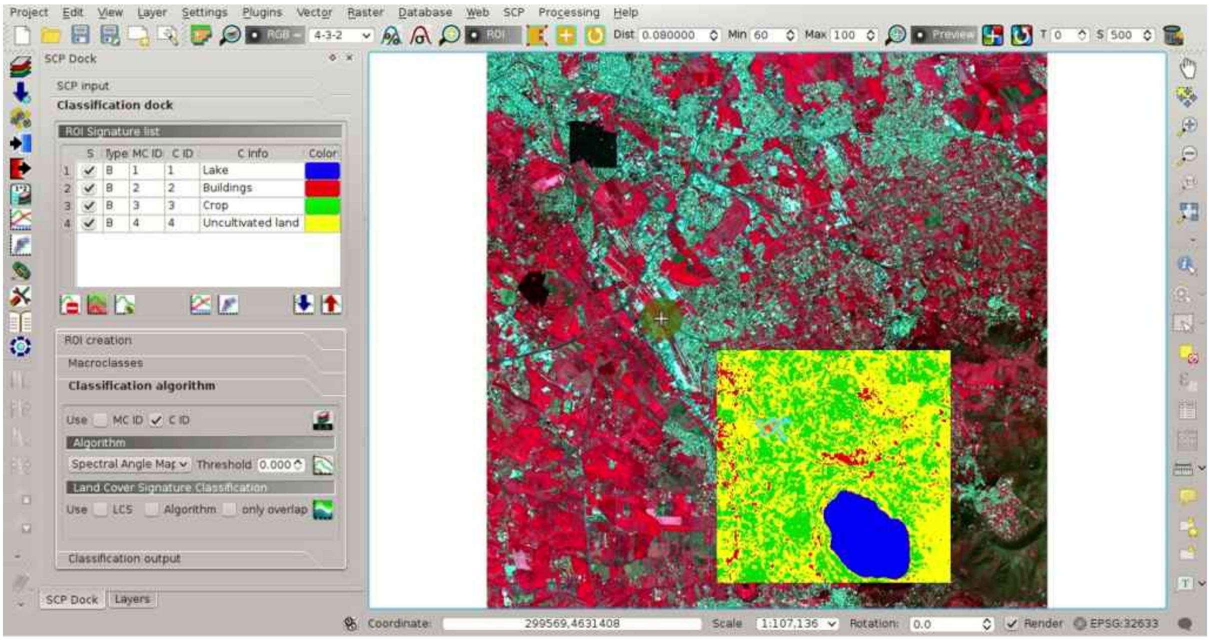


Fig. 19.16: *Classification preview displayed over the image*

In the *Classification output* (pagina 46) click the button  and define the path of the classification output, which is a raster file (.tif). If  *Play sound when finished* is checked in *Classification process* (pagina 118) settings, a sound is played when the process is finished.

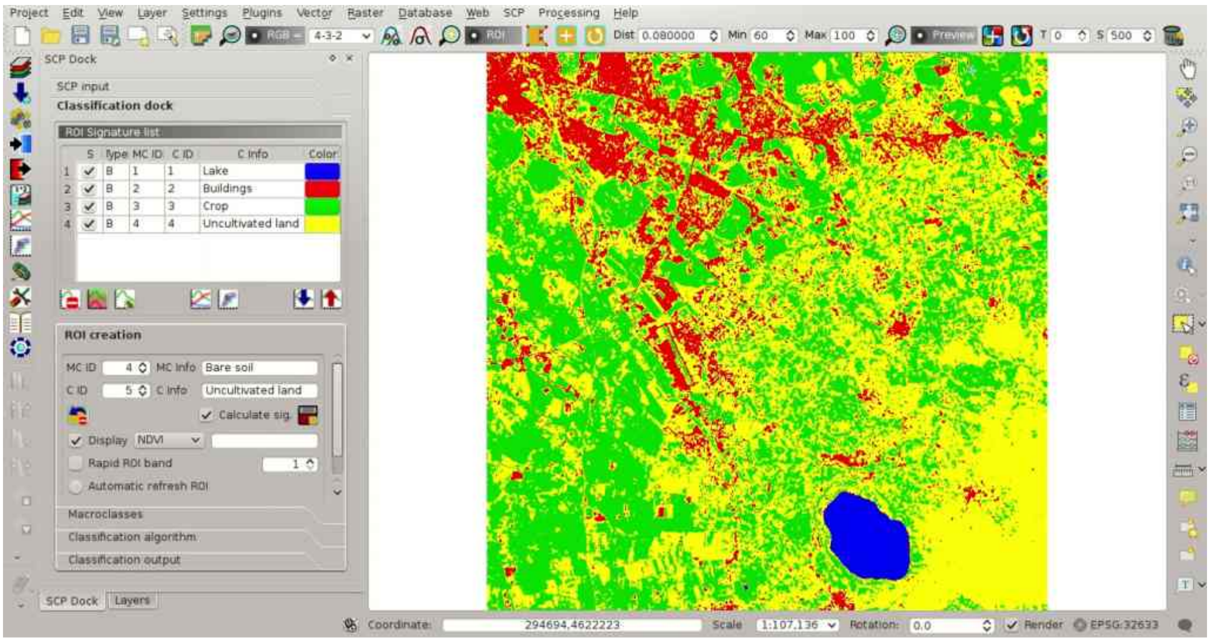


Fig. 19.17: *Result of the land cover classification*

Well done! You have just performed your first land cover classification.

Water and vegetation are correctly identified. However, you can see that there are several classification errors (especially soil classified as built-up and vice versa), because the number of ROIs (spectral signatures) is insufficient.

We can improve the classification using some of the tools described in the next tutorial.

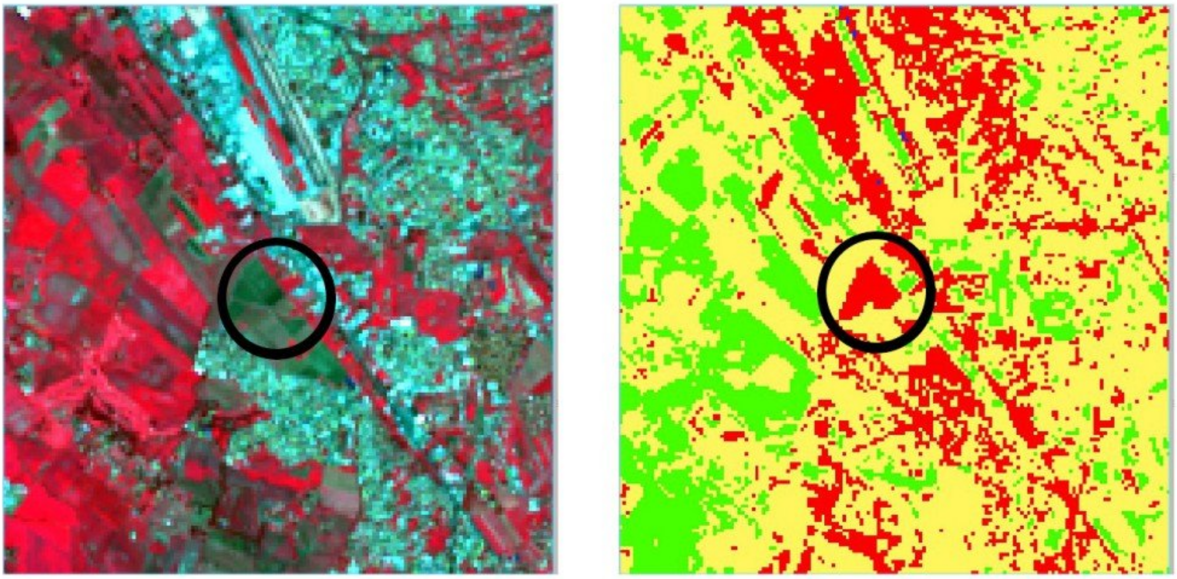


Fig. 19.18: *Example of error: Bare soil classified as Built-up*

CAPITOLO 20

Tutorial 2

Tutorial 2: Land Cover Classification of Sentinel-2 Images

This tutorial describes the main phases for the classification of images acquired by *Sentinel-2 Satellite* (pagina 145). In addition, some of the *SCP* tools are illustrated.

We are going to classify the following land cover classes:

1. Water;
2. Built-up;
3. Vegetation;
4. Bare soil.

Following the video of this tutorial.

http://www.youtube.com/watch?v=FcETq8OWM0k

Data Download

We are going to **download a Sentinel-2 image** provided by the Copernicus Scientific Data Hub. In particular we are going to use the following Sentinel-2 bands (for more information read *Sentinel-2 Satellite* (pagina 145)):

- Band 2 - Blue;
- Band 3 - Green;
- Band 4 - Red;
- Band 5 - Vegetation Red Edge;
- Band 6 - Vegetation Red Edge;
- Band 7 - Vegetation Red Edge;
- Band 8 - NIR;
- Band 8A - Vegetation Red Edge;
- Band 11 - SWIR;
- Band 12 - SWIR;

> **TIP** : In case you have slow internet connection you can download a subset of the image (about 50MB) from this link (© Copernicus Sentinel data 2016) which is the result of steps *Data Download* (pagina 188) and *Clip the Data* (pagina 192).

Start a new QGIS project. Open the tab *Download images* (pagina 51) clicking the button in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37). Select the tab *Sentinel-2 download* (pagina 55). We are searching a specific image acquired on May 06, 2016.

In *Login Sentinels* (pagina 56) enter the user name and password for accessing data (free registration is required).

> **WARNING** : The guest/guest account is not available anymore. Free registration is required. See https://scihub.copernicus.eu/news/News00097 .

In *Search area* (pagina 56) enter:

- *UL X (Lon)*: 12
- *UL Y (Lat)*: 42
- *LR X (Lon)*: 13
- *LR Y (Lat)*: 41

> **TIP** : In general it is possible to define the area coordinates clicking the button and drawing a rectangle in the map.

In *Search* (pagina 56) set:

- *Date from*: 2016-05-06
- *to*: 2016-05-06

Now click the button *Find* and after a few seconds the image will be listed in the `Image list`.

> **Tip**: download this zip file containing the shapefile of Sentinel-2 granules for identifying the zone; load this shapefile in QGIS, select the granules in your search area and open the attribute table to see the zone name.

In the result table, click the item `T32TQM` in the field *Zone*, which is the *Granule* `S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM`, and click the button . A preview will be downloaded and displayed in the map, which is useful for assessing the quality of the image and the cloud cover.

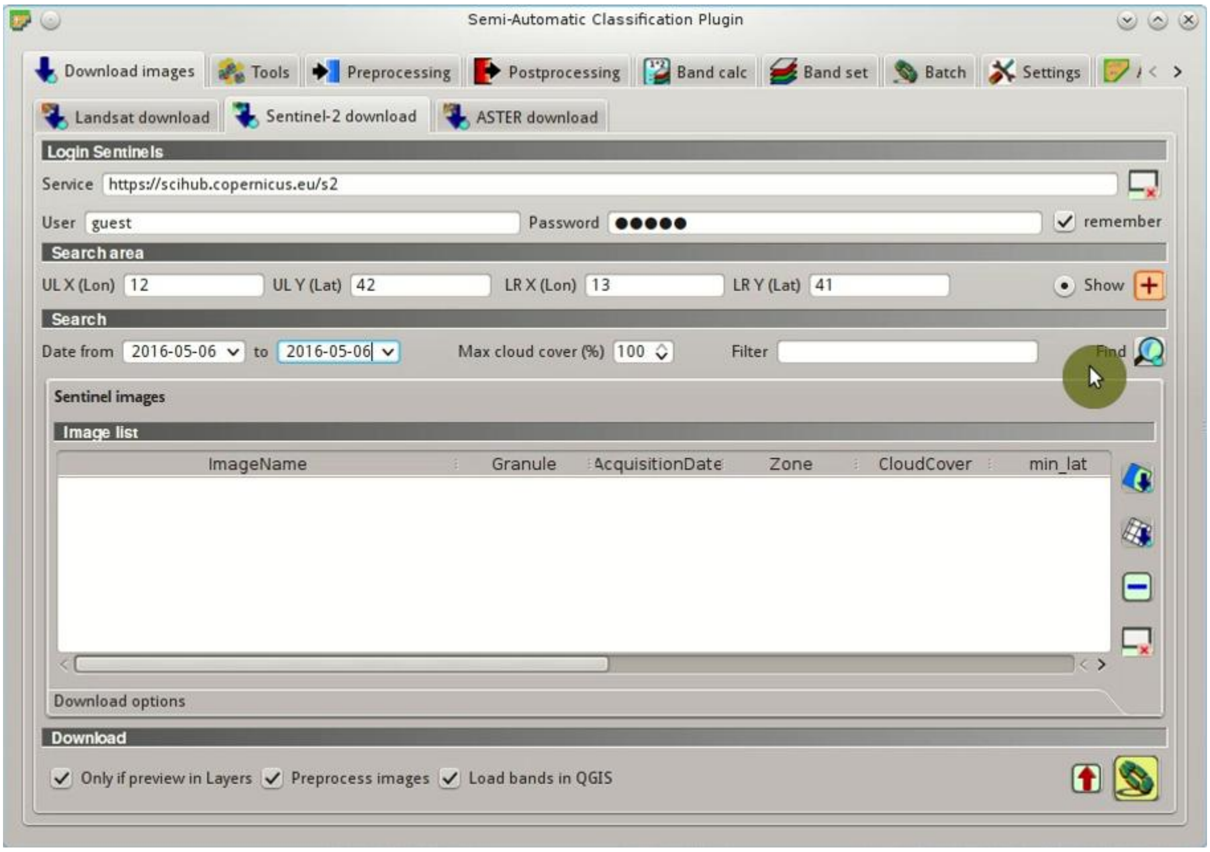


Fig. 20.1: *Search Sentinel-2 images*

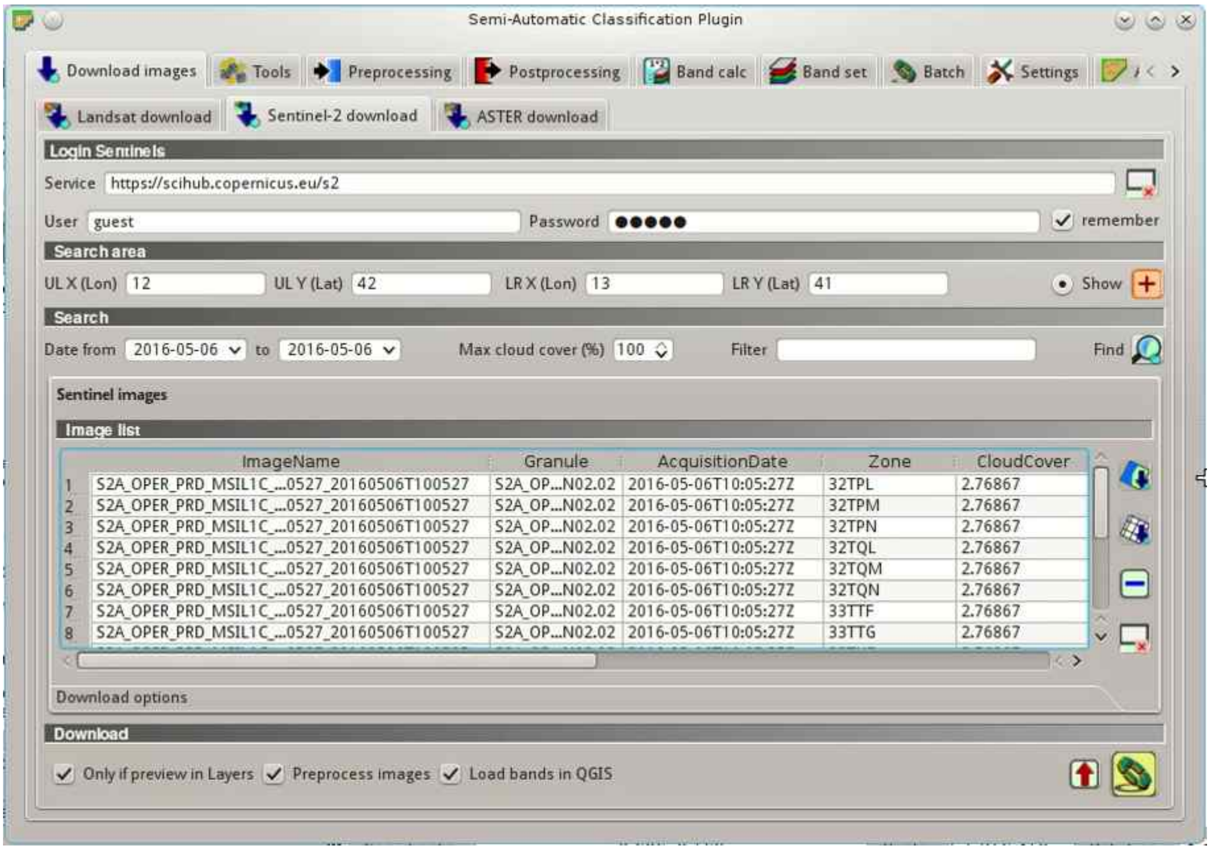


Fig. 20.2: *Sentinel-2 search result*

> **TIP** : It is also possible to display the image overview (which is composed of several granules) with the button .

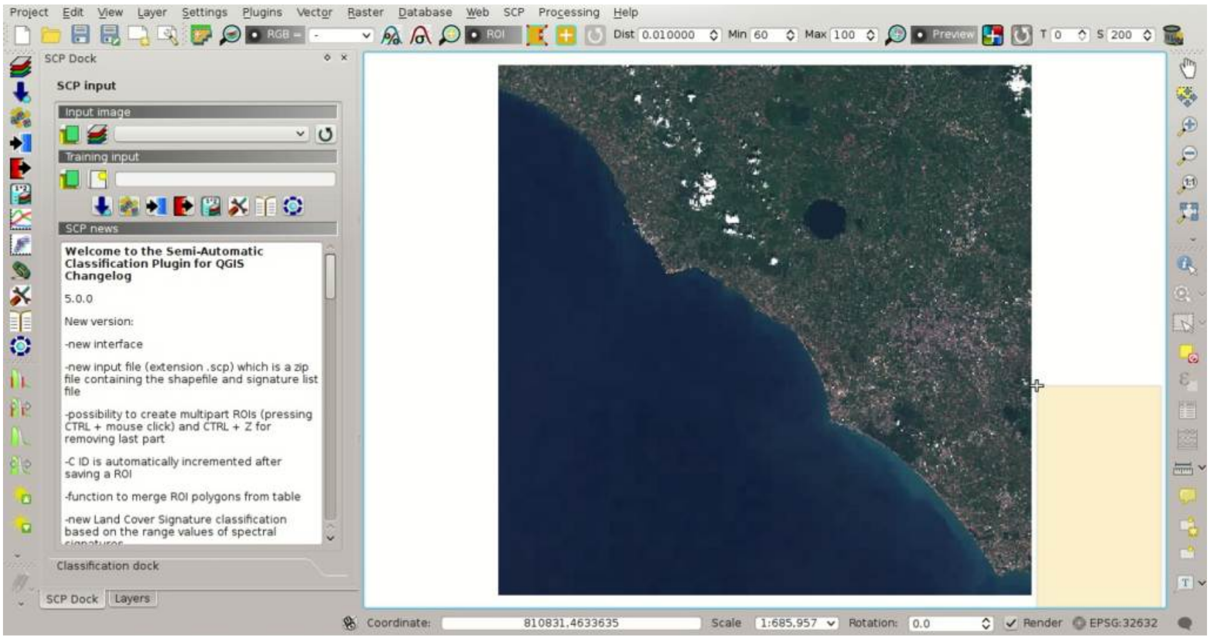


Fig. 20.3: *Image preview*

Click the tab *Download options* (pagina 57) and uncheck bands 1, 9, and 10. Also, uncheck the options  *Preprocess images* (usually this should be checked, but for the purpose of this tutorial we are going to preprocess images in the step *Automatic Conversion to Surface Reflectance* (pagina 190)) and  *Load bands in QGIS* (because we are going to clip the images).

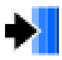
> **TIP** : The option  *Only if preview in Layers* allows for downloading only images in the result table which are loaded as previews in the map. It is convenient to check this option and remove the images previews in the QGIS layer list, leaving only the previews of images that one wish to download.

In order to start the image download, click the button  and select a directory where bands are saved (e.g. `Desktop`). The download could last a few minutes according to your internet connection speed (band size ranges from 30 to 90MB). The download progress is displayed in a bar.

After the download, all the bands and the metadata files are saved in the output directory.

Automatic Conversion to Surface Reflectance

Conversion to reflectance (see *Radianza e Riflettanza* (pagina 143)) can be performed automatically. The metadata file (a .xml file whose name contains `MTD_SAFL1C`) downloaded with the images contains the required information for the conversion. Read *Image conversion to reflectance* (pagina 163) for information about the *Top Of Atmosphere (TOA) Reflectance* (pagina 163) and *Surface Reflectance* (pagina 164).

In order to convert bands to reflectance, open the tab *Preprocessamento* (pagina 77) clicking the button  in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37), and select the tab *Sentinel-2* (pagina 79).

Click the button *Directory containing Sentinel-2 bands*  and select the directory that should be named `S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM`. The list of bands is automa-

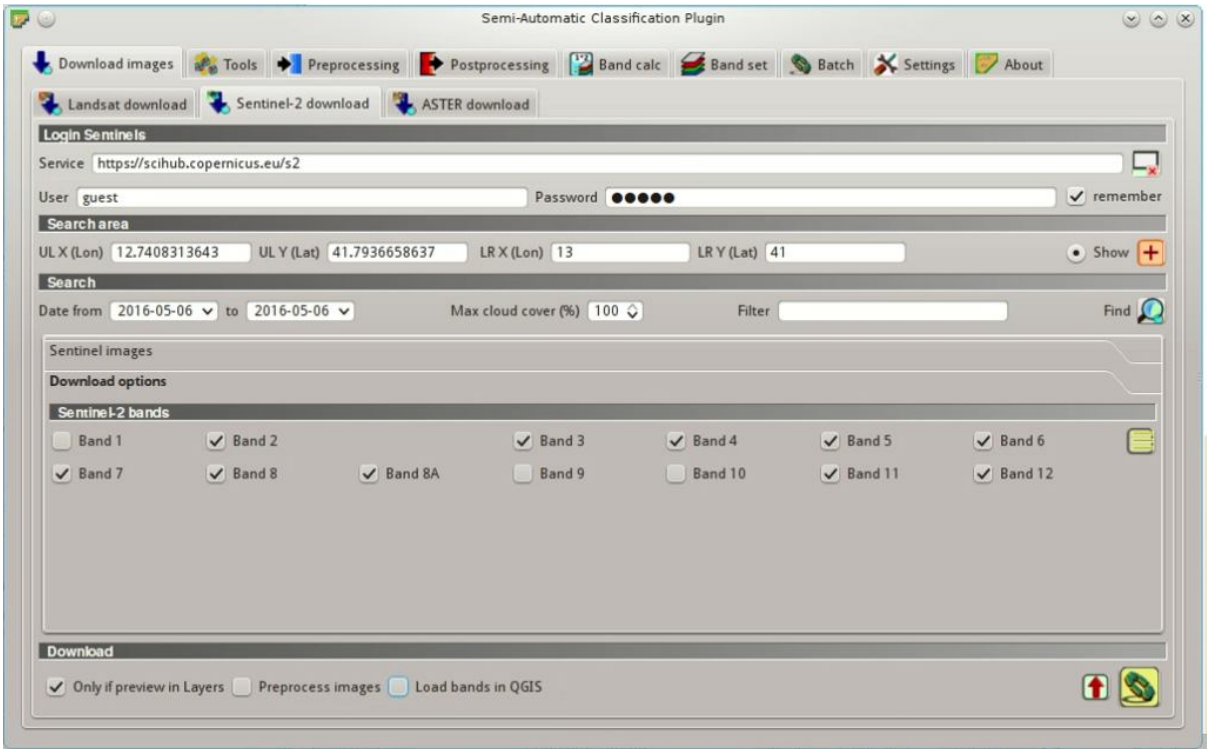


Fig. 20.4: *Selection of bands for download*

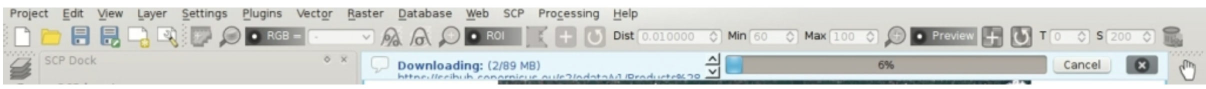


Fig. 20.5: *Download of Sentinel bands*

tically loaded in the table *Metadata* (pagina 80). Also, the metadata information for each band is loaded (because the metadata file is inside the same directory).

> **TIP** : If a Sentinel-2 image was downloaded directly from the site https://scihub.copernicus.eu and you want to convert images to reflectance using *SCP*, you should copy the .xml file whose name contains `MTD_SAFL1C` (included in the granule directory) and paste it inside the same directory of bands (files .jp2).

In order to calculate *Surface Reflectance* (pagina 164) we are going to apply the *Correzione DOS1* (pagina 164); therefore, enable the option *Apply DOS1 atmospheric correction*.

> **TIP** : It is recommended to perform the DOS1 atmospheric correction to the entire image (before clipping the image) in order to improve the calculation of parameters based on the image.

Uncheck the option *Create Band set and use Band set tools* because we are going to define this in the following step *Create the Band Set* (pagina 194). In order to start the conversion process, click the button and select the directory where converted bands are saved (e.g. `Desktop`).

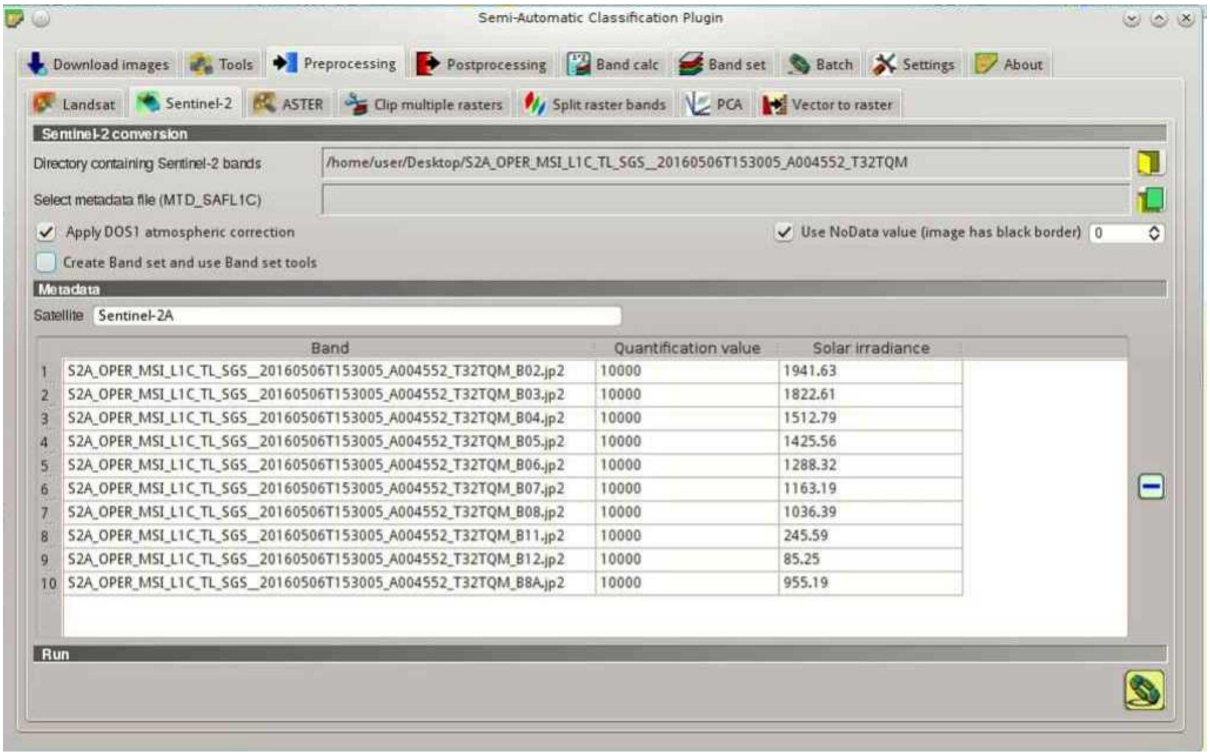


Fig. 20.6: *Sentinel-2 conversion to reflectance*

After a few minutes, converted bands are loaded and displayed (file name starts with `RT_`). If *Play sound when finished* is checked in *Classification process* (pagina 118) settings, a sound is played when the process is finished.

Clip the Data

Sentinel-2 images have a large extent. In order to reduce the computational time, we are going to clip bands to the same study area as *Tutorial 1: Your First Land Cover Classification* (pagina 175). Open the tab *Preprocessamento* (pagina 77) and select the tab *Clip multiple rasters* (pagina 84).

Click the button to refresh the layer list, and check all the layers whose name starts with `RT_` (the band number is at the end of the layer name).

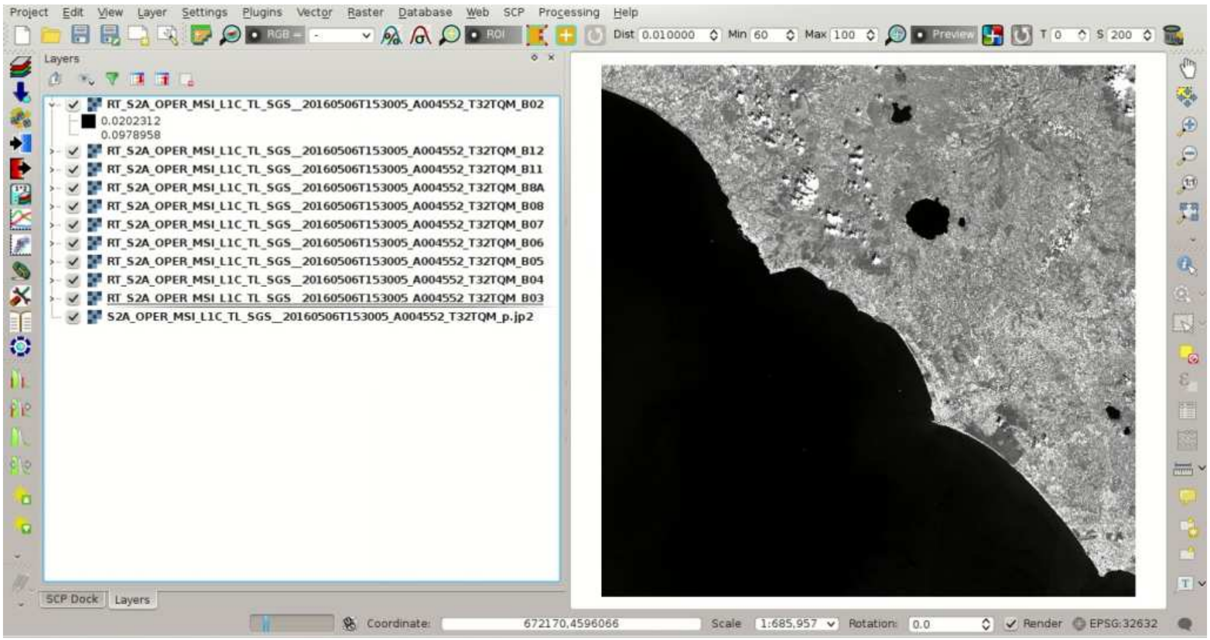


Fig. 20.7: *Converted Sentinel-2 bands*

Click the button and select an area such as the following image, or enter the following values:

- *UL X*: 791810
- *UL Y*: 4643020
- *LR X*: 809750
- *LR Y*: 4626230

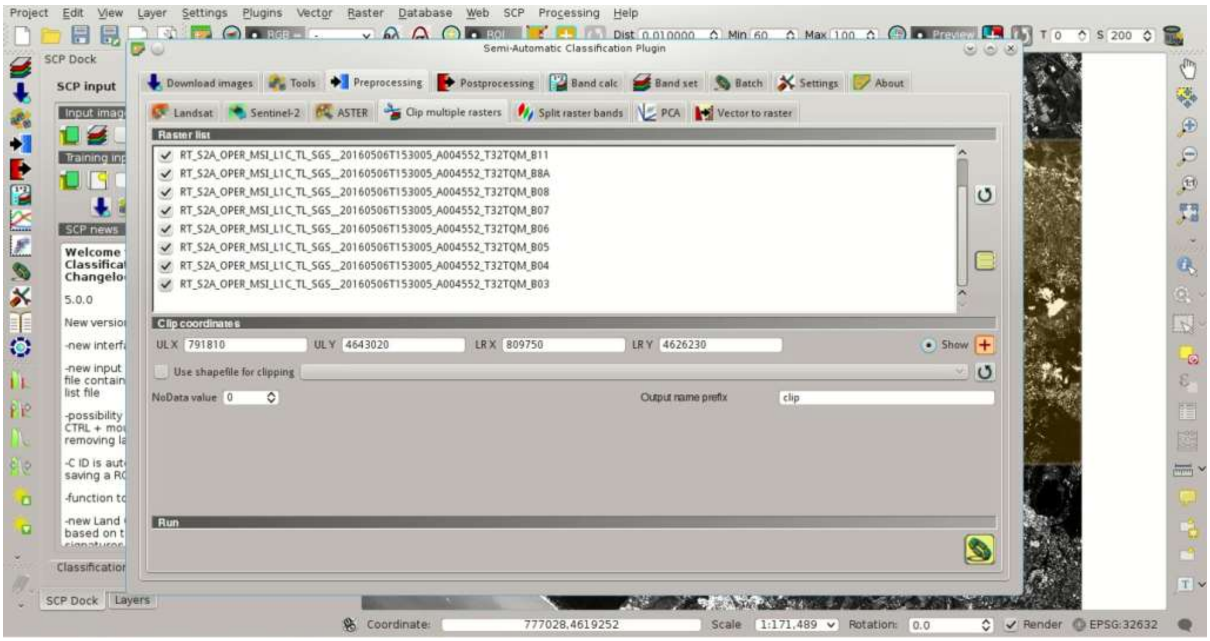


Fig. 20.8: *Clip area*

Click the button and select a directory (e.g. `clip`) where clipped bands are saved (with the file name prefix defined in *Output name prefix*). When the process is completed, clipped rasters are loaded and displayed. We can remove the bands whose names start with RT_ from QGIS layers.

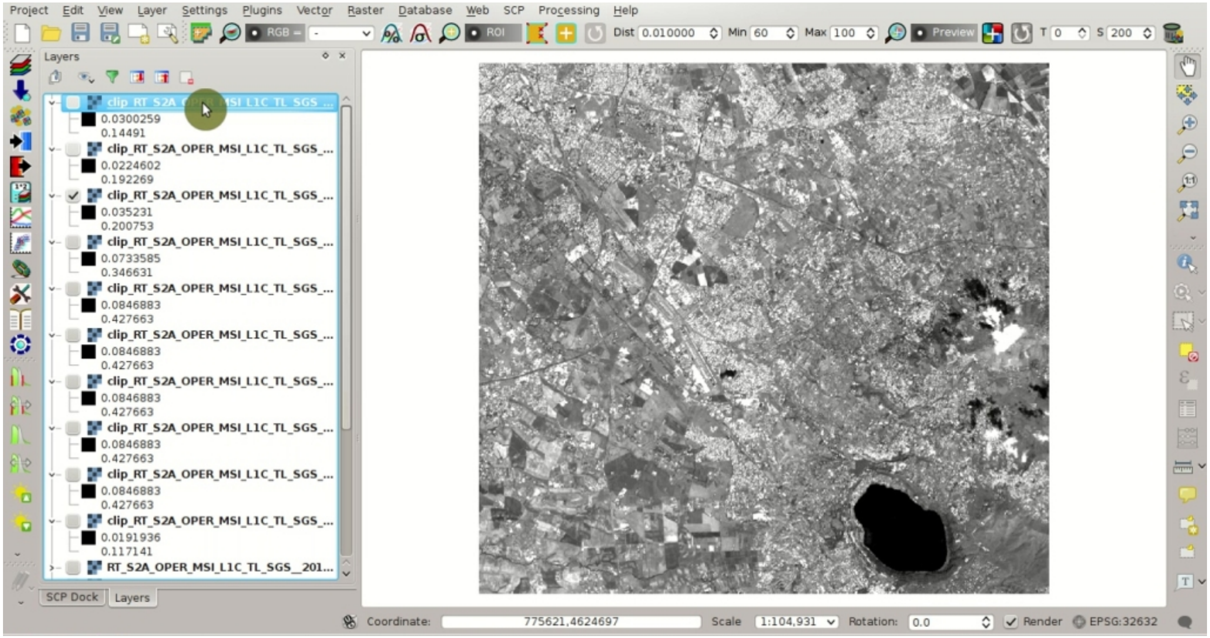


Fig. 20.9: *Clipped bands*

Create the Band Set

Now we need to define the *Band set* which is the input image for *SCP*. Open the tab *Band set* (pagina 110) clicking the button in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37).

Click the button to refresh the layer list, and check all the clipped bands; then click to add selected rasters to the *Band set*. In the table *Band set definition* order the band names in ascending order (click to sort bands by name automatically), then highlight band 8A (i.e. single click on band name in the table) and use the buttons or to place this band at number 8. Finally, select *Sentinel-2* from the list *Quick wavelength settings*, in order to set automatically the *Center wavelength* of each band and the *Wavelength unit* (required for spectral signature calculation).

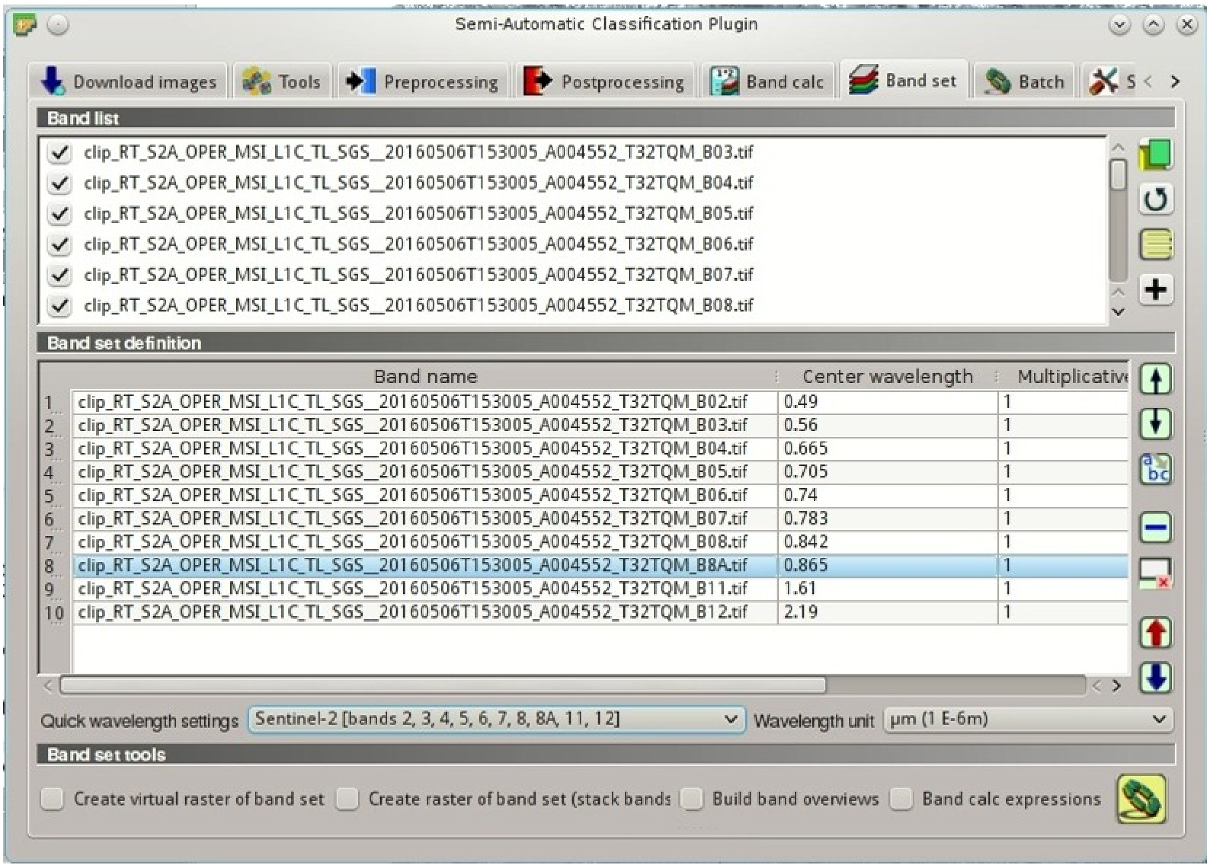
You can notice that the item << band set >> is selected as *Input image* (pagina 38) in the *SCP dock* (pagina 37).

Create the ROIs

In order to collect ROIs we need to *Create the Training Input File* (pagina 177) as described in *Tutorial 1: Your First Land Cover Classification* (pagina 175) (in the *SCP dock* (pagina 37) click the button and define a file name). The *Training input* stores the ROIs and the *Firma Spettrale* (pagina 143) thereof.

We are going to create several ROIs using the Macroclass IDs defined in the following table (see *Classi e Macroclassi* (pagina 153)).

Macroclasses



	Band name	Center wavelength	Multiplicative
1	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B02.tif	0.49	1
2	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B03.tif	0.56	1
3	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B04.tif	0.665	1
4	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B05.tif	0.705	1
5	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B06.tif	0.74	1
6	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B07.tif	0.783	1
7	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B08.tif	0.842	1
8	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B8A.tif	0.865	1
9	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B11.tif	1.61	1
10	clip_RT_S2A_OPER_MSI_L1C_TL_SGS__20160506T153005_A004552_T32TQM_B12.tif	2.19	1

Fig. 20.10: *Definition of a band set*

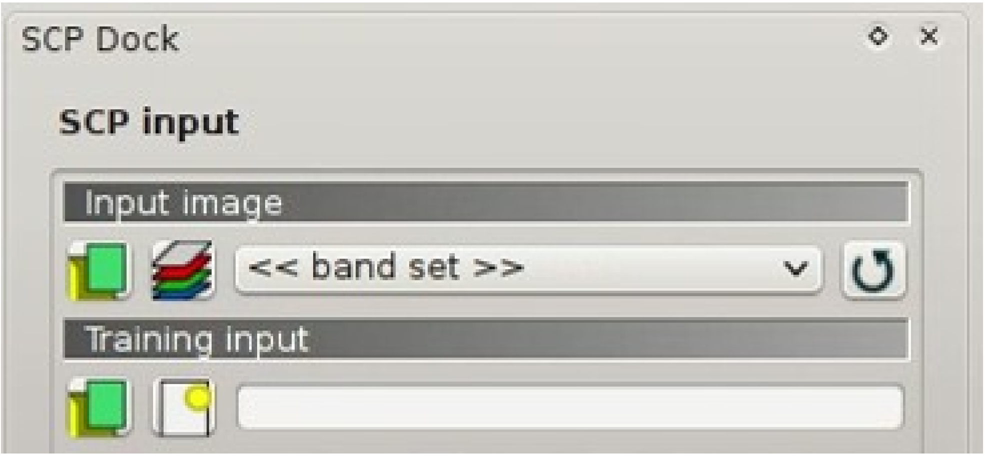


Fig. 20.11: *Band set*

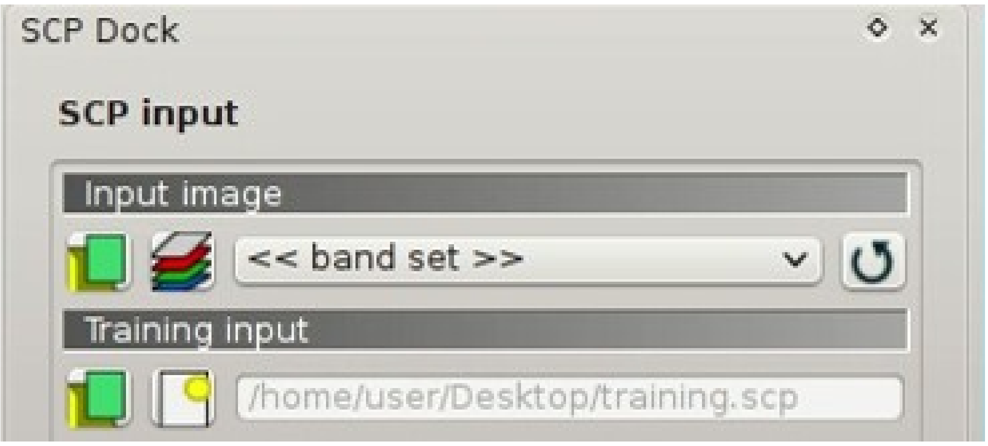


Fig. 20.12: *Definition of Training input in SCP*

Macroclass name	Macroclass ID
Water	1
Built-up	2
Vegetation	3
Bare soil	4

In this phase we are creating the database of spectral signatures used to identify land cover classes (the ones defined as macroclasses). However, these macroclasses are composed of several materials having different spectral signatures; in order to achieve good classification results we should separate spectral signatures of different materials, even if belonging to the same macroclass. Thus, we are going to create several ROIs for each macroclass (setting the same *MC ID*, but assigning a different *C ID* to every ROI).

In the list *RGB=* of *Working toolbar* (pagina 33) select `3-2-1` to display a natural color image (see ref:*color_composite_definition* and *Sentinel-2 Satellite* (pagina 145)). After a few seconds, the *Colore Composito* (pagina 147) will be displayed. We can see that urban areas are white and vegetation is green.

> **TIP** : If a *Band set* (pagina 110) is defined, a temporary virtual raster (named `band_set.vrt`) is created automatically, which allows for the display of *Colore Composito* (pagina 147). In order to speed up the visualization, you can show only the virtual raster and hide all the layers in the QGIS Layers.

Now in the list *RGB=* of the *Working toolbar* (pagina 33) type `3-7-10` (you can also use the tool *RGB list* (pagina 75)). Using this color composite, urban areas are purple and vegetation is green. You can notice that this color composite `RGB = 3-7-10` highlights roads more than natural color (`RGB = 3-2-1`). Also, you can see that there are clouds in the right part of the image.

Now create the ROIs following the same steps described in *Create the ROIs* (pagina 177) of *Tutorial 1: Your First Land Cover Classification* (pagina 175). After clicking the button in the *Working toolbar* (pagina 33) you should notice that the cursor in the map displays a value changing over the image. This is the NDVI value of the pixel beneath the cursor (NDVI is displayed because the function *Display* is checked in *Creazione ROI* (pagina 42)). The NDVI value can be useful for identifying spectrally pure pixels, in fact vegetation has higher NDVI values than soil.

For instance, move the mouse over a vegetation area and left click to create a ROI when you see a local maximum value. This way, the created ROI and the spectral signature thereof will be particularly representative of healthy vegetation.

The color composite `RGB = 7-3-2` is also useful for highlighting vegetation.

Create several ROIs (the more is the better). The region growing algorithm can create more homogeneous ROIs (i.e. standard deviation of spectral signature values is low) than manually drawn ones; the manual creation of ROIs can be useful in order to account for the spectral variability of classes (especially when using the algorithm *Maximum Likelihood* (pagina 154)).

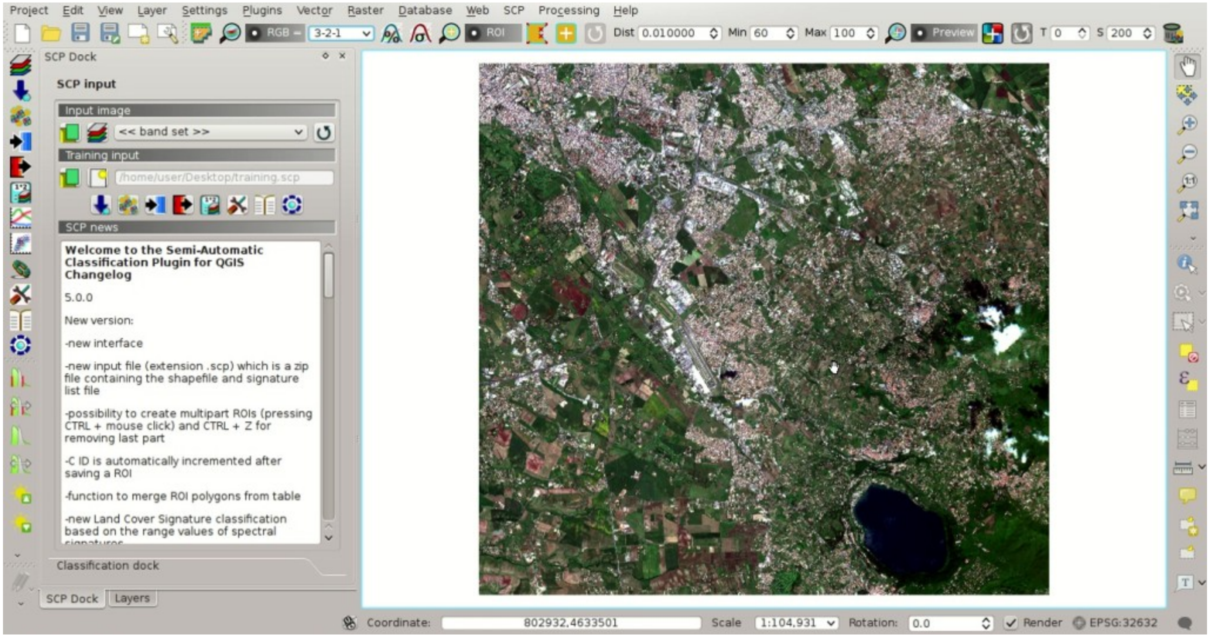


Fig. 20.13: *Color composite RGB = 3-2-1*

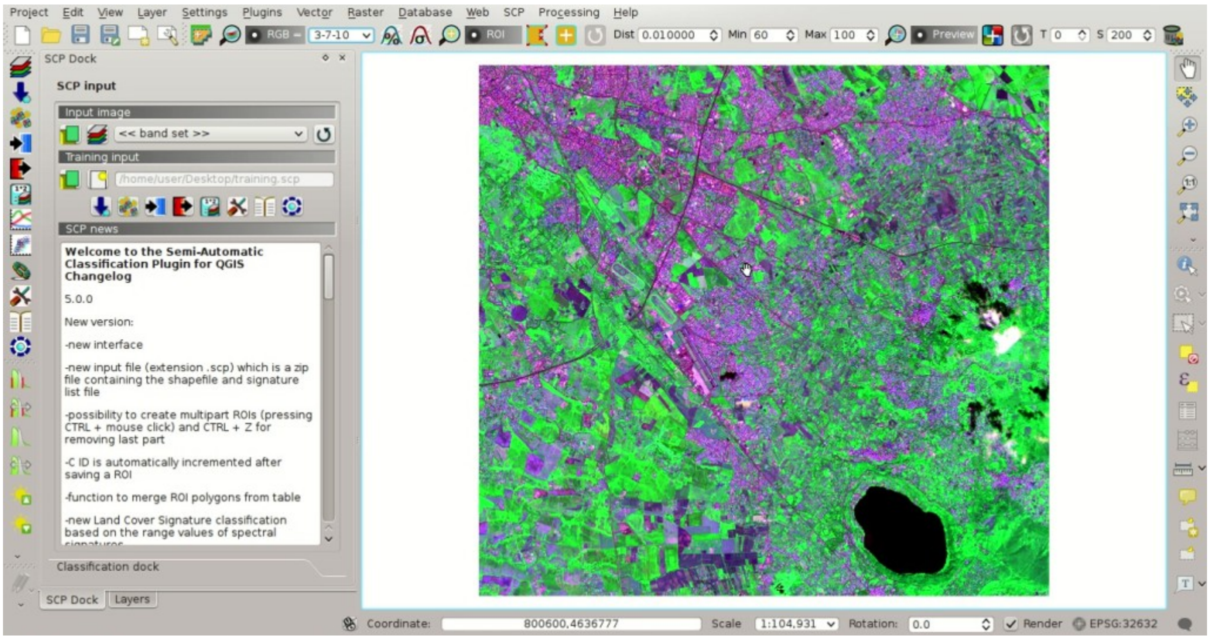


Fig. 20.14: *Color composite RGB = 3-7-10*

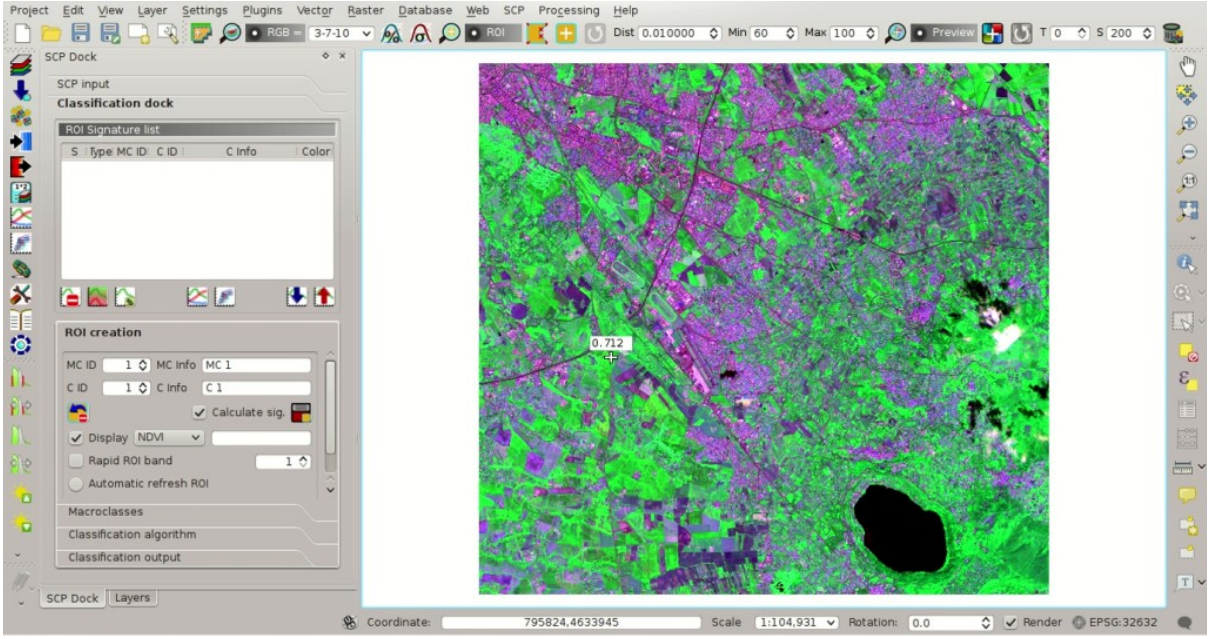


Fig. 20.15: *NDVI value of vegetation pixel displayed in the map*

In general, you should create one ROI for each color that you can distinguish in the image. Therefore, change the color composite in order to identify the different types of land cover.

> **TIP** : Change frequently the *Colore Composito* (pagina 147) in order to clearly identify the materials at the ground; use the mouse wheel on the list *RGB=* of the *Working toolbar* (pagina 33) for changing the color composite rapidly; also use the buttons  and  for better displaying the *Input image* (i.e. image stretching).

A few examples of ROIs are illustrated in the following figures.

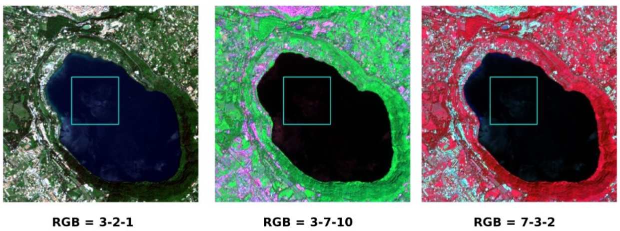


Fig. 20.16: *Water ROI: lake*

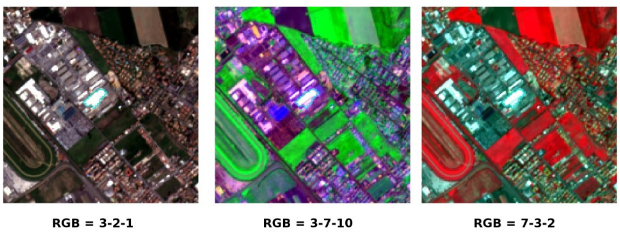


Fig. 20.17: *Built-up ROI: large buildings*

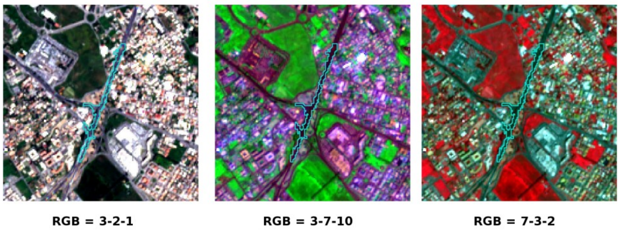


Fig. 20.18: *Built-up ROI: road*

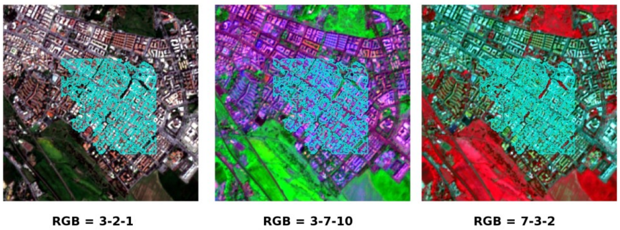


Fig. 20.19: *Built-up ROI: buildings and narrow roads*

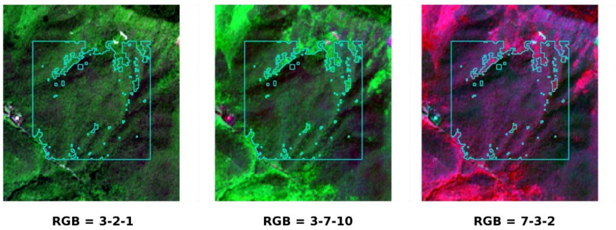


Fig. 20.20: *Vegetation ROI: deciduous trees*

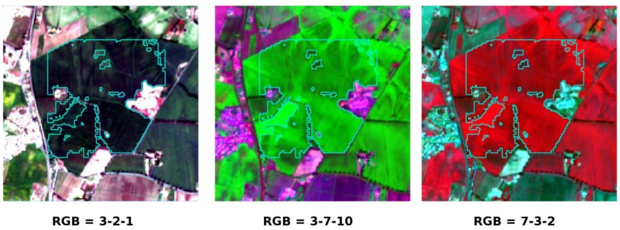


Fig. 20.21: *Vegetation ROI: crop*

Fig. 20.22: *Bare soil ROI: uncultivated land*

It is worth mentioning that you can show or hide the temporary ROI clicking the button *ROI* in *Working toolbar* (pagina 33).

> **TIP** : Install the plugin QuickMapServices in QGIS, and add a map (e.g. OpenStreetMap) in order to facilitate the identification of ROIs using high resolution data.

We can also try to mask clouds in the image, creating ROIs of clouds and assigning the special *MC ID* = 0 (which is an ID used for labelling intentionally unclassified pixels) and a different *C ID*. In fact spectral signatures with the *MC ID* = 0 are normally used in the classification, but every pixel assigned to these spectral signatures is labelled `unclassified` in the classification result. Therefore, this is a simple way for masking particular spectral signatures such as clouds (of course there are more advanced methods for masking clouds that will be discussed in other tutorials).

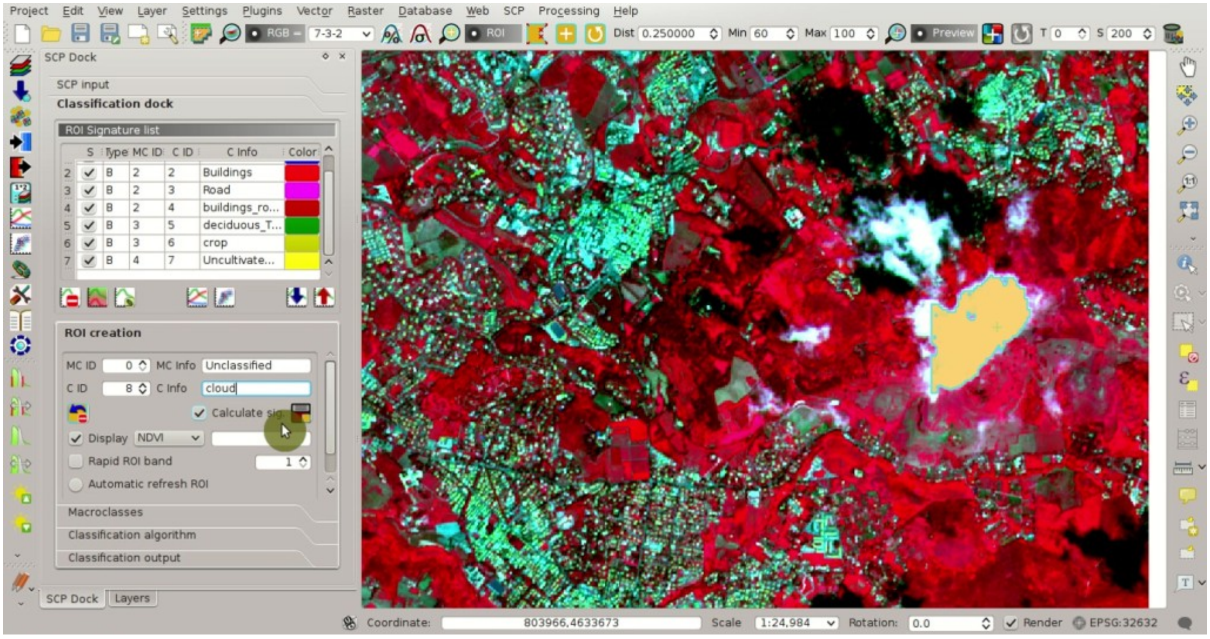


Fig. 20.23: *Example of ROI for clouds*

Create a Classification Preview

As pointed out in *Tutorial 1: Your First Land Cover Classification* (pagina 175), previews are temporary classifications that are useful for assessing the effects of spectral signatures during the ROI collection.

Set the colors of the spectral signatures in the *ROI Signature list* (pagina 41); then, in the *Classification algorithm* (pagina 44) select the classification algorithm *Maximum Likelihood* (pagina 154). In *Classification preview* (pagina 35) set *Size* = 500; click the button and then left click a point of the image in the map.

The classification preview is displayed in the map.

In order to create a classification preview using Macroclass IDs check the option *MC ID* in the tab *Classification algorithm* (pagina 44) of the *SCP dock* (pagina 37). In the tab *Macroclasses* (pagina 43) of the *SCP dock* (pagina 37) change the colors of *MC ID* (in the table *Macroclasses* (pagina 43) double click the color of each macroclass to choose a representative color).

Now click the button in the *Working toolbar* (pagina 33) to calculate a new preview at the same area of the previous one. In the following figure you can notice that there are fewer classes (only the *MC ID*) than the previous preview; also, clouds are unclassified (black pixels).

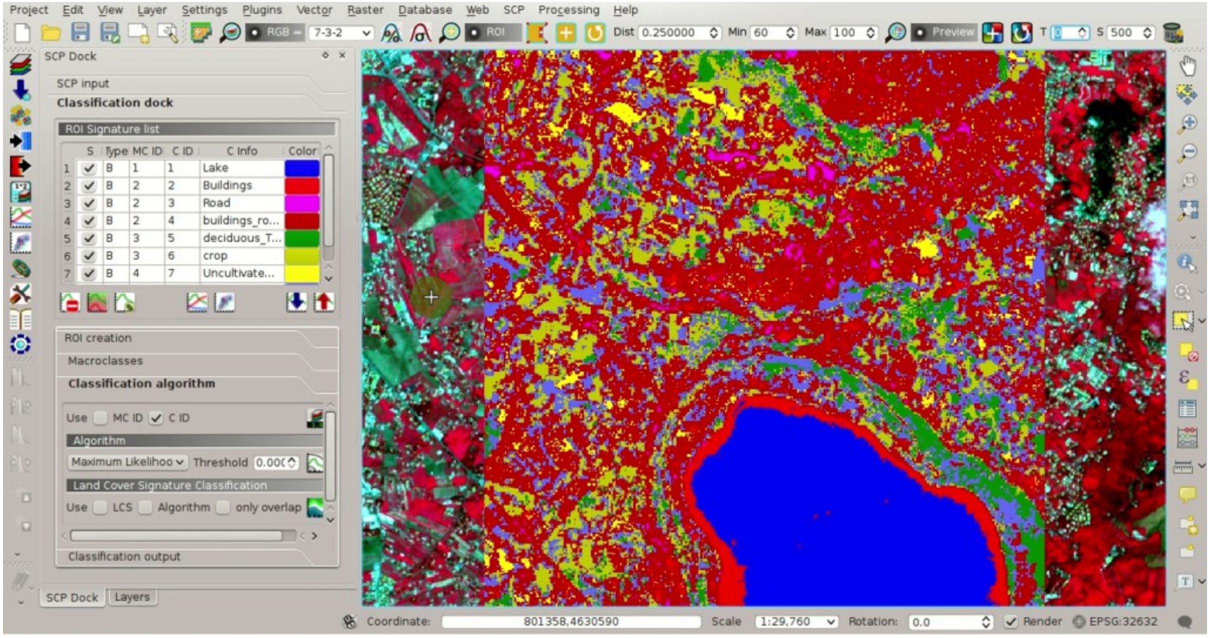


Fig. 20.24: *Example of preview using C IDs*

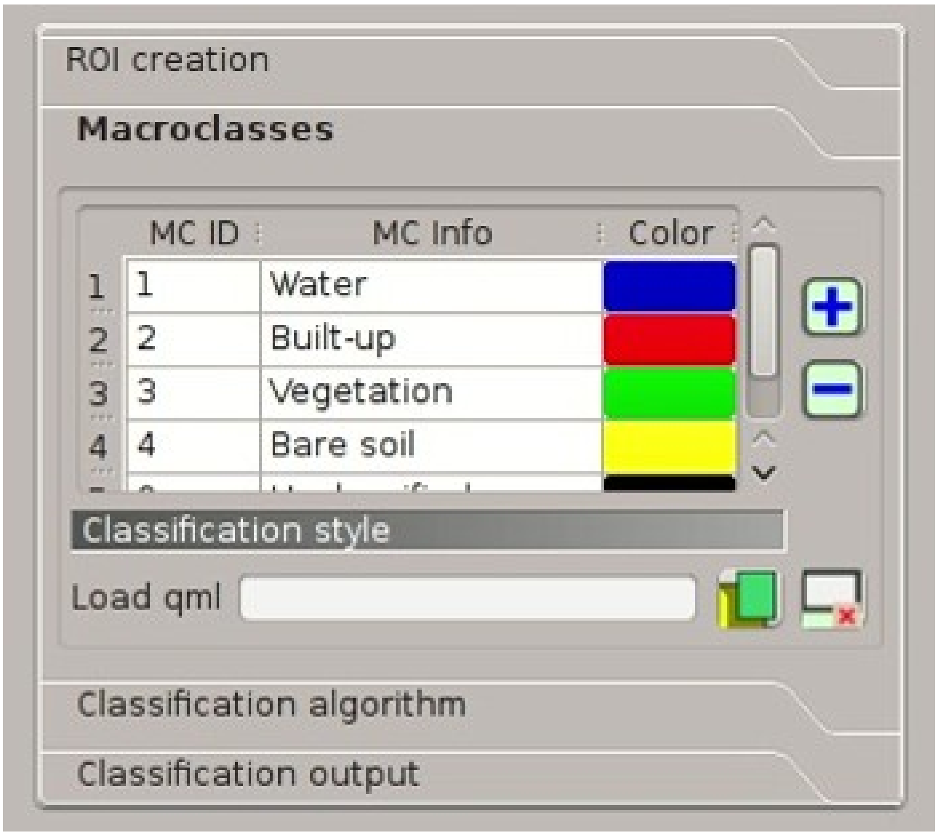


Fig. 20.25: *COlors of MC IDs*

TIP : In the *Working toolbar* (pagina 33) click the button *Preview* to easily show or hide the classification previews, and the button *RGB=* to show or hide the *Input image*.

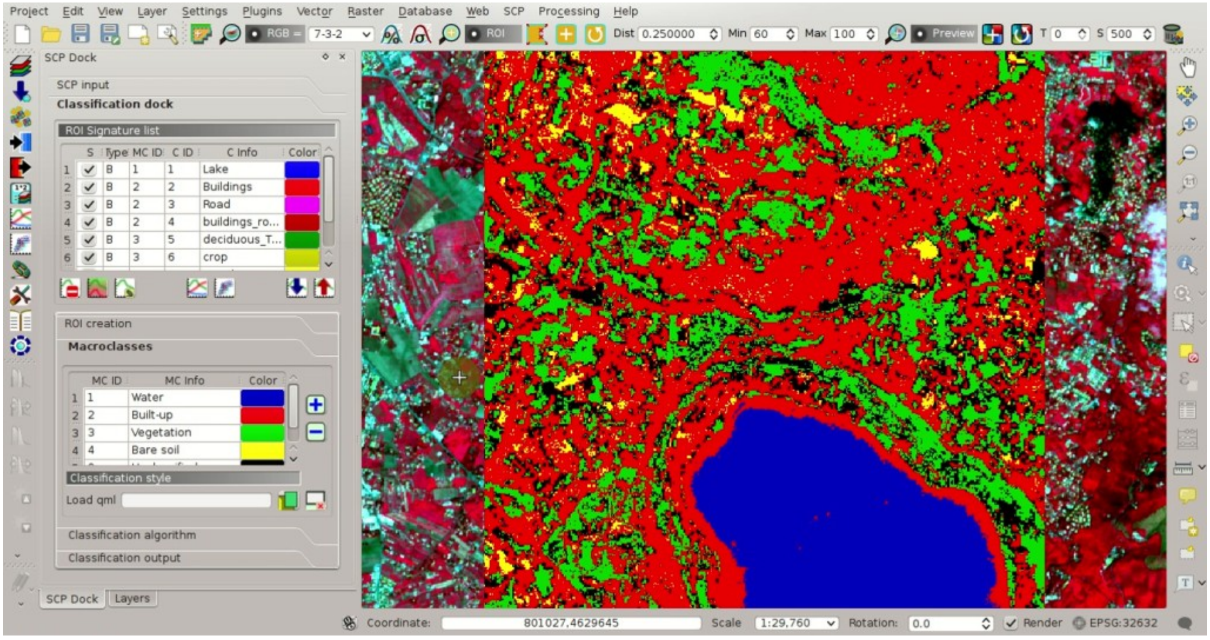


Fig. 20.26: *Example of preview using MC IDs*

Assess Spectral Signatures

Spectral signatures are used by *Classification Algorithms* (pagina 154) for labelling image pixels. Different materials may have similar spectral signatures (especially considering multispectral images) such as built-up and soil. If spectral signatures used for classification are too similar, pixels could be misclassified because the algorithm is unable to discriminate correctly those signatures. Thus, it is useful to assess the *Spectral Distance* (pagina 159) of signatures to find similar spectral signatures that must be removed. Of course the concept of distance vary according to the algorithm used for classification.

One can simply assess spectral signature similarity by displaying a signature plot. In order to display the signature plot, in the *ROI Signature list* (pagina 41) highlight two or more spectral signatures (with click in the table), then click the button . The *Spectral Signature Plot* (pagina 123) is displayed in a new window. Move ans zoom inside the *Plottaggio* (pagina 125) to see if signatures are similar (i.e. very close). We can see in the following figure a signature plot of different materials.

In the plot we can see the line of each signature (with the color defined in the *ROI Signature list* (pagina 41)), and the spectral range (minimum and maximum) of each band (i.e. the semi-transparent area colored like the signature line). The larger is the semi-transparent area of a signature, the higher is the standard deviation, and therefore the heterogeneity of pixels that composed that signature. Spectral signature values are displayed in the *Signature details* (pagina 126).

Additionally, we can calculate the spectral distances of signatures (for more information see *Spectral Distance* (pagina 159)). Highlight two or more spectral signatures with click in the table *Plot Signature list* (pagina 123), then click the button ; distances will be calculated for each pair of signatures. Now open the tab *Spectral distances* (pagina 126); we can notice that similarity between signatures vary according to considered algorithm.

For instance, two signatures can be very similar *Spectral Angle Mapping* (pagina 155) (very low *Spectral Angle* (pagina 159)), but quite distant for the *Maximum Likelihood* (pagina 154) (*Jeffries-Matusita Distance* (pagina 159) value near 2). The similarity of signatures is affected by the similarity of materials (in relation to the number of spectral bands available in the *Input image*); also, the way we create ROIs influences the signatures.

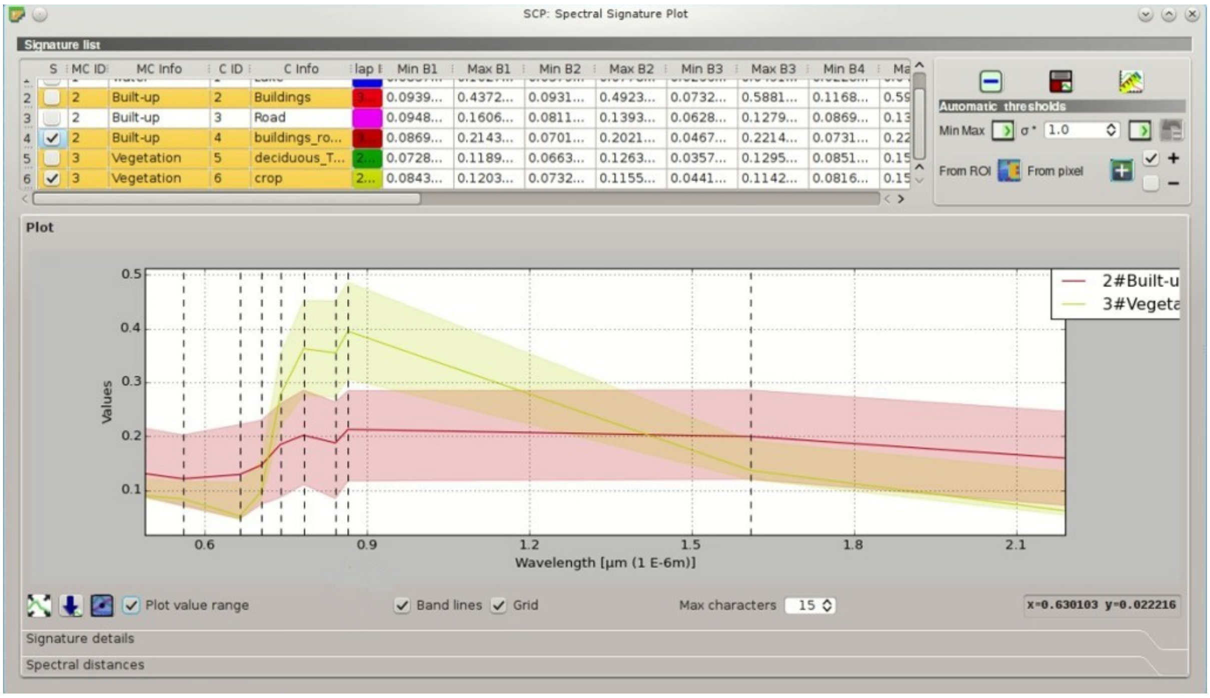


Fig. 20.27: *Spectral plot*

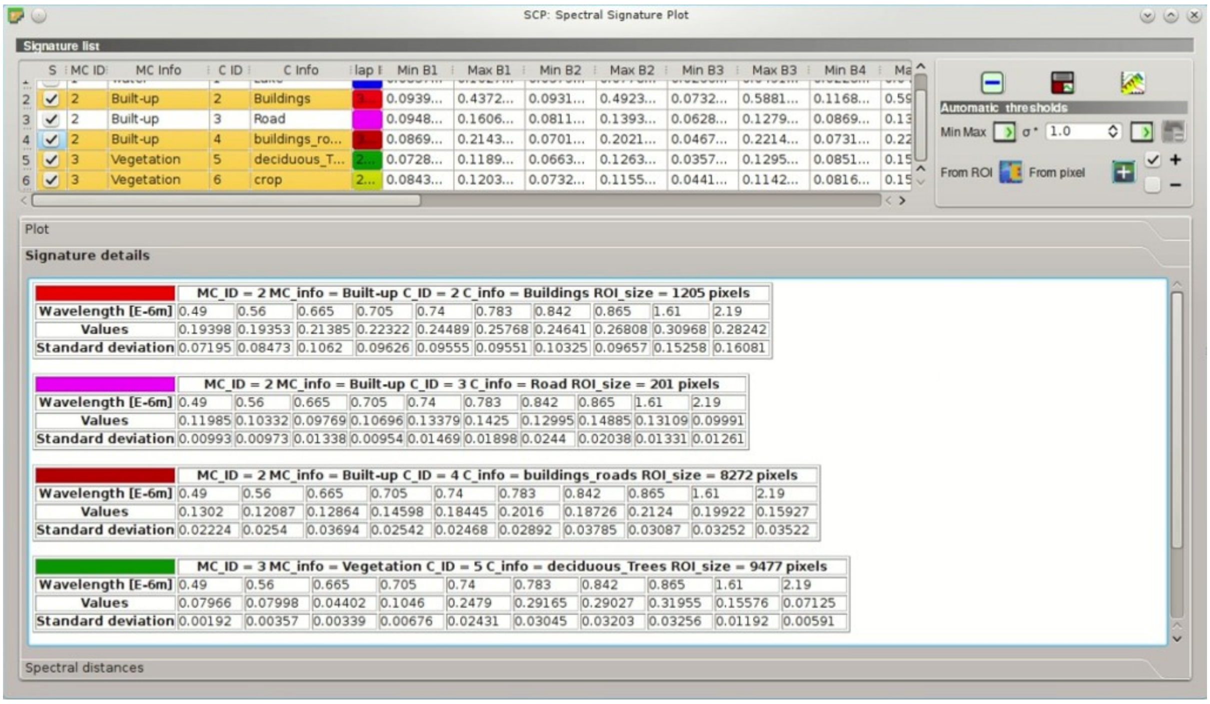


Fig. 20.28: *Spectral signature values*

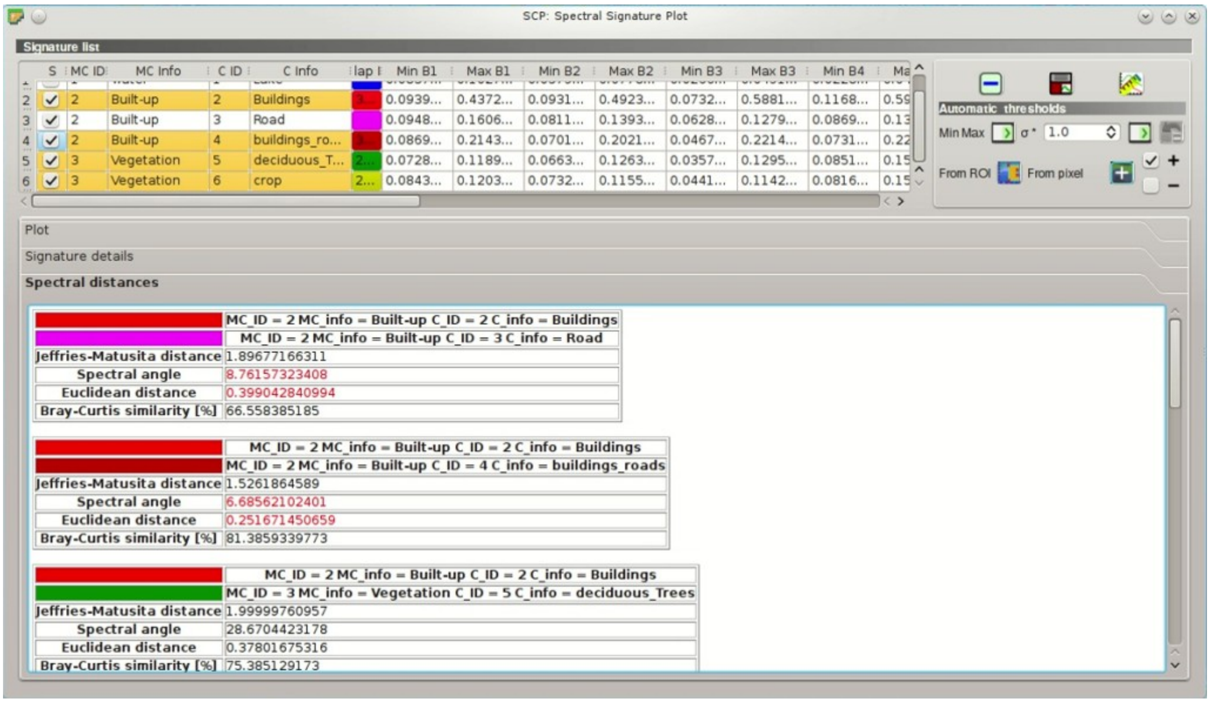


Fig. 20.29: *Spectral distances*

Create the Classification Output

Repeat iteratively the phases *Create the ROIs* (pagina 194), *Create a Classification Preview* (pagina 200), and *Assess Spectral Signatures* (pagina 202) until the classification previews show good results.

To start the classification of the entire image, open the tab *Classification output* (pagina 46), click the button  and define the name of the classification output.

> **TIP** : Set the *Available RAM (MB)* in *RAM* (pagina 120) settings, in order to reduce the computational time; the recommended value is half of the system RAM.

If  *Play sound when finished* is checked in *Classification process* (pagina 118) settings, a sound is played when the process is finished.

It is worth mentioning that *SCP* provides other tools and techniques that can improve the classification results, which are described in *Thematic Tutorials* (pagina 211).

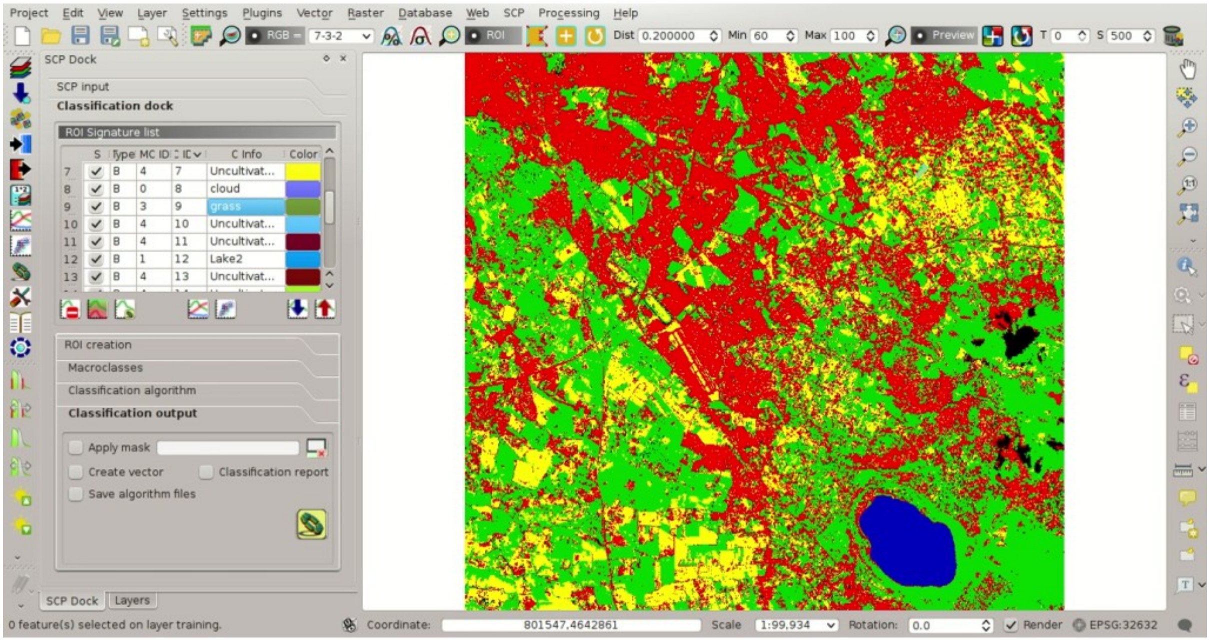


Fig. 20.30: *Classification*

CAPITOLO 21

NASA ARSET Webinar

NASA ARSET is a program for fostering the acquisition and use of NASA satellite data for supporting decisions, through online webinars and in-person workshops.

NASA ARSET offered the webinar **Land Cover Classification with Satellite Imagery** which covered very interesting objectives such as access and download Landsat imagery and learn the basic steps for performing a supervised classifications using the *SCP*.

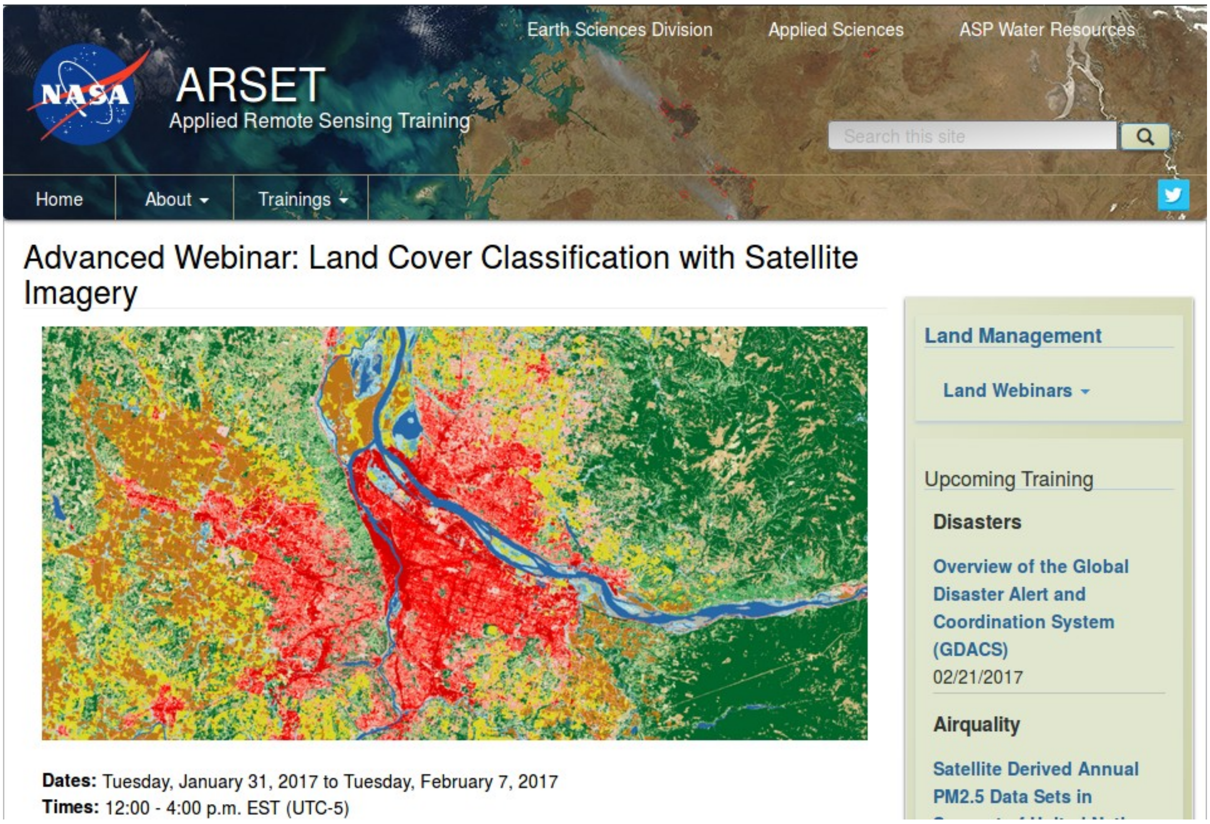


Fig. 21.1: *NASA ARSET website*

This webinar is organized in two sessions:

- Introduction to Land Cover Classification and QGIS
- Improving a Supervised Land Cover Classification

The entire webinar is very informative, and I recommend watching the recordings. In particular, the *Land Cover Signature Classification* (pagina 156) is illustrated during the exercise of the second session.

Slides of presentations, in English and Spanish, and the recordings of both sessions are freely available at this link https://arset.gsfc.nasa.gov/land/webinars/advanced-land-classification.

Many thanks to NASA ARSET for their effort in teaching remote sensing using open source software.

After these tutorials, please check the *Thematic Tutorials* (pagina 211) .

Parte VI

Thematic Tutorials

Quelli che seguono sono i tutorial tematici. Prima di questi tutorial, si raccomanda di leggere i *Tutorials di Base* (pagina 173)

CAPITOLO 22

Tutorial: Land Cover Signature Classification

This tutorial is about the *Land Cover Signature Classification* (pagina 156). It is assumed that one has the basic knowledge of *SCP* and *Tutorials di Base* (pagina 173).

Following the video of this tutorial.

http://www.youtube.com/watch?v=wUr5ZjpWBo0

First download the sample image from this link (© Copernicus Sentinel data 2016) which is a Sentinel-2 image, and unzip the file.

Create the Band Set

Open the tab *Band set* (pagina 110), click the button and select the bands of the downloaded Sentinel-2 image. In the table *Band set definition* order the band names in ascending order (click to sort bands by name automatically), then highlight band `8A` (i.e. single click on band name in the table) and use the buttons or to place this band at number 8. Finally, select *Sentinel-2* from the list *Quick wavelength settings*, in order to set automatically the *Center wavelength* of each band and the *Wavelength unit* (required for spectral signature calculation).

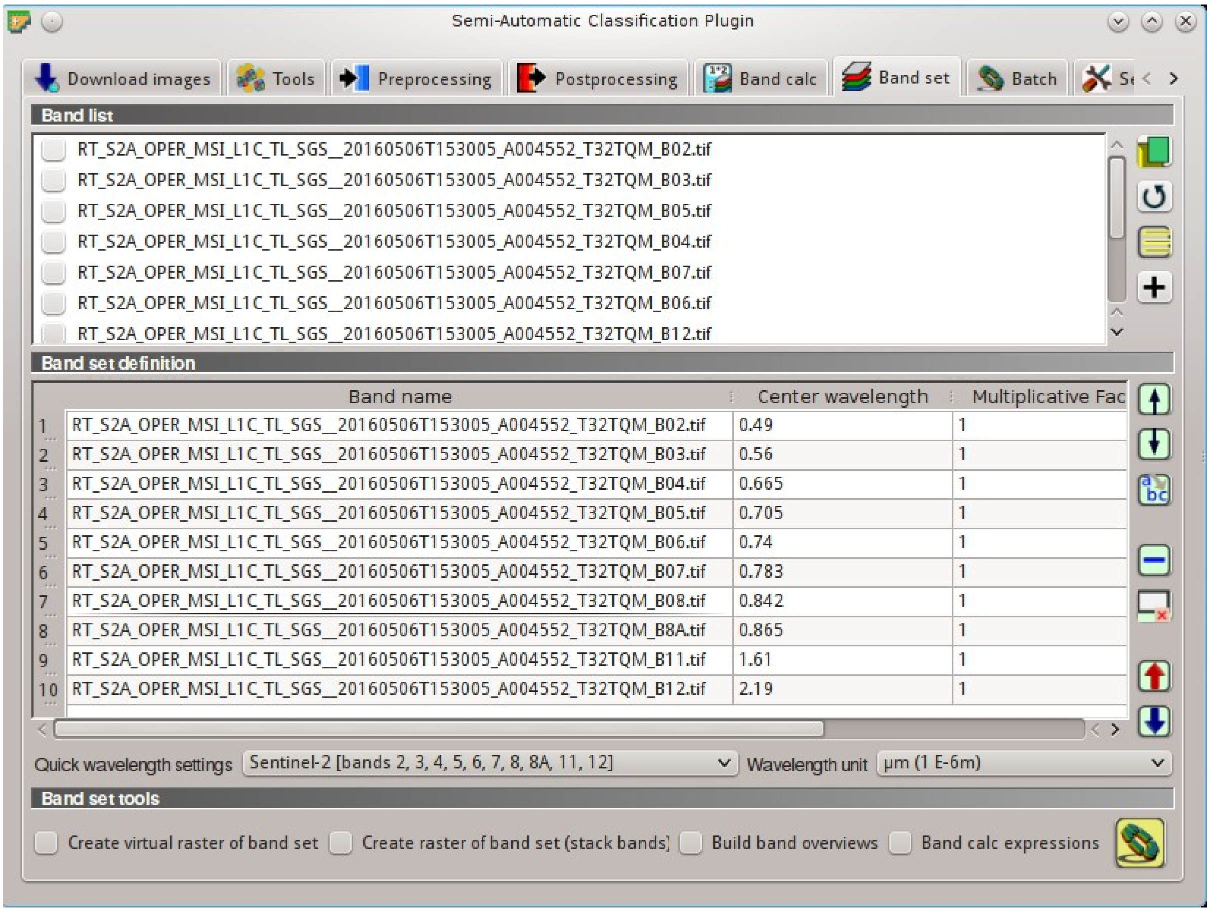


Fig. 22.1: *Band set definition*

Create the ROIs and Define the Spectral Thresholds

In the *SCP dock* (pagina 37) click the button and define a file name for the *Training input*. We are going to create ROIs similarly to *Tutorial 2: Land Cover Classification of Sentinel-2 Images* (pagina 187).

We are going to use the following Macroclass IDs (see *Classi e Macroclassi* (pagina 153)).

Macroclasses

Macroclass name	Macroclass ID
Water	1
Built-up	2
Vegetation	3
Bare soil	4

In addition, we can mask clouds in the image, creating ROIs of clouds and assigning the special *MC ID* = 0.

In the list *RGB=* of *Working toolbar* (pagina 33) define a *Colore Composito* (pagina 147) such as `RGB = 3-2-1` or `RGB = 7-3-2`.

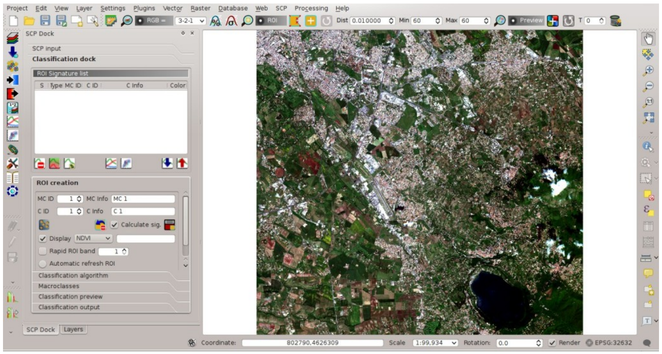


Fig. 22.2: *Color composite*

Now create some ROIs. ROIs are used in *Land Cover Signature Classification* (pagina 156) for defining a spectral region. The *Land Cover Signature Classification* (pagina 156) can use additional classification algorithms for pixels falling inside overlapping regions or outside any spectral region (in this tutorial we are going to use *Minimum Distance* (pagina 154)), therefore it is important that ROIs are homogeneous in order to train correctly the additional algorithm. Following the ROI creation we are going to change the signature thresholds in the *LCS threshold* (pagina 73).

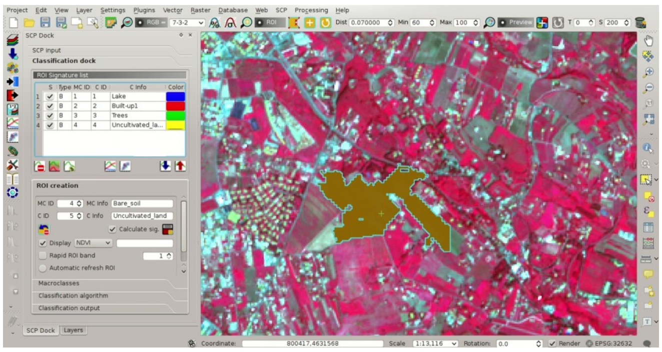


Fig. 22.3: *ROI creation*

After the ROI creation, in the *ROI Signature list* (pagina 41) highlight these spectral signatures, then click the button .

Fig. 22.4: *Signature plot*

Spectral signatures are displayed with the respective colors; also, the semi-transparent area represents the spectral range of each ROI. The minimum and maximum values of these spectral range are displayed in the *Plot Signature list* (pagina 123). You can manually edit these ranges or use the tools *Automatic thresholds* (pagina 125). It is worth noticing the same spectral ranges (of spectral signatures in *ROI Signature list* (pagina 41)) are displayed in the *Signature threshold* (pagina 72).

In *Classification algorithm* (pagina 44) select *Use* *LCS* to use the in *Land Cover Signature Classification* (pagina 156). Now create a classification preview over the lake (see *Create a Classification Preview* (pagina 200)).

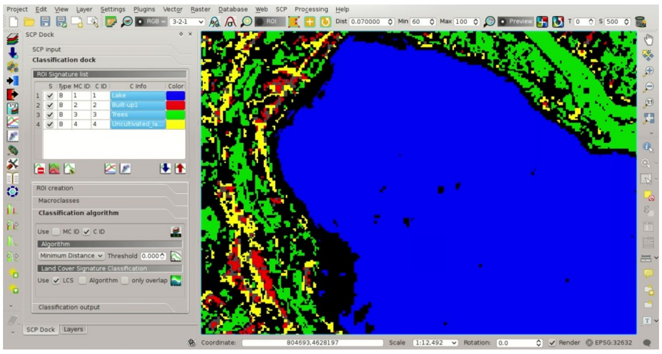


Fig. 22.5: *Classification preview*

You can see that several pixels are unclassified (black) because they are outside any spectral range. In the *Plot Signature list* (pagina 123) highlight a signature of macroclass `Water` and click the button *From pixel* . This tool allows you to extend the spectral range to include a pixel signature. Click an unclassified pixel in the map over the lake; you should see that the spectral range of highlighted signature is larger now. Click the button in the *Working toolbar* (pagina 33).

Now the area classified as water is larger and should include the pixel that was clicked before. Create a temporary ROI over the unclassified area of the lake and click the button *From ROI* .

This way, the spectral range is extended to include the minimum and maximum value of this ROI for each band.

Creating another classification preview we can see that the classified area is extended according to the temporary ROI.

You can extend the spectral range to classify the whole lake as water.

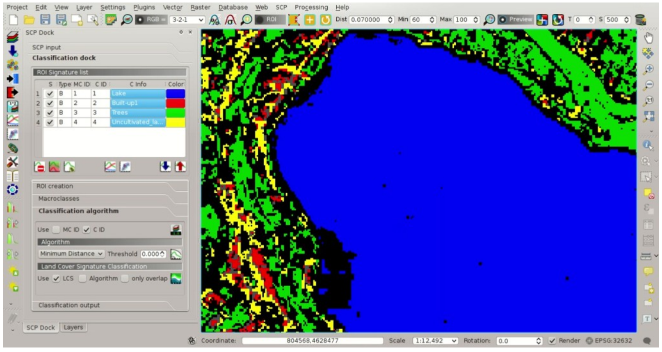


Fig. 22.6: *Classification preview*

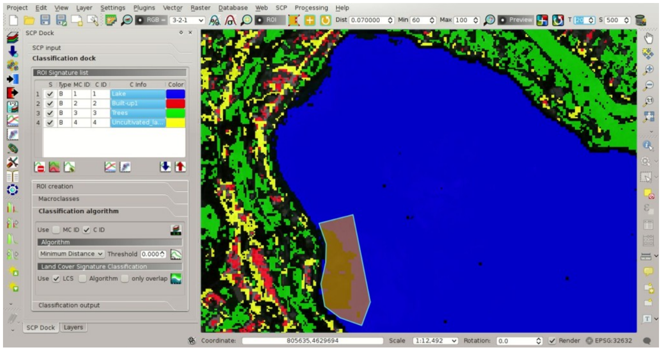


Fig. 22.7: *Signature plot: the spectral range is extended*

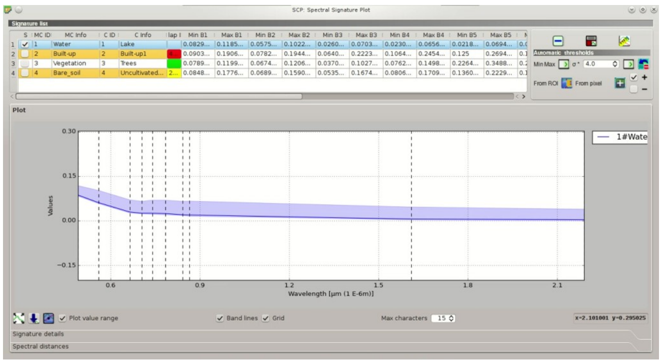


Fig. 22.8: *Signature plot: the spectral range is extended*

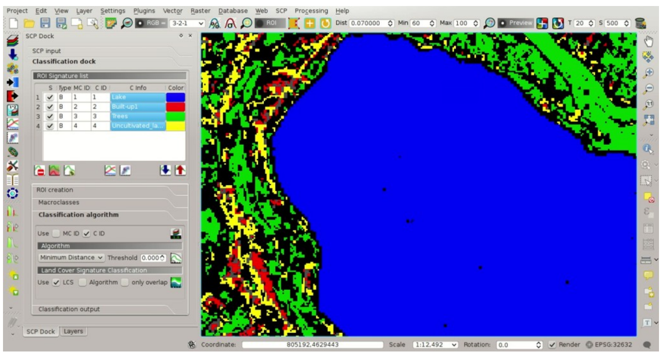


Fig. 22.9: *Classification preview*

> **TIP** : During ROI creation, click the button in *Working toolbar* (pagina 33) and right click on the map for displaying the spectral signature of a pixel in the *Spectral Signature Plot* (pagina 123). This can be useful for assessing unclassified pixels and extend one or more spectral ranges.

Particular attention should be posed on the spectral similarity of classes. For instance soil and built-up can have very similar spectral signatures. Therefore, several ROIs should be collected in the attempt to separate these classes.

Spectral ranges should not overlap in order to avoid unclassified pixels. In the following figure, two signatures have overlapping ranges (it means that potentially there is a signature whose values fall in two classes); these signatures are highlighted in orange in the *Plot Signature list* (pagina 123) (also in the *LC Signature threshold* (pagina 73)) and the combinations `MC ID - C ID` of overlapping signatures are displayed in the column *Color [overlap MC_ID-C_ID]*.

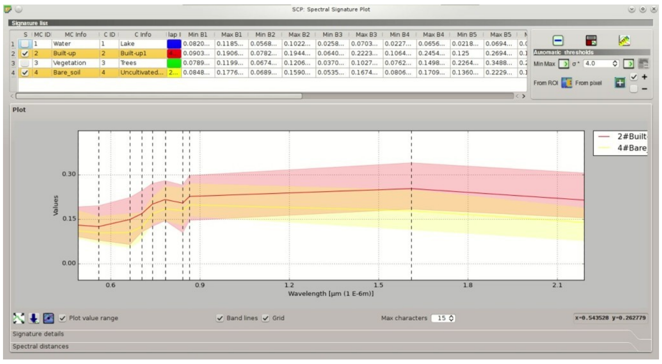


Fig. 22.10: *Overlapping signatures*

It is possible to reduce the range with the button *From ROI* or *From pixel* if the checkbox **–** is checked. In this case, the range is reduced to exclude the values of selected pixels or ROIs.

In addition, it is possible to edit the range directly from the plot. In the *Plot Signature list* (pagina 123) highlight a signature, click the button , then click inside the plot to extend or reduce the range. As a general procedure, you should compare spectral signatures and identify one or more values that could separate the overlapping ranges (if spectral ranges are not overlapping at least in one band then classes are correctly separated).

In case two spectral regions belonging to different classes are overlapping, you should consider reducing the ranges, collecting other spectral signatures with reduced ranges, or extending the spectral range of one signature to include the range of the other spectral signature that will be deleted. For instance, it could be convenient to create two spectral ranges (with two spectral signatures) for the same class in order to easily separate a third spectral signature whose values are comprised between the minimum and maximum values of the other two ranges.

> **TIP** : Check the *Automatic plot* to display automatically the plot of a temporary ROI in the *Spectral Signature Plot* (pagina 123), and assess the spectral range before saving the ROI.

Now check *MC ID* in *Classification algorithm* (pagina 44). When *MC ID* is checked, the classification is performed using all the spectral signatures (without any modification of original spectral values) but assigning the macroclass code. Moreover, only overlapping signatures belonging to different macroclasses are highlighted in *Plot Signature list* (pagina 123). This allows spectral signatures sharing the same *MC ID* to be overlapping.

Also, open the tab *LCS threshold* (pagina 73) for checking the overlap of all the spectral signatures saved in the *Training input*.

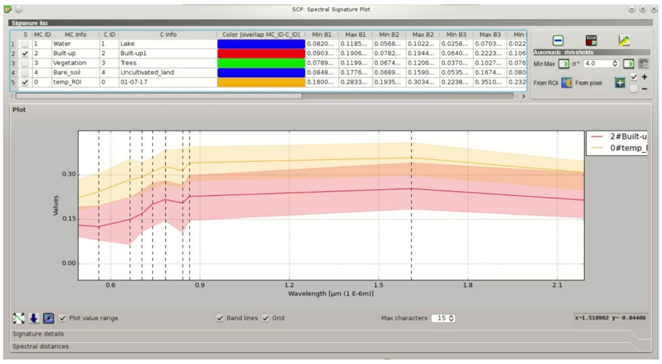


Fig. 22.11: *The plot of a temporary ROI*

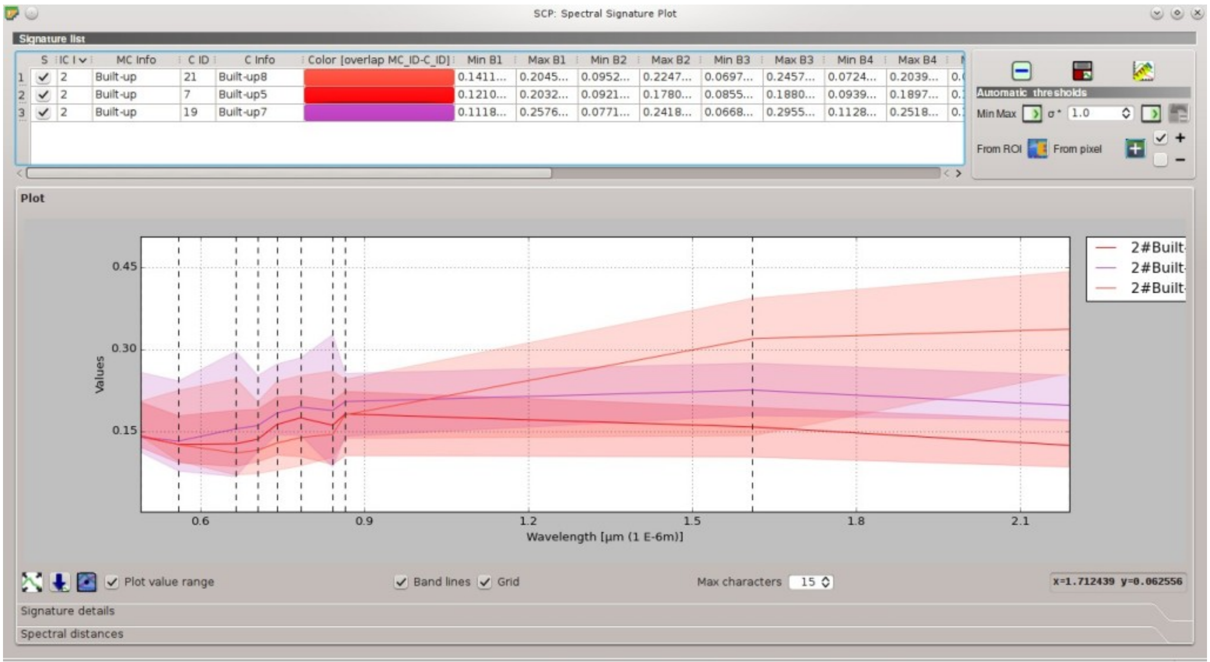


Fig. 22.12: *Overlapping regions belonging to the same MC ID*

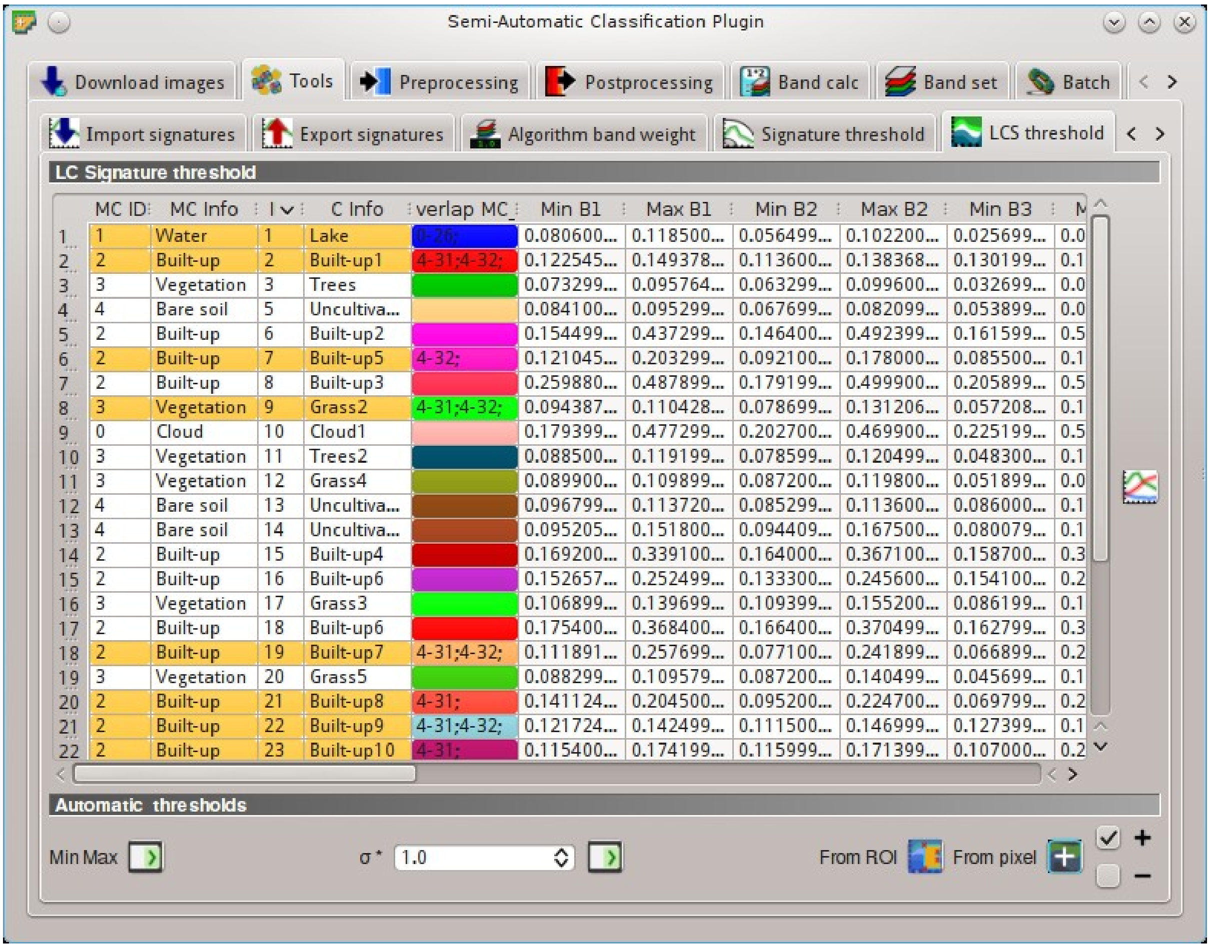


Fig. 22.13: *LCS threshold. Overlapping regions are highlighted in orange*

Land Cover Classification

After the creation of several ROIs and the definition of spectral ranges, we can perform the classification for the whole image.

Having selected *MC ID* and *LCS* in *Classification algorithm* (pagina 44), click the button in the *Classification output* (pagina 46) and select an output destination. After the processing, the classification will be displayed in QGIS.

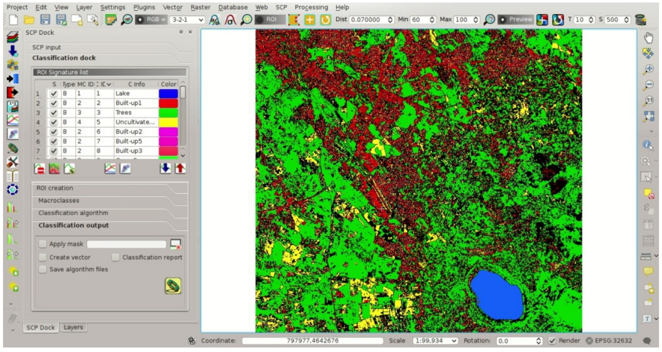


Fig. 22.14: *LCS classification*

Unclassified pixels, displayed in black, are pixels whose spectral signature is not completely contained in any spectral region. Also, pixels contained in more than one spectral region (having different *MC ID*) are classified as *Class Overlap*.

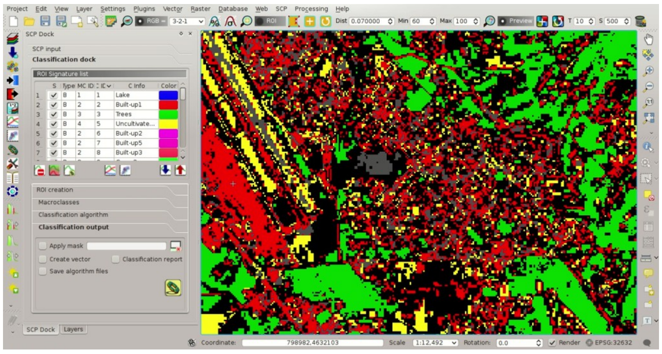


Fig. 22.15: *LCS classification. Class Overlap*

We could create other spectral regions in order to classify all the unclassified pixels. Alternatively, we can use the selected *Algorithm* (pagina 45) for classifying those pixels. Check the *Algorithm* in *Land Cover Signature Classification* (pagina 46) and select the *Minimum Distance* (pagina 154) in *Algorithm* (pagina 45); then click the button in the *Classification output* (pagina 46).

Pixels that were unclassified by *LCS* now are classified using the *Minimum Distance* (pagina 154), which compares calculates the Euclidean distance between pixels and spectral signatures. Black pixels are clouds classified using the special *MC ID* = 0.

In addition, we can use the *Minimum Distance* (pagina 154) to classify only pixels that were labelled *Class Overlap* by *LCS*, leaving unclassified pixels whose spectral signature is not completely contained in any spectral region. Check *only overlap* in *Land Cover Signature Classification* (pagina 46), leaving checked *Algorithm*; then click the button in the *Classification output* (pagina 46).

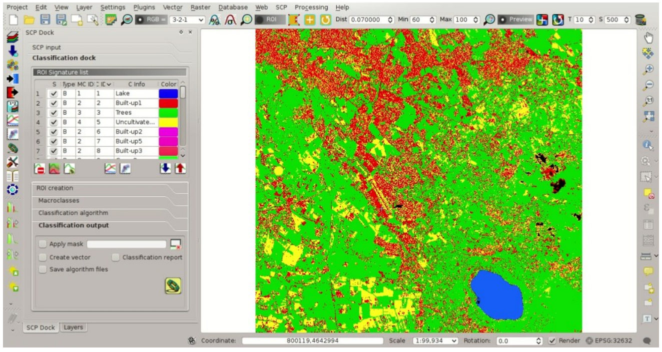


Fig. 22.16: *LCS classification. Classification using the additional classification algorithm*

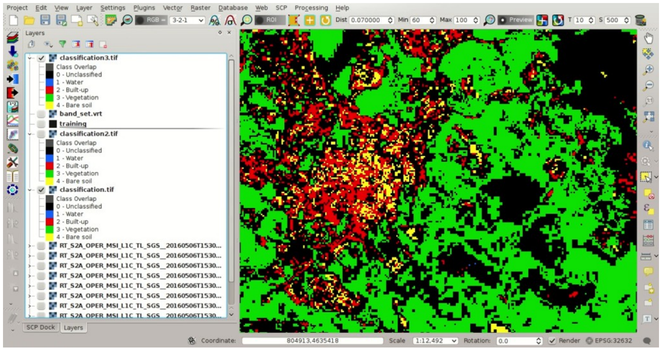


Fig. 22.17: *LCS classification. Classification using the additional classification algorithm only for Class Overlap*

The *Land Cover Signature Classification* (pagina 156) can be useful for the classification of a single land cover class, defining only the spectral ranges that identify our objective. For instance, if we were interested in built-up classification only, we could collect only ROIs for this class, obtaining a classification such as in the following image.

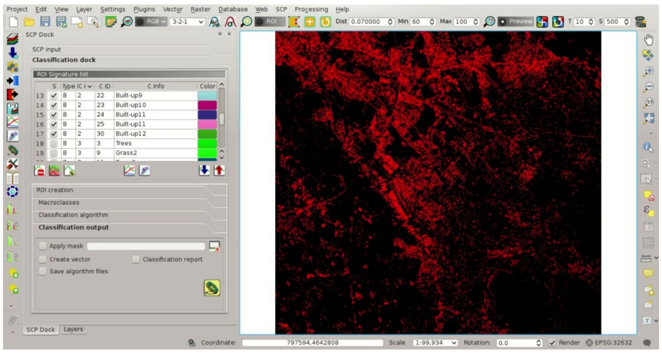


Fig. 22.18: *LCS classification. Classification of the class Built-up*

Other Tutorials

For other tutorials visit the blog From GIS to Remote Sensing .

CAPITOLO 23

Tutorial: Estimation of Land Surface Temperature with Landsat and ASTER

This tutorial is about the estimation land surface temperature using *Satellite Landsat* (pagina 143) and *ASTER Satellite* (pagina 145) images. In this tutorial we are going to use a **land cover classification** for the definition of **surface emissivity**, which is required for the calculation of the **land surface temperature**. It is assumed that one has the basic knowledge of *SCP* and *Tutorials di Base* (pagina 173).

Our study area will be Paris (France), an area covered by urban surfaces, vegetation and agricultural fields.

Before downloading data, please watch the following video that illustrates the study area and provides very useful information about thermal infrared images, and their application (footage courtesy of European Space Agency/ESA). Also, a brief description of the area that we are going to classify is available here .

http://www.youtube.com/watch?v=Vjg5REQb-Bc

The **thermal infrared** band is particularly useful for assessing the temperature difference between the city and the surrounding rural areas, and studying the urban heat island phenomenon. We are going to use **Landsat and ASTER images** for the estimation of land surface temperature. For more information about the conversion of raster bands please read *Conversione At-Satellite Brightness Temperature* (pagina 167). Following the video of this tutorial.

http://www.youtube.com/watch?v=7W4IwlvPLbQ

Data Download and Conversion

We are going to download the **Landsat 8** image acquired in 2015 (image ID = `LC81990262015270LGN00`, data available from the U.S. Geological Survey).

Start a new QGIS project. Open the tab *Download images* (pagina 51) clicking the button in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37). Select the tab *Landsat download* (pagina 51).

In *Login https://ers.cr.usgs.gov/* (pagina 52) you should enter the user name and password for accessing data (free registration at USGS EROS is required) in *User* and *Password*. However, in this case login should not be required because this Landsat 8 image is available directly from the Amazon Web Services (AWS) .

In *Search area* (pagina 52) enter:

- *UL X (Lon)*: 2
- *UL Y (Lat)*: 49
- *LR X (Lon)*: 2.5
- *LR Y (Lat)*: 48.8

> **TIP** : In general it is possible to define the area coordinates clicking the button and drawing a rectangle in the map.

In *Search* (pagina 52) select `L8 OLI/TIRS` from the list *Satellites* and set the acquisition date:

- *Date from*: 2015-09-27
- *to*: 2015-09-27

Now click the button *Find* and after a few seconds the image will be listed in the `Image list`.

In the result table, click the item `LC81990262015270LGN00` in the field *ImageID*, and click the button . A preview will be downloaded and displayed in the map, which is useful for assessing the quality of the image and the cloud cover.

Click the tab *Download options* (pagina 53) and leave checked only the following bands:

- 2 = Blue
- 3 = Green
- 4 = Red
- 5 = Near-Infrared
- 6 = Short Wavelength Infrared 1
- 7 = Short Wavelength Infrared 2
- 10 = Thermal Infrared (TIRS) 1

Bands from 2 to 7 will be used for the land cover classification, and band 10 for the estimation of land surface temperature (see *Why using only Landsat 8 band 10 in the estimation of surface temperature?* (pagina 264)).

The checkbox *Preprocess images* allows for the automatic conversion of bands after the download, according to the settings defined in *Landsat* (pagina 77); we are going to apply the *Correzione DOS1* (pagina 164). Bands from 2 to 7 will be converted to reflectance and band 10 will be converted to At-Satellite Brightness Temperature.

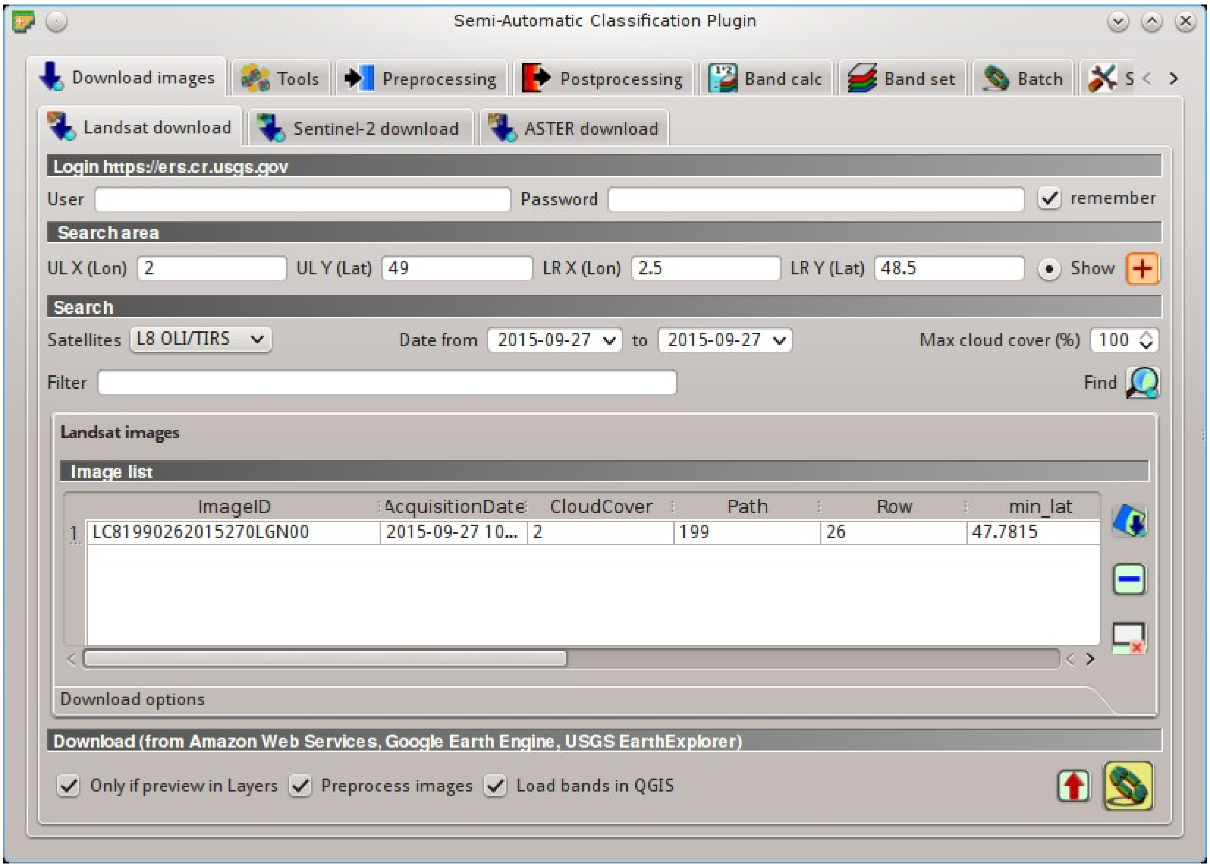


Fig. 23.1: *Landsat search result*

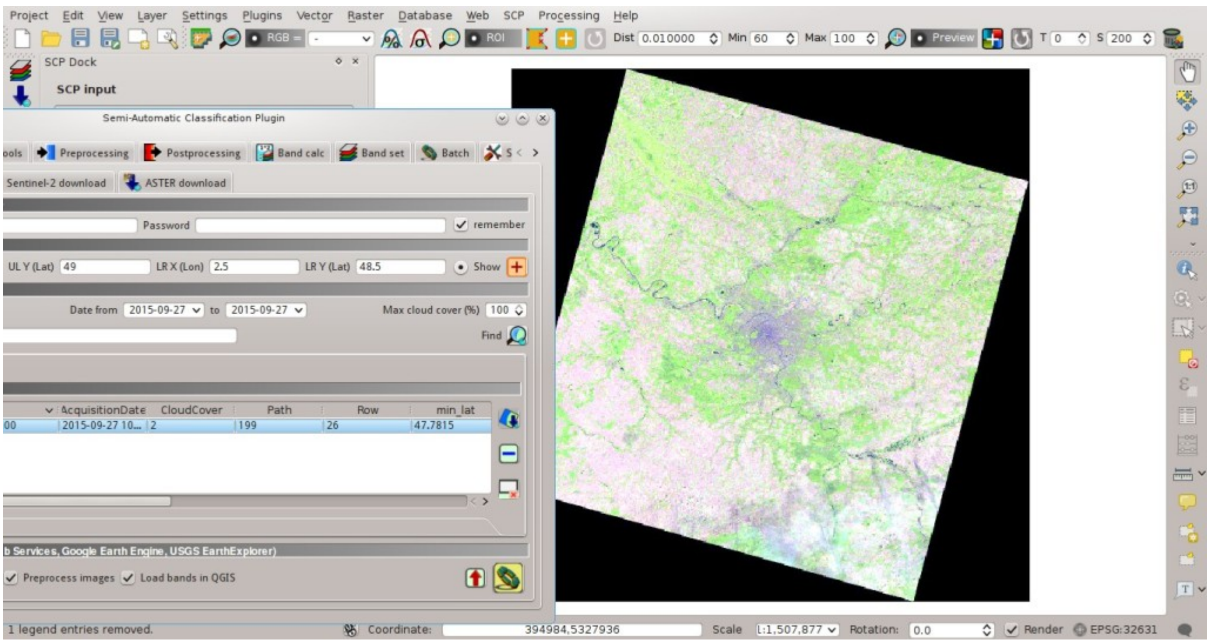


Fig. 23.2: *Image preview*

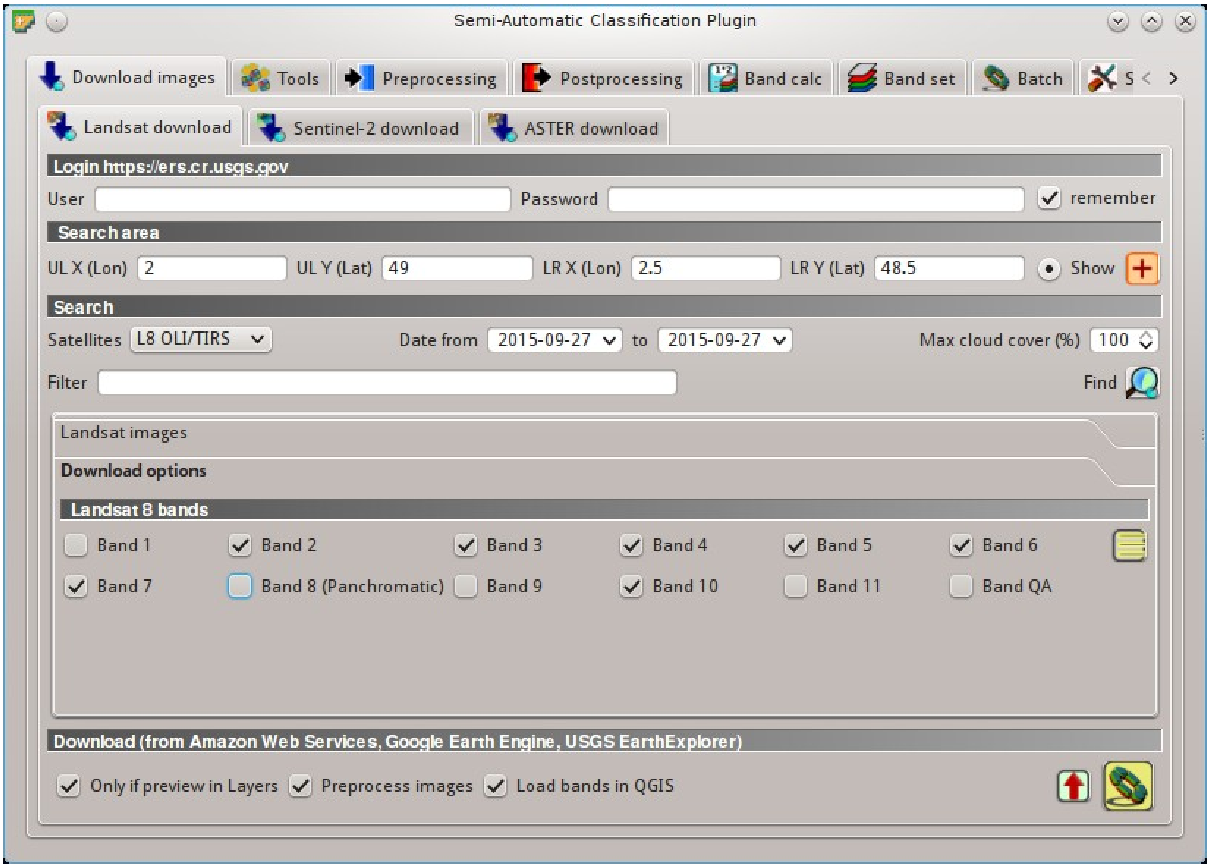


Fig. 23.3: *Selection of bands for download*

Open the tab *Landsat* (pagina 77), check *Apply DOS1 atmospheric correction* and uncheck *Create Band set and use Band set tools* (we are going to create the *Band set* after the clip of the image to study area).

In order to start the **download and conversion process**, open the tab *Landsat download* (pagina 51), click the button and select the directory where converted bands are saved (e.g. `Desktop`). After a few minutes, converted bands are loaded and displayed (file name starts with `RT_`).

Clip to Study Area

We are going to **clip the Landsat images** to our study area.

Open the tab *Preprocessamento* (pagina 77) clicking the button in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37). Select the tab *Clip multiple rasters* (pagina 84) and click the button to refresh the layer list and show the loaded rasters. Click the button to select all the rasters to be clipped, and in *Clip coordinates* (pagina 84) type the following values:

- *UL X*: 402705
- *UL Y*: 5461065
- *LR X*: 480824
- *LR Y*: 5381535

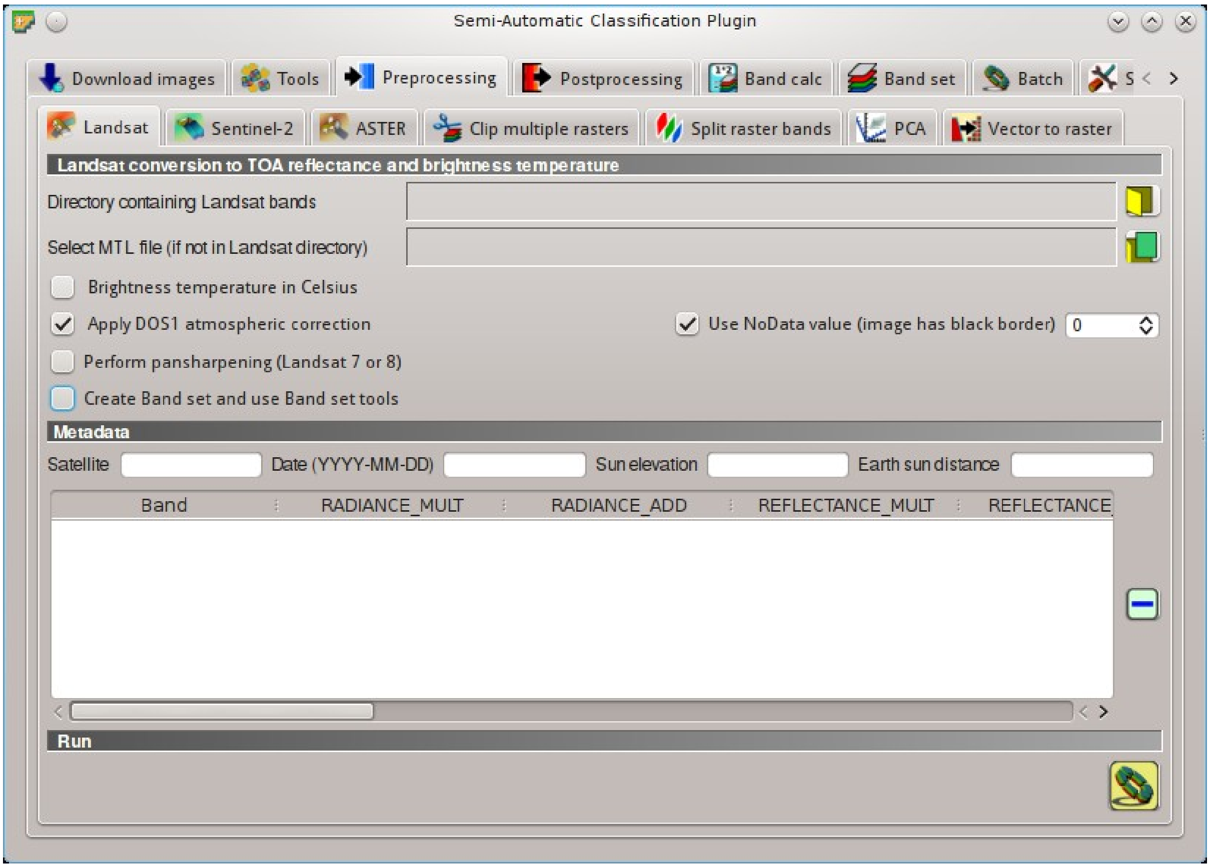


Fig. 23.4: *Conversion settings*

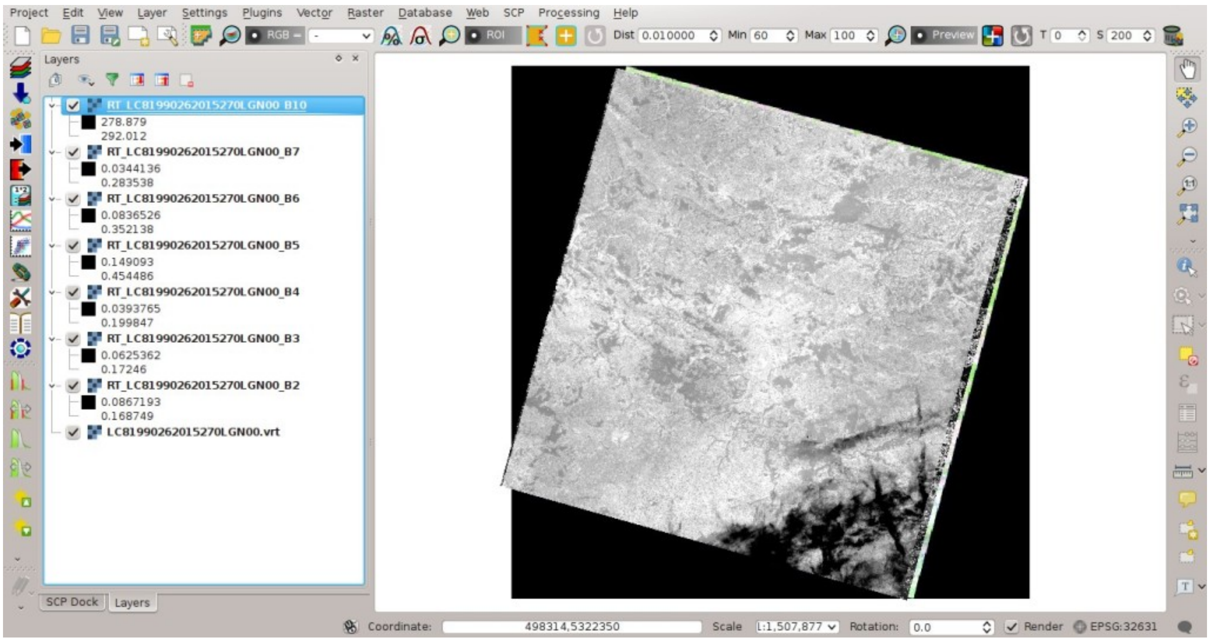


Fig. 23.5: *Converted Landsat bands*

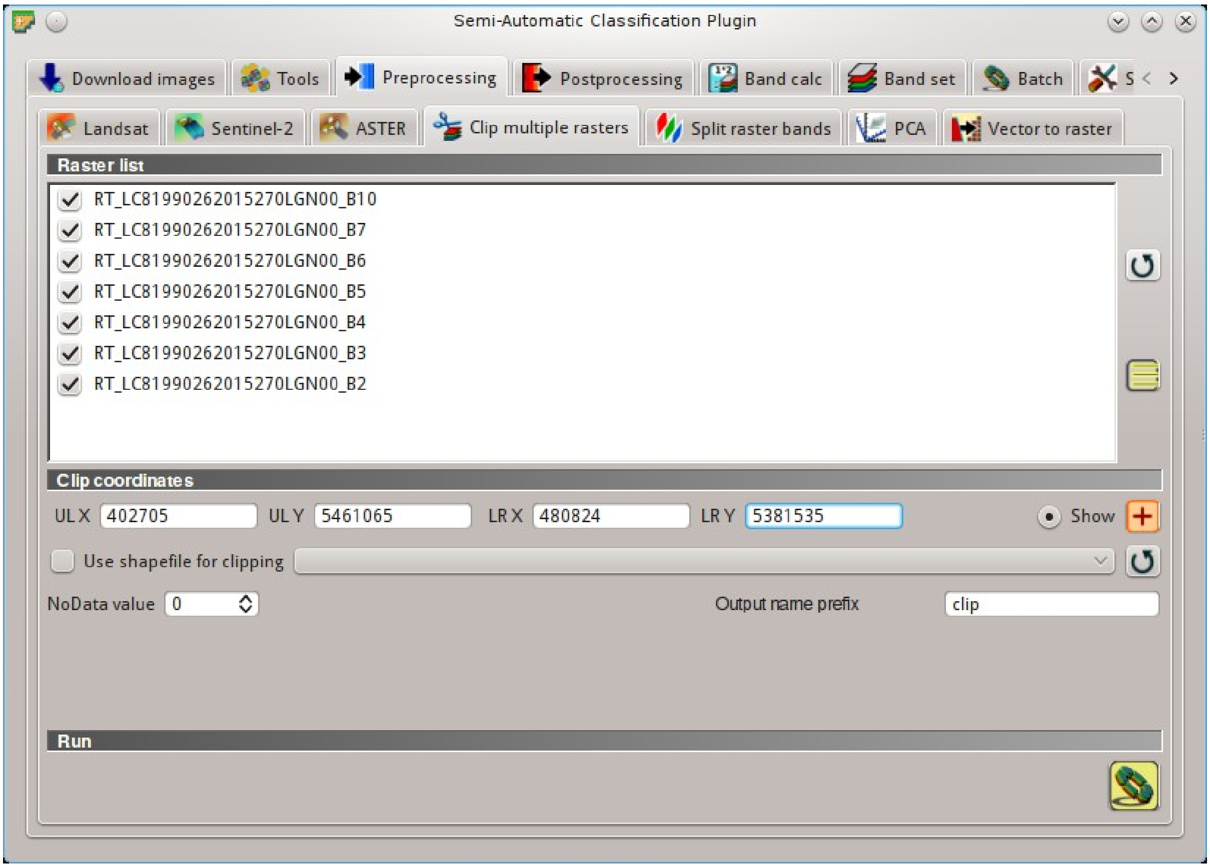


Fig. 23.6: *Clip area*

Now click the button  and select the directory where clipped bands are saved (e.g. `Desktop`). Clipped bands have the prefix `clip_` and will be automatically loaded and displayed. We can remove the bands whose names start with `RT_` from QGIS layers.

Land Cover Classification

Now we need to classify land cover, which will be used later for the creation of the emissivity raster. For detailed instructions about the **classification process** please see *Tutorial 2: Land Cover Classification of Sentinel-2 Images* (pagina 187).

We are going to use the following **Macroclass IDs** (see *Classi e Macroclassi* (pagina 153)).

Macroclasses

Macroclass name	Macroclass ID
Water	1
Built-up	2
Vegetation	3
Bare soil	4

Open the tab *Band set* (pagina 110) clicking the button  and define the Landsat 8 *Band set* using clipped bands from 2 to 7 (excluding band 10).

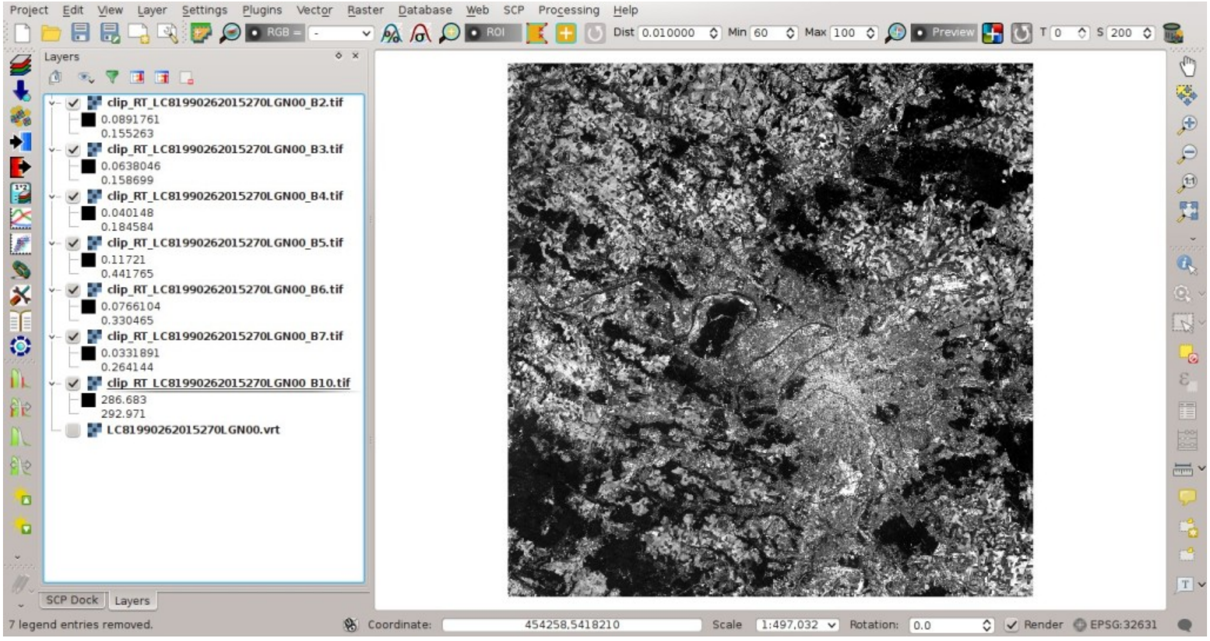


Fig. 23.7: *Clipped bands*

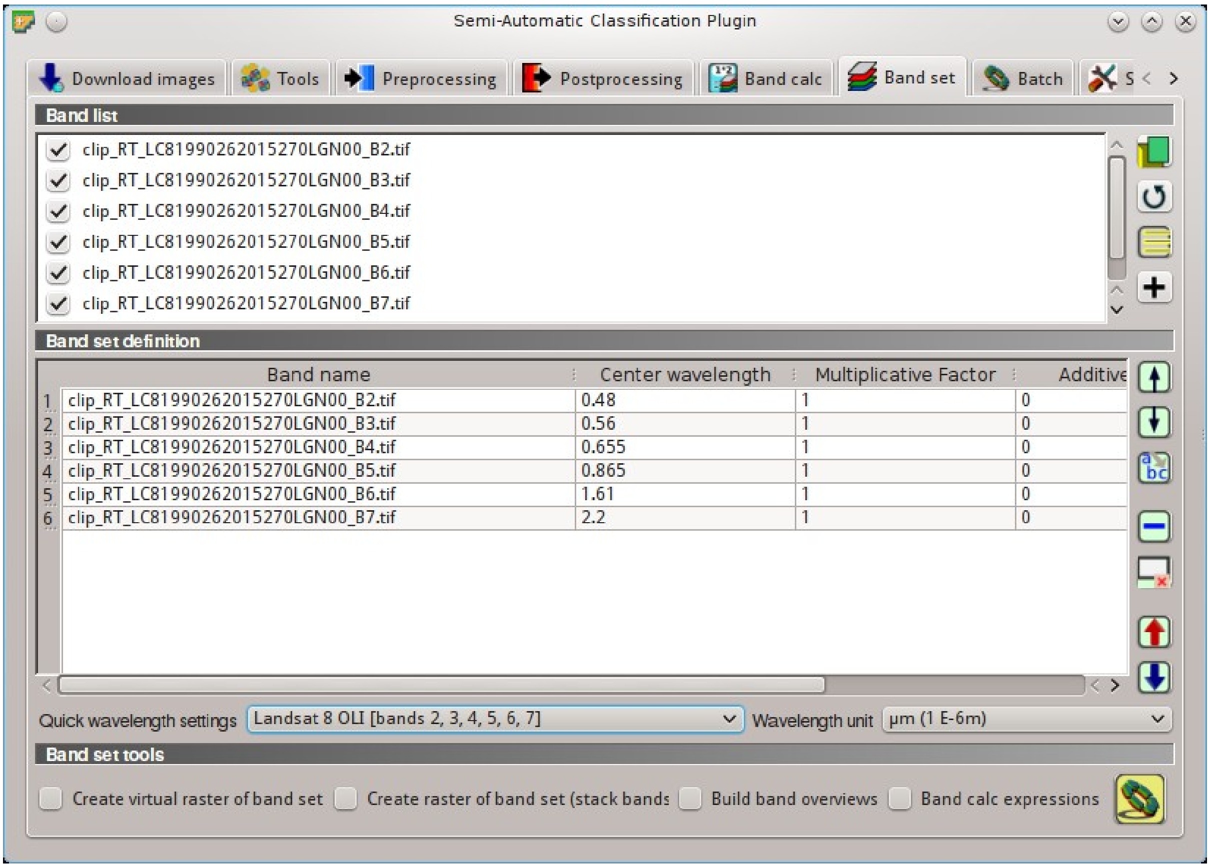


Fig. 23.8: *Band set*

In the *SCP dock* (pagina 37) click the button , define a file name for the *Training input*. In the list *RGB=* of *Working toolbar* (pagina 33) select `4-3-2` to display a false color composite corresponding to the bands: Near-Infrared, Red, and Green (see *Colore Composito* (pagina 147)).

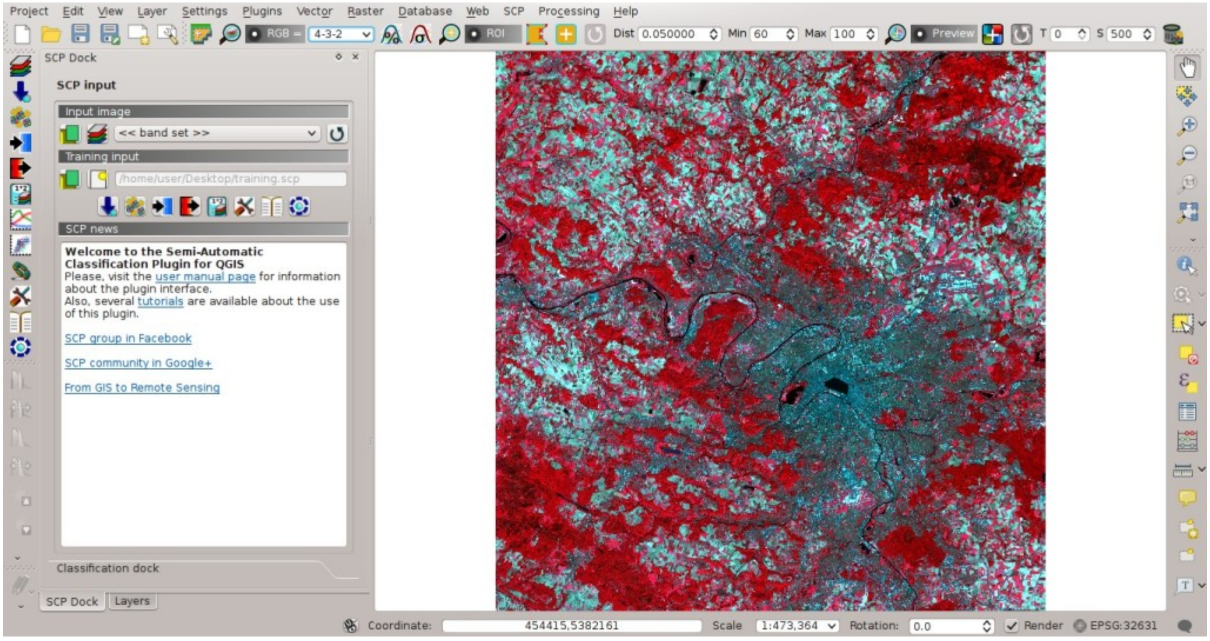


Fig. 23.9: *Color composite*

After the creation of several ROIs for each land cover class, we can perform the classification of the whole image (see *Tutorial 2: Land Cover Classification of Sentinel-2 Images* (pagina 187)). After setting the colors of *MC ID* (in the tab *Macroclasses* (pagina 43) of the *SCP dock* (pagina 37)), in the tab *Classification algorithm* (pagina 44) check the option *MC ID* to use Macroclass IDs and select the classification algorithm *Maximum Likelihood* (pagina 154).

Then, open the tab *Classification output* (pagina 46), click the button and define the name of the classification output.

Reclassification of Land Cover Classification to Emissivity Values

Now we are going to reclassify the classification raster using the **land surface emissivity** values. The emissivity (e) values for the land cover classes are provided in the following table (values used in this tutorial are only indicative, because emissivity of every material should be obtained from field survey):

Emissivity values

Land surface	Emissivity e
Water	0.98
Built-up	0.94
Vegetation	0.98
Bare soil	0.93

Open the tab *Postprocessamento* (pagina 91) clicking the button in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37). Select the tab *Reclassification* (pagina 96) and click the button to refresh the layer list and show the loaded rasters. Select the classification raster from the list.

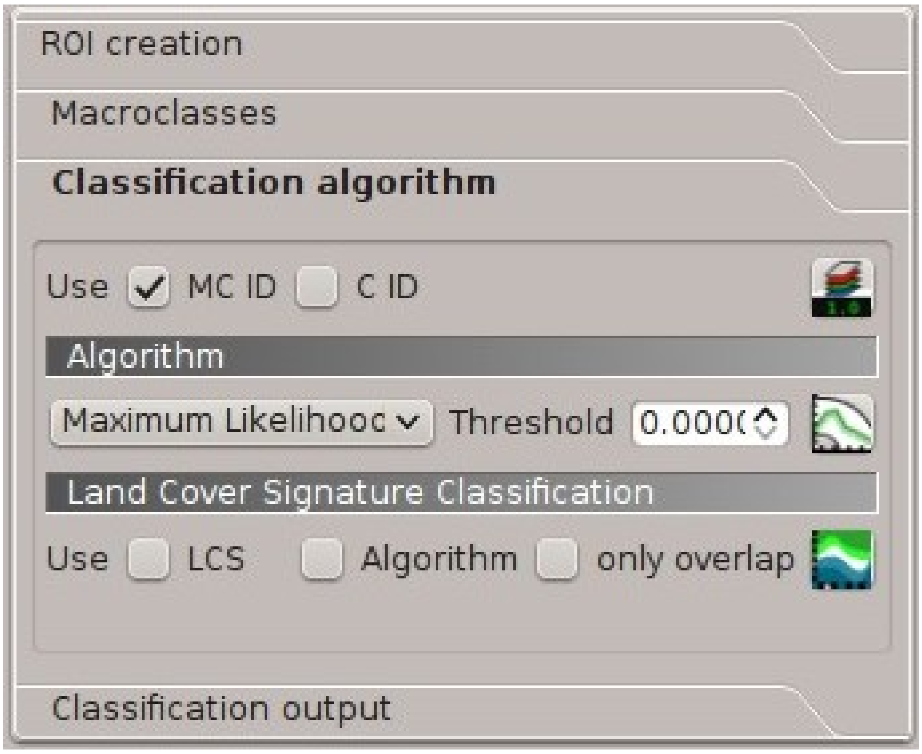


Fig. 23.10: *Classification algorithm*

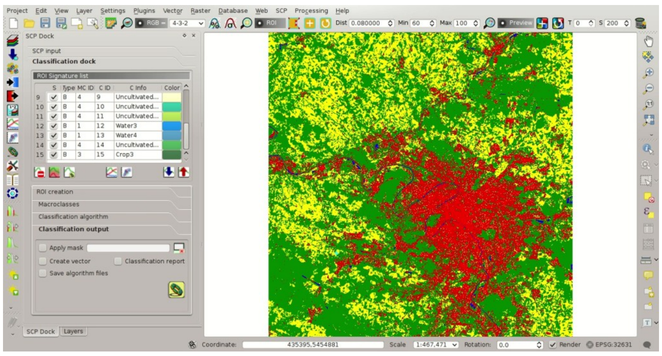


Fig. 23.11: *Land cover classification*

Click the button to add 4 rows to the table *Values*. In this table, set the old value (the Macroclass ID of the classification) and the new value (the corresponding emissivity e) for every land cover class. Uncheck the checkbox *Use code from Signature list*, click the button and define the name of the output raster (e.g. `emissivity.tif`).

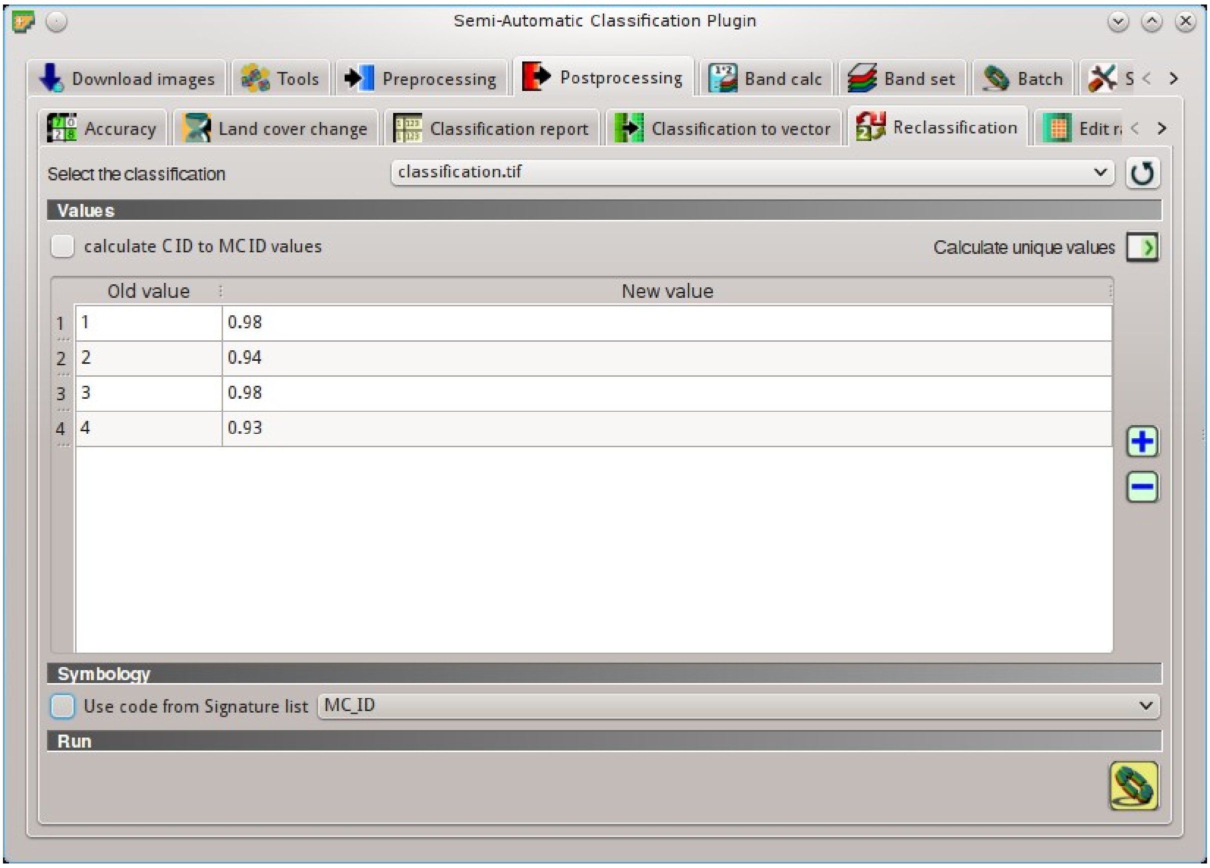


Fig. 23.12: *Reclassification*

This is the emissivity raster, where each pixel has the emissivity value that we have defined for the respective land cover class.

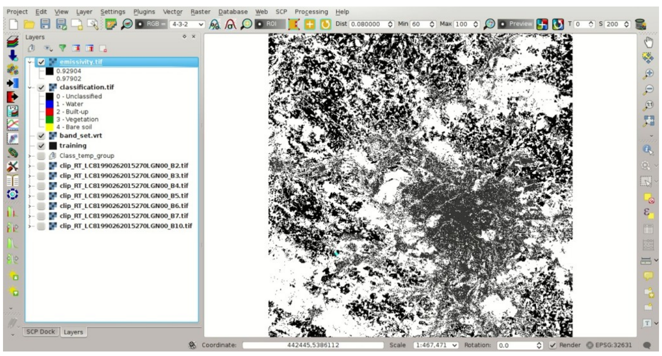


Fig. 23.13: *Emissivity raster*

Conversion from At-Satellite Temperature to Land Surface Temperature

Now we are ready to convert the At-Satellite Brightness Temperature to **Land Surface Temperature**, using the following equation (see *Estimation of Land Surface Temperature* (pagina 168)):

$$T = T_B/[1 + (\lambda * T_B/c_2) * ln(e)]$$

where:

- λ = wavelength of emitted radiance
- $c_2 = h * c/s = 1.4388 * 10^{-2}$ m K = 14388 µm K
- h = Planck's constant = $6.626 * 10^{-34}$ J s
- s = Boltzmann constant = $1.38 * 10^{-23}$ J/K
- c = velocity of light = $2.998 * 10^{8}$ m/s

The values of λ for Landsat bands are listed in the following table.

Center wavelength of Landsat bands

Satellite	Band	$\lambda(m)$
Landsat 4, 5, and 7	6	11.45
Landsat 8	10	10.8
Landsat 8	11	12

Open the tab *Band calc* (pagina 104) clicking the button in the *SCP menu* (pagina 29), or the *SCP Tools* (pagina 31), or the *SCP dock* (pagina 37). Click the button to refresh the layer list and show the loaded rasters. We have used band 10 of Landsat 8, therefore in the *Expression* (pagina 107) type the equation for conversion adapted to our rasters:

```
"clip_RT_LC81990262015270LGN00_B10.tif" / ( 1 + ( 10.8 * "clip_RT_
↪LC81990262015270LGN00_B10.tif" / 14388 ) * ln("emissivity.tif") )
```

Click the button and define the name of the output raster (e.g. `surface_temperature.tif`). After the calculation, the Land Surface Temperature (in kelvin) will be loaded, and we can change the layer style. In addition, in the tab *Band calc* (pagina 104) we can calculate the temperature in Celsius with the expression:

```
"surface_temperature.tif" - 273.15
```

We can notice that the urban area and uncultivated land have the highest temperatures, while vegetation has the lowest temperature. The aim of this tutorial is to describe a methodology for the estimation of surface temperature using open source programs and free images. It is worth highlighting that in order to achieve more accurate results, one should perform field survey for improving the land cover classification and the estimation of surface emissivities.

In addition to Landsat, we are going to use an ASTER image and use the same methodology for the estimation of Land Surface Temperature.

Data Download and Conversion of ASTER Image

Open the tab *Download images* (pagina 51) and select the tab *ASTER download* (pagina 59).

In *Login https://urs.earthdata.nasa.gov* (pagina 60) enter the user name and password required for accessing data (free registration at EOSDIS Earthdata is required) in *User* and *Password*. The ASTER L1T data products are

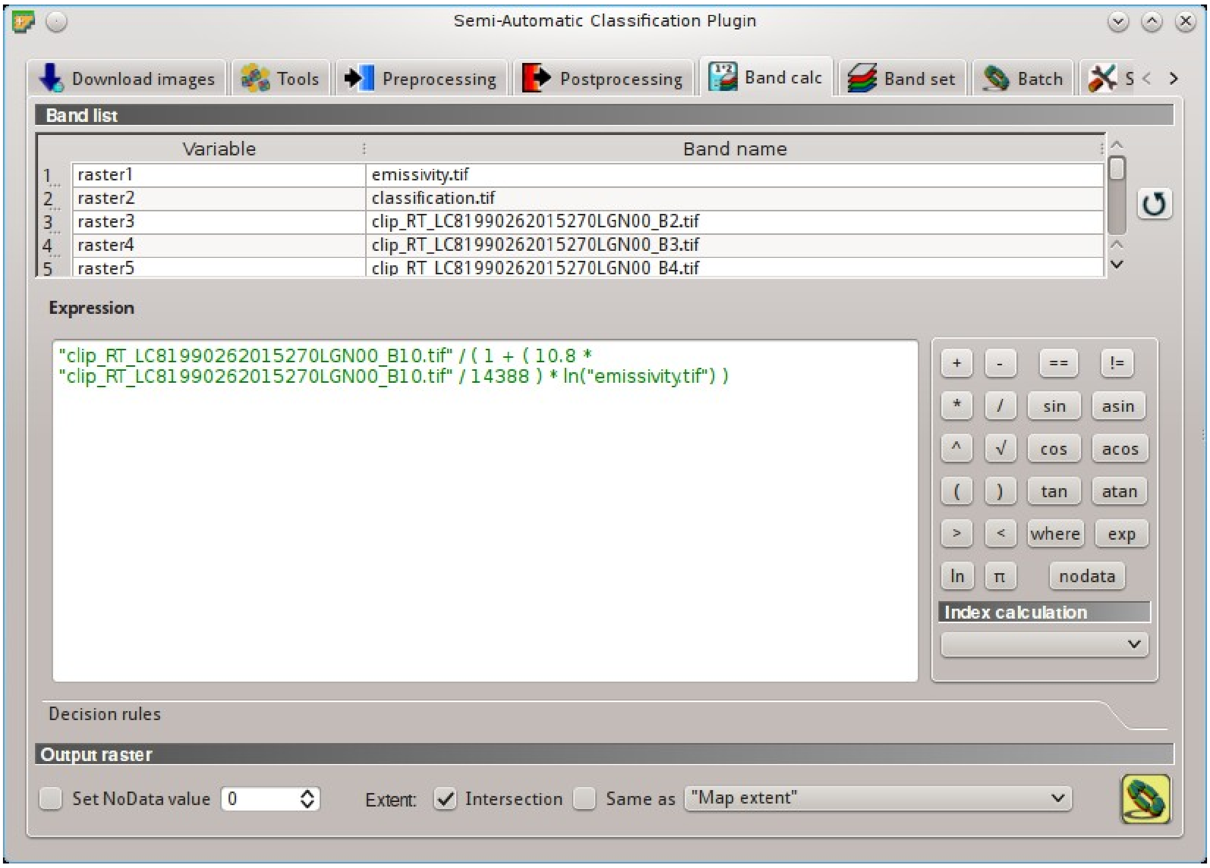


Fig. 23.14: *Calculation of surface temperature*

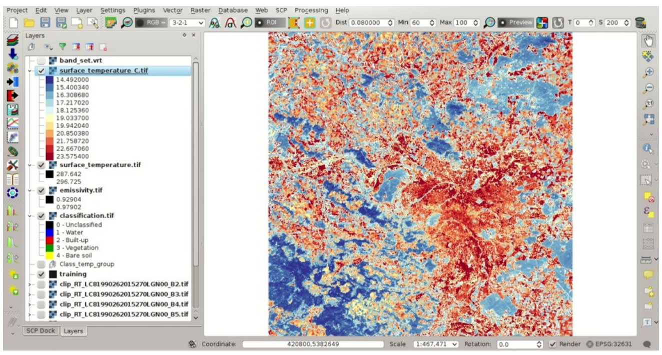


Fig. 23.15: *Land Surface Temperature of the Landsat Image*

retrieved from the online Data Pool, courtesy of the NASA Land Processes Distributed Active Archive Center (LP DAAC), USGS/Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota, https://lpdaac.usgs.gov/data_access/data_pool.

In *Search area* (pagina 60) enter:

- *UL X (Lon)*: 2
- *UL Y (Lat)*: 49
- *LR X (Lon)*: 2.5
- *LR Y (Lat)*: 48.8

In *Search* (pagina 60) set the acquisition date:

- *Date from*: 2000-08-24
- *to*: 2000-08-24

Now click the button *Find* and after a few seconds the image will be listed in the `Image list`.

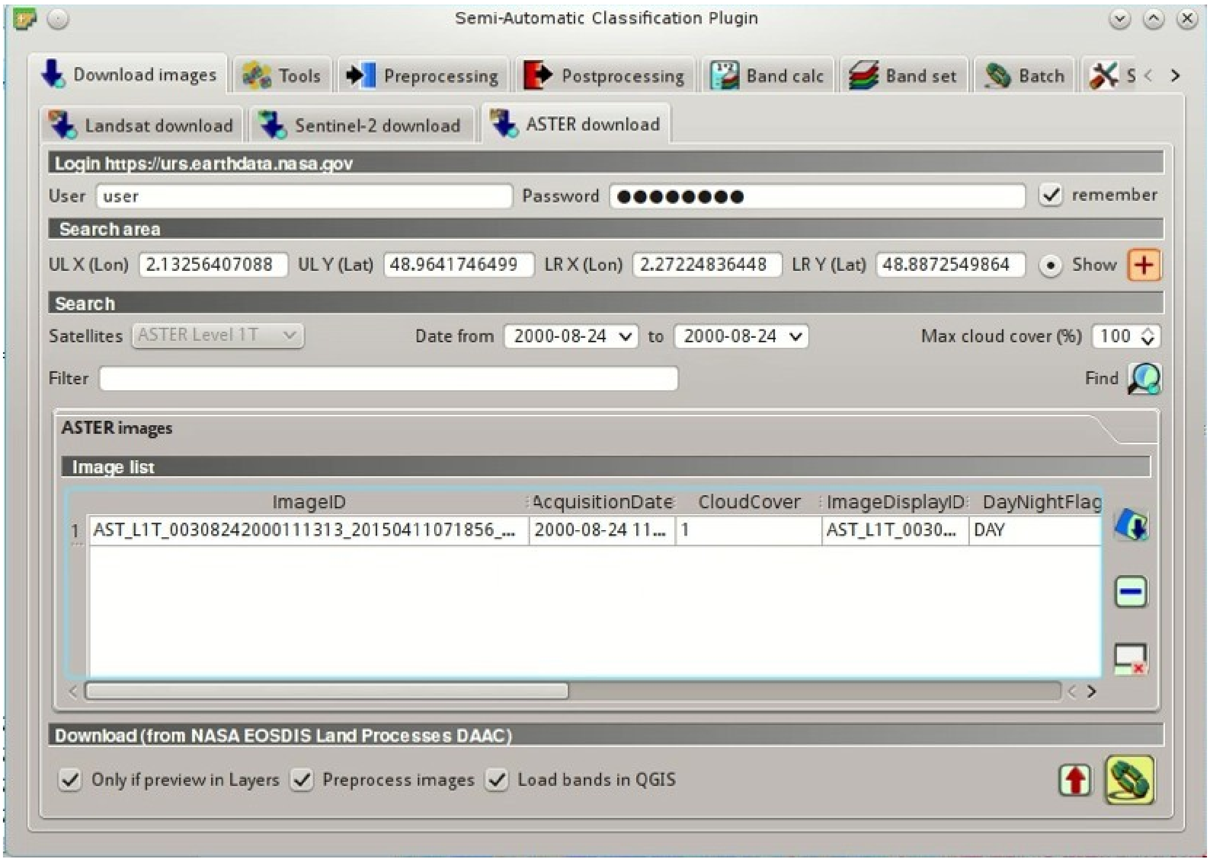


Fig. 23.16: *ASTER search result*

In the result table, click the item `AST_L1T_00308242000111313_20150411071856_3805` in the field *ImageID*, and click the button . A preview will be downloaded and displayed in the map, which is useful for assessing the quality of the image and the cloud cover.

As we did for Landsat, we are going to apply the *Correzione DOS1* (pagina 164). The checkbox *Preprocess images* allows for the automatic conversion of bands after the download, according to the settings defined in *ASTER* (pagina 80). Bands from 1 to 9 will be converted to reflectance and bands from 10 to 14 will be converted to At-Satellite Brightness Temperature.

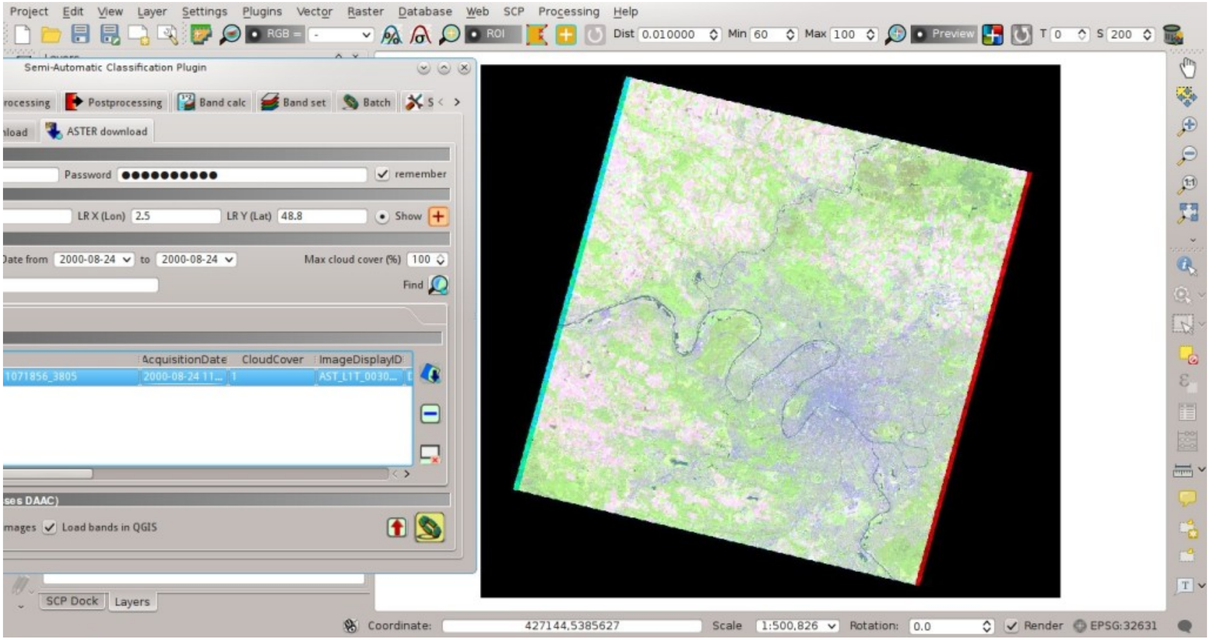


Fig. 23.17: *ASTER image preview*

Open the tab *ASTER* (pagina 80), check *Apply DOS1 atmospheric correction* and leave checked *Create Band set and use Band set tools* (this is useful to automatiacally create a *Band set*, which is required for the next step).

In order to start the **download and conversion process**, open the tab *ASTER download* (pagina 59), click the button and select the directory where converted bands are saved (e.g. `Desktop`). After a few minutes, converted bands are loaded and displayed (file name starts with `RT_`).

Clip to Study Area of ASTER image

We are going to **clip the ASTER images** to our study area, because bands are not aligned at the border.

Open the tab *Preprocessamento* (pagina 77) clicking the button . Select the tab *Clip multiple rasters* (pagina 84) and click the button to refresh the layer list and show the loaded rasters. *Band set'Click the button |select_all| to select all the rasters to be clipped, and check |checkbox| :guilabel:'Use temporary ROI for clipping*. Now, we can draw a manual ROI (because a *Band set* is already defined, see *Creazione ROI* (pagina 42)) about the same shape of the ASTER image, about 20 pixels within the border thereof (in order to align the border of all the bands).

Now click the button and select the directory where clipped bands are saved (e.g. `Desktop`). Clipped bands have the prefix `clip_` and will be automatically loaded and displayed. We can remove the bands whose names start with `RT_` from QGIS layers.

Land Cover Classification of ASTER Image

Using the same Macroclass IDs used for Landsat, we are going to classify the ASTER image.

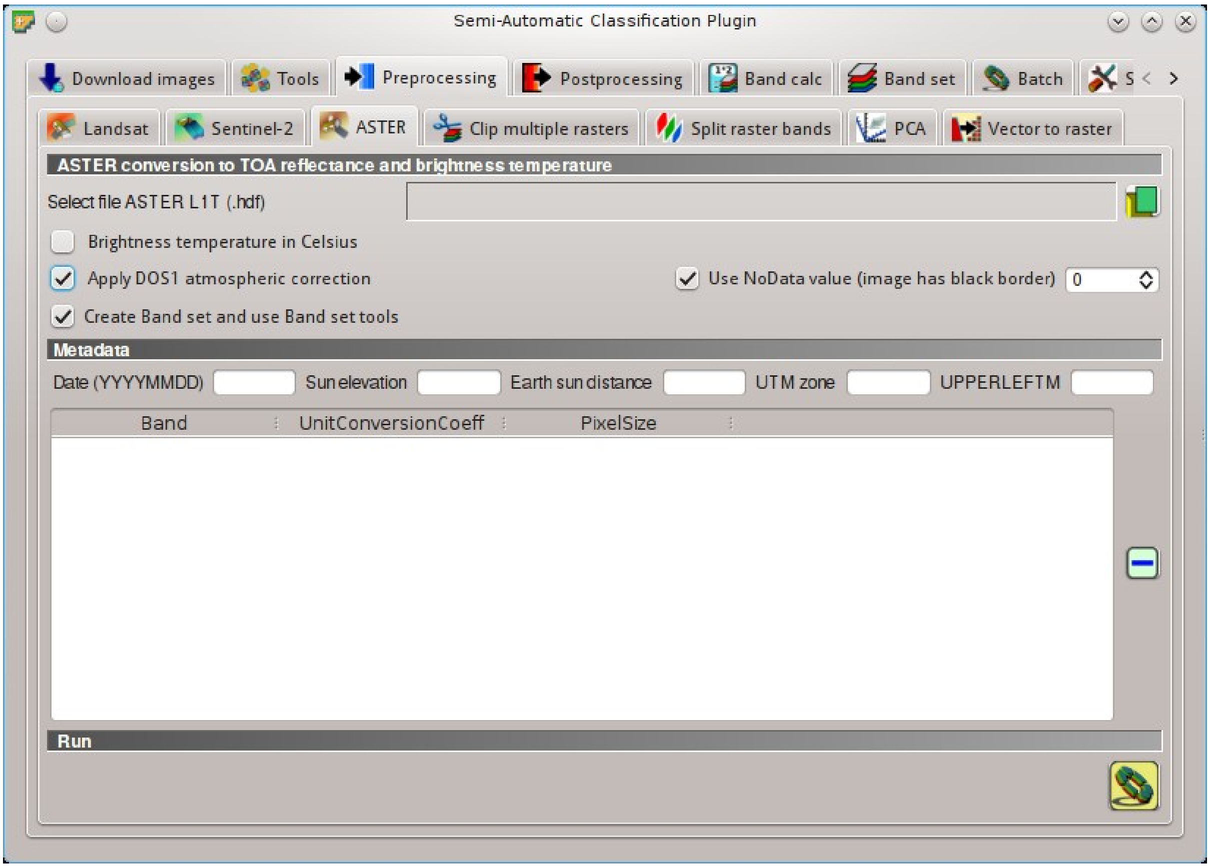


Fig. 23.18: *Conversion settings*

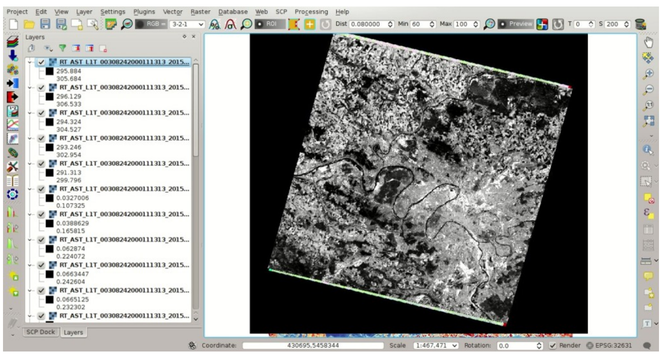


Fig. 23.19: *Converted ASTER bands*

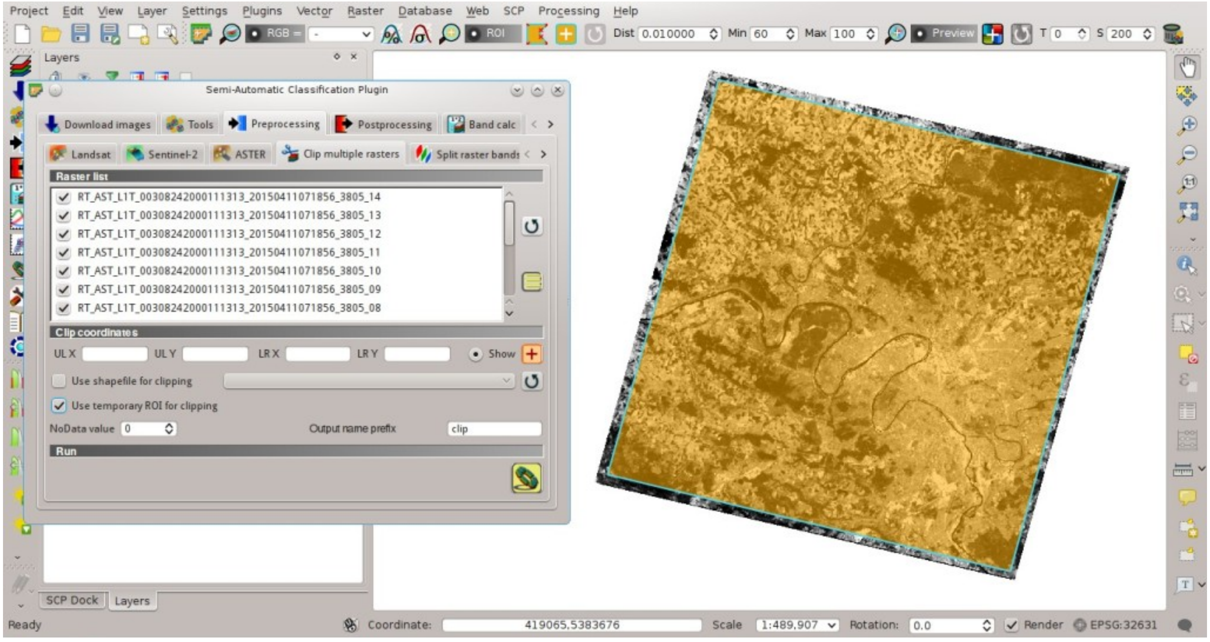


Fig. 23.20: *Clip area*

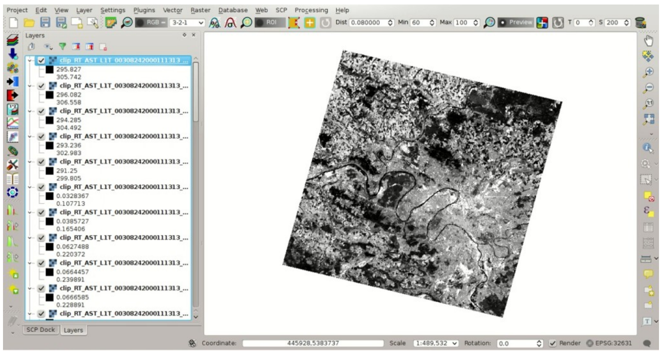


Fig. 23.21: *Clipped bands*

Open the tab *Band set* (pagina 110) clicking the button . Click tha button to clear all bands from *Band set* and define the ASTER *Band set* using the clipped bands from 1 to 9.

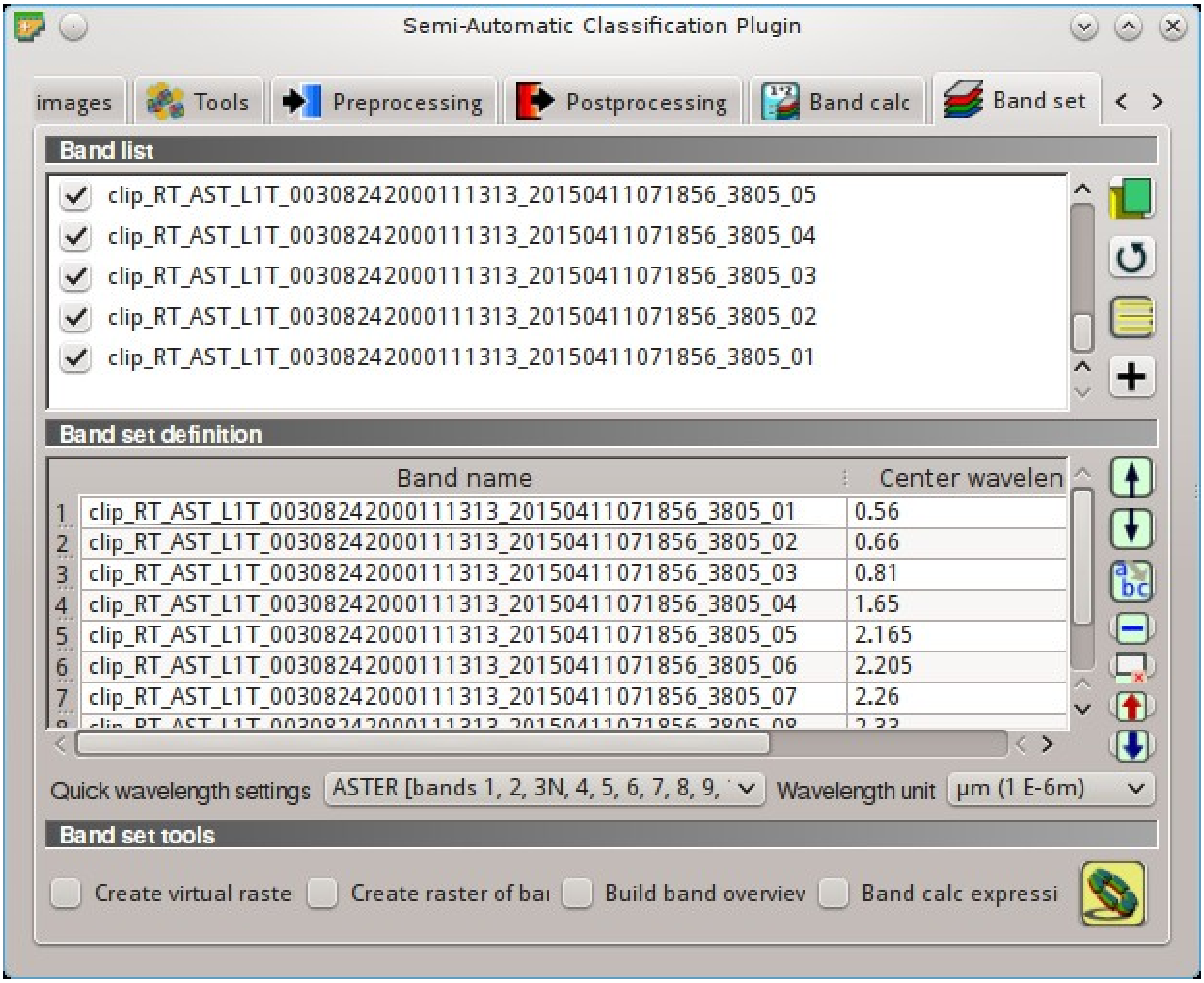


Fig. 23.22: *ASTER band set*

In the *SCP dock* (pagina 37) click the button , define a file name for the *Training input* (e.g. `training_ASTER`). Clear the table *ROI Signature list* (pagina 41) highlighting all the spectral signatures created previously for Landsat and clicking the button .

In the list *RGB=* of *Working toolbar* (pagina 33) select `3-2-1` to display a false color composite corresponding to the bands: Near-Infrared, Red, and Green (see *Colore Composito* (pagina 147)).

After the creation of several ROIs for each land cover class, we can perform the classification of the whole image. After setting the colors of *MC ID* (in the tab *Macroclasses* (pagina 43) of the *SCP dock* (pagina 37)), in the tab *Classification algorithm* (pagina 44) check the option *MC ID* to use Macroclass IDs and select the classification algorithm *Maximum Likelihood* (pagina 154). Then, open the tab *Classification output* (pagina 46), click the button and define the name of the classification output (e.g. `classification_aster.tif`).

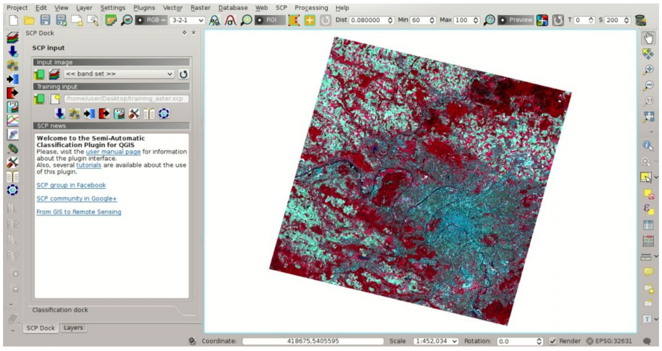


Fig. 23.23: *ASTER color composite*

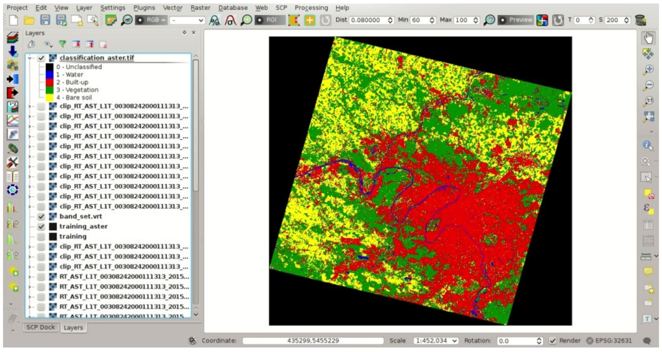


Fig. 23.24: *ASTER land cover classification*

Reclassification of Land Cover Classification to Emissivity Values of ASTER Image

Now we are going to reclassify the classification raster using the same **land surface emissivity** values used for Landsat.

Open the tab *Postprocessamento* (pagina 91) clicking the button . Select the tab *Reclassification* (pagina 96) and click the button to refresh the layer list and show the loaded rasters. Select the classification raster from the list.

Click the button to add 4 rows to the table *Values*. In this table, set the old value (the Macroclass ID of the classification) and the new value (the corresponding emissivity e) for every land cover class. Uncheck the checkbox *Use code from Signature list*, click the button and define the name of the output raster (e.g. `emissivity_aster.tif`).

The following figure show the emissivity raster of ASTER image.

Conversion from At Satellite Temperature to Land Surface Temperature of ASTER Image

We can convert the At-Satellite Brightness Temperature to **Land Surface Temperature**, using the same equation used for Landsat (see *Estimation of Land Surface Temperature* (pagina 168)).

The values of λ for ASTER bands are listed in the following table.

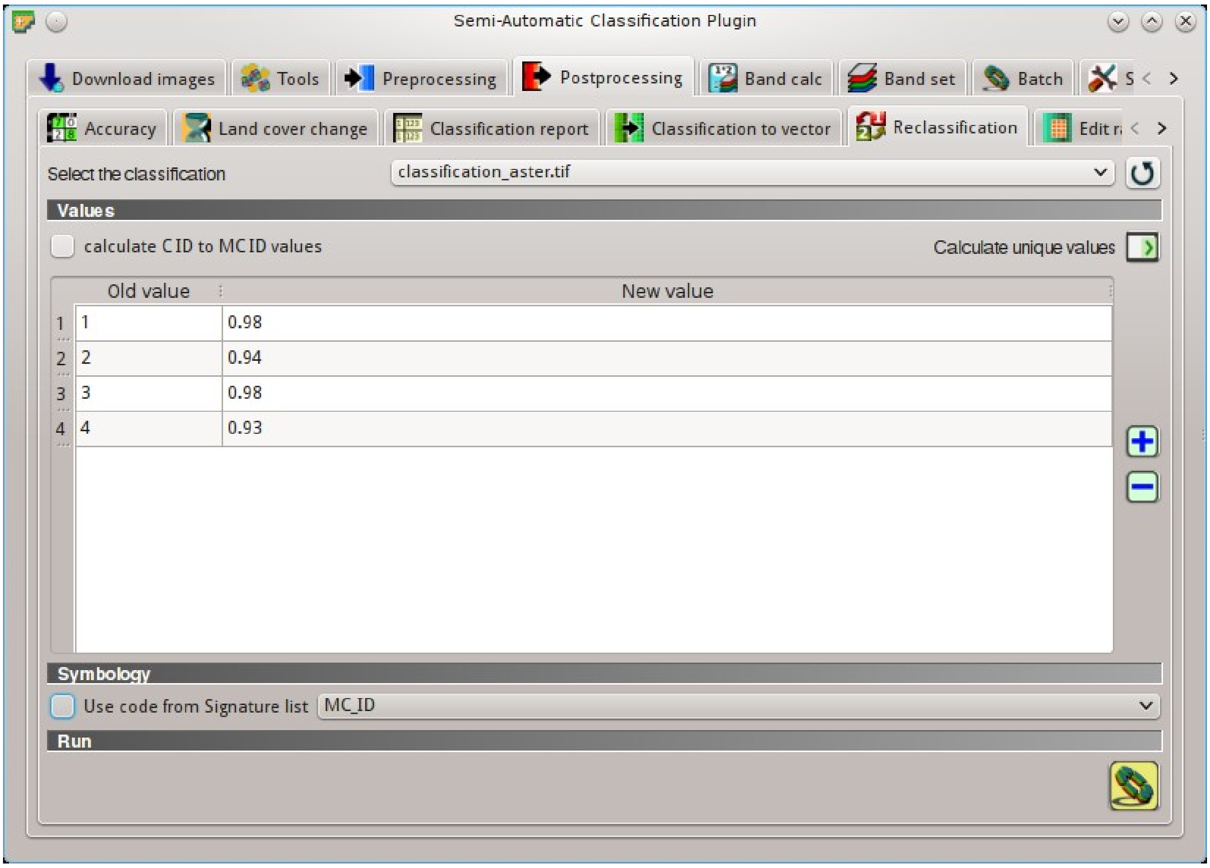


Fig. 23.25: *ASTER reclassification*

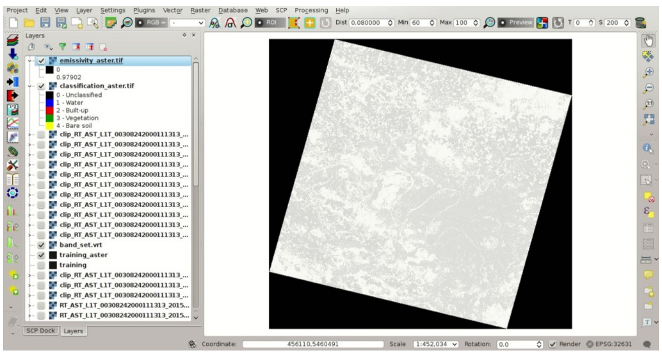


Fig. 23.26: *ASTER emissivity raster*

Center wavelength of ASTER bands

Satellite	Band	$\lambda(m)$
ASTER	10	8.3
ASTER	11	8.65
ASTER	12	9.1
ASTER	13	10.6
ASTER	14	11.3

We are going to use ASTER band 13 that has a λ value very similar to the Landsat band 10.

Open the tab *Band calc* (pagina 104) clicking the button . Click the button  to refresh the layer list and show the loaded rasters, and in the *Expression* (pagina 107) type equation for conversion adapted to our rasters:

```
"clip_RT_AST_L1T_00308242000111313_20150411071856_3805_13.tif" / ( 1 + ( 10.6 *
↪"clip_RT_AST_L1T_00308242000111313_20150411071856_3805_13.tif" / 14388 ) * ln(
↪"emissivity_aster.tif") )
```

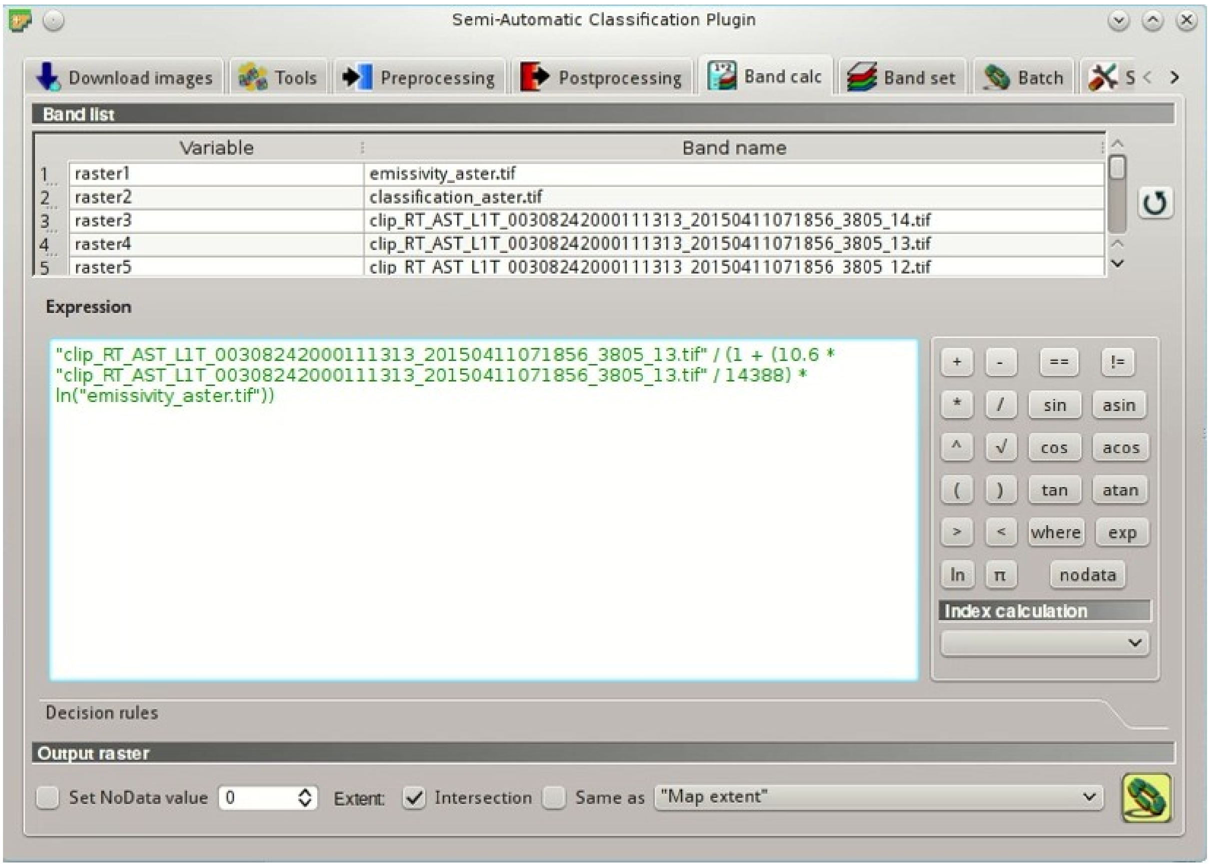


Fig. 23.27: *Calculation of surface temperature*

Click the button  and define the name of the output raster (e.g. `surface_temperature_aster.tif`). After the calculation, the Land Surface Temperature (in kelvin) will be loaded, and we can change the layer style. In addition, in the tab *Band calc* (pagina 104) we can calculate the temperature in Celsius with the expression:

```
"surface_temperature_aster.tif" - 273.15
```

The ASTER image shows temperature values higher than the Landsat image. For instance, we could perform the difference between the two surface temperature rasters (Landsat and ASTER) to assess the variation of temperature. However, we should notice that the two images were acquired in different months (Landsat on 27-09-2015 and ASTER on 24-08-2000).

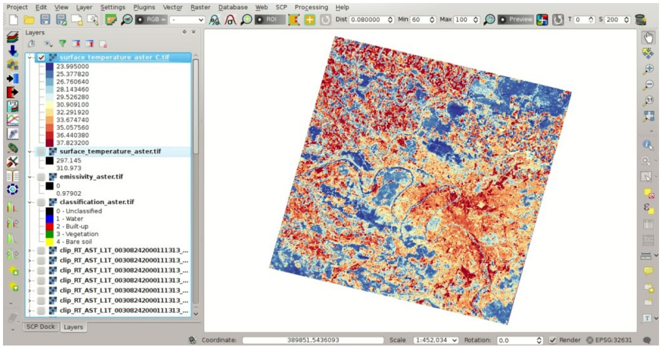


Fig. 23.28: *Land Surface Temperature of the ASTER Image*

The large availability of Landsat and ASTER images for the past decades allows for the reliable monitoring of land cover and surface temperature. Nevertheless, cloud cover can limit the number of images that can be effectively used.

This tutorial illustrated a methodology of temperature estimation using these satellite images and open source programs. One should always consider that the estimation accuracy depends on several factors, such as the thematic and spatial accuracy of land cover classifications and the reliability of the emissivity values. Estimation errors can be of 1 K or even more. Other methods have been developed which can provide more accurate results, and the reader can continue the research.

Other Tutorials

For other tutorials visit the blog From GIS to Remote Sensing .

Also, visit the blog From GIS to Remote Sensing for other tutorials such as:

- Flood Monitoring Using The Semi-Automatic Classification Plugin;
- Wildfire Monitoring Using The Semi-Automatic Classification Plugin;
- From Image Download to NDVI Calculation in One Move: SCP Batch;

For other unofficial tutorials, also in languages other than English, see *Other tutorials about SCP, also in languages other than English?* (pagina 272).

Parte VII

Semi-Automatic OS

The Semi-Automatic OS is a lightweight virtual machine for the land cover classification of remote sensing images. It includes the Semi-Automatic Classification Plugin (SCP) for QGIS, already configured along with all the required dependencies, and installed through the official SCP repository (https://semiautomaticgit.github.io/SemiAutomaticClassificationPlugin/repository.xml) which provides always the latest version of SCP.

Fig. 23.29: *Semi-Automatic OS desktop*

The Semi-Automatic OS is based on Debian , and it is designed to require very little hardware resources. It uses LXDE and Openbox as main desktop environment. This virtual machine can be useful for testing the Semi-Automatic Classification Plugin, or when the installation of the required programs in the host system is problematic.

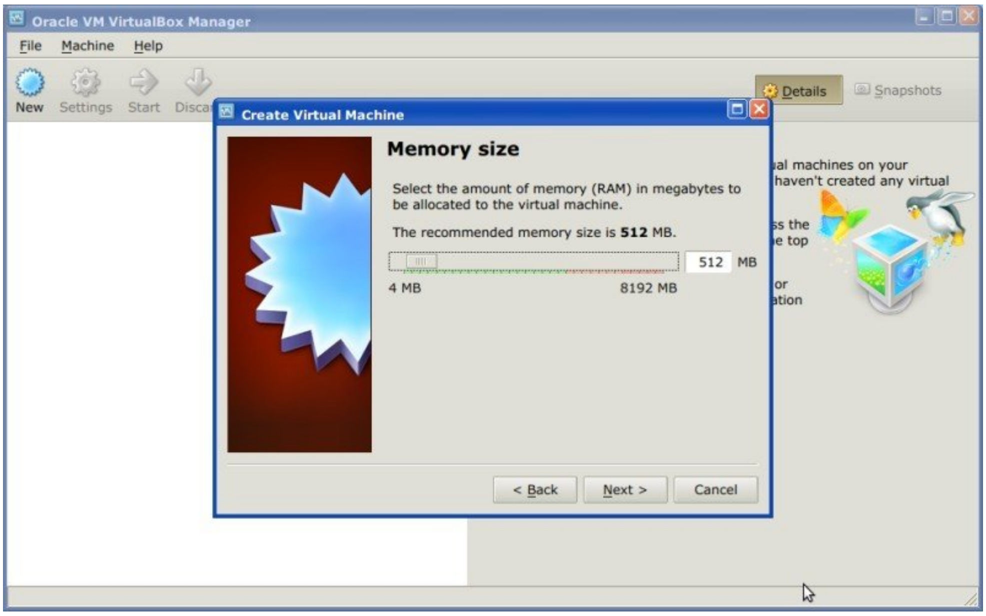
The Semi-Automatic OS is available as a 32 bit and 64 bit virtual machine that can be run in the open source VirtualBox, or any other virtualization program. The following is a guide for the installation of the Semi-Automatic OS in the open source program of virtualization VirtualBox.

CAPITOLO 24

Installation in VirtualBox

1. Download VirtualBox open source software (select a proper version depending on your OS) and install it; at the end of the installation restart the system;
2. Download the Semi-Automatic OS virtual machine (about 800 MB) from here (32 bit or 64 bit);
3. Extract the virtual machine content in a directory (it requires about 3 GB of disk space); the file is compressed in 7z format (if needed, download the open source extraction software from http://www.7-zip.org/);
4. Run VirtualBox and create a new Debian virtual machine;
   (a) Click the New button;
   (b) Type a name for the virtual machine (for instance Semi-Automatic OS); select Linux and Debian (32 or 64 bit) as Type and Version respectively; click Next;

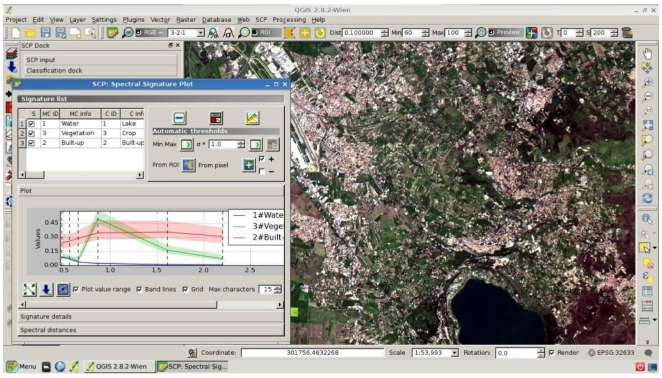
   (c) Set the memory size; the more is the better, but this parameter should not exceed a half of the host system RAM (for instance if the host system has 1 GB of RAM, type 512 MB); click Next;



(d) In the Hard drive settings select Use an existing virtual hard drive file and select the downloaded file SemiAutomaticOS.vmdk; click Create;

5. Start the Semi-Automatic OS by clicking the Start button;
6. It is recommended to install the virtualbox-guest-utils in the virtual machine, from the Menu > Preferences > Synaptic Package Manager; it allows for a better integration of the Semi-Automatic OS in the host system, such as: the resize of the system window, or the folder sharing.

The Semi-Automatic OS includes a sample dataset of Landsat image (available from the U.S. Geological Survey) and a Sentinel-2 image (© Copernicus Sentinel data 2016) which are the input for the two basic tutorials.



Parte VIII

Frequently Asked Questions

If you have comments or questions please join the Facebook group or the Google+ Community .

Before asking, please check the official site From GIS to Remote Sensing and the following Frequently Asked Questions.

CAPITOLO 25

Installazione del Plugin

Come installare il plugin manualmente?

The SCP can be installed manually (this can be useful when an internet connection is not available, or the installation is required on multiple computers), following a few steps:

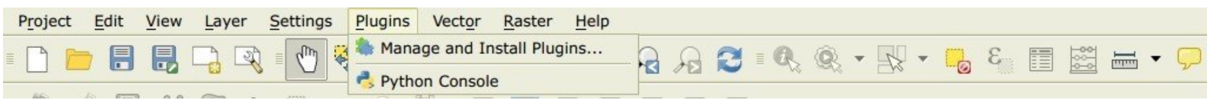
1. download the SCP zip archive from https://github.com/semiautomaticgit/SemiAutomaticClassificationPlugin/archive/master.zip ;
2. extract the content of the archive (several files such as `COPYING.txt` and folders such as `ui`) in a new folder named `SemiAutomaticClassificationPlugin` (without `-master`);
3. open the QGIS `plugins` directory (in Windows usually `C:\Users\username\.qgis2\python\plugins`, in Linux and Mac usually `/home/username/.qgis2/python/plugins/`) and delete the folder `SemiAutomaticClassificationPlugin` if present;
4. copy the folder `SemiAutomaticClassificationPlugin` inside the QGIS `plugins` directory;
5. the plugin should be installed; start QGIS, open the Plugin Manager and be sure that `Semi-Automatic Classification Plugin` is checked.

How to install the plugin from the official SCP repository?

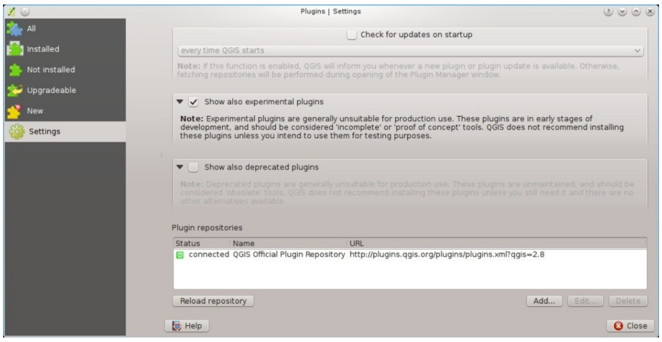
It is possible to install the SCP using the official repository. This repository allows for the installation of the latest version of SCP (`master`), in some cases also before the availability thereof in the QGIS repository. Therefore, this can be useful if you need a fix or a new function that is still not available in the QGIS repository. Moreover, the `master` version in the SCP repository can be installed along with the version available in the QGIS repository.

In order to install the SCP repository follow these steps:

- Run QGIS 2;
- From the main menu, select `Plugins` > `Manage and Install Plugins`;



- Click `Settings` then click the button `Add`;



- Inside the `Repository details` enter:

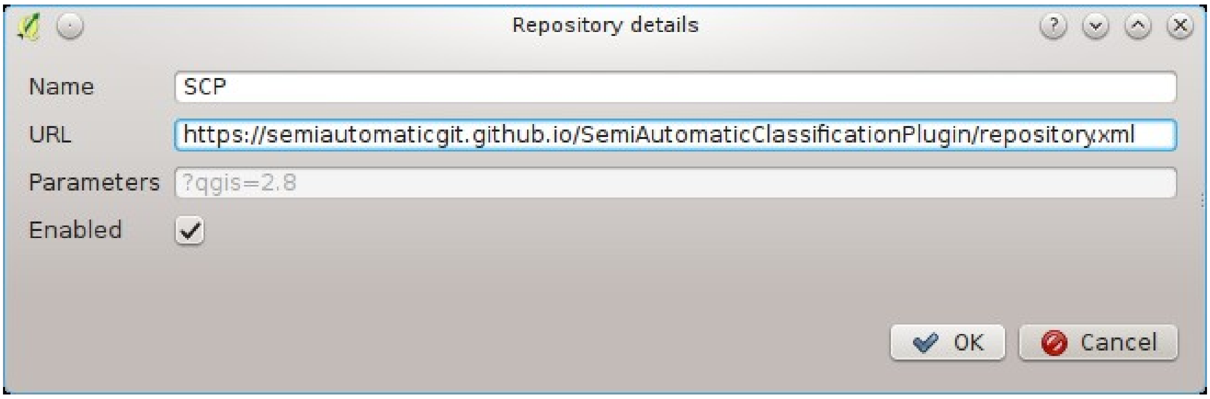
Name:

```
SCP
```

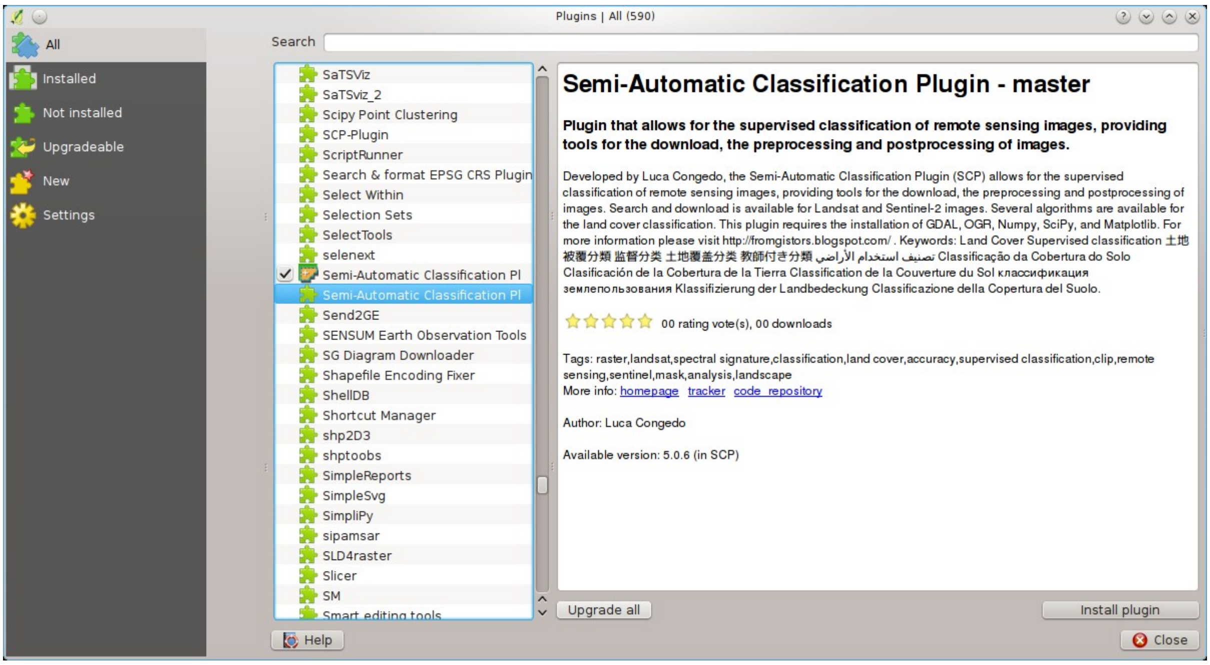
URL:

```
https://semiautomaticgit.github.io/SemiAutomaticClassificationPlugin/repository.xml
```

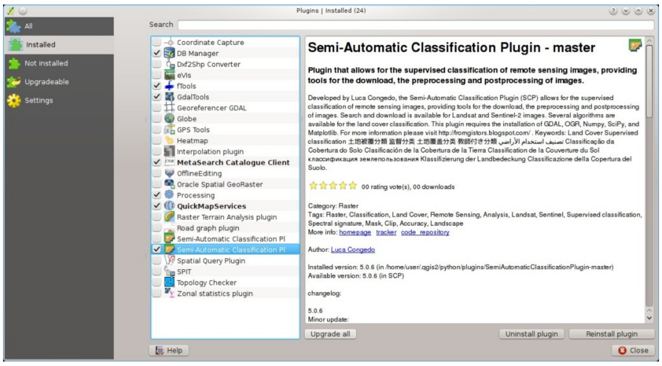
and click `OK`;



- After the repository update, the item `Semi-Automatic Classification Plugin - master` should be listed with the other plugins;



- From the menu All, select the Semi-Automatic Classification Plugin - master and click the button Install plugin; the latest version of SCP should be automatically activated (ignore errors, the restart of QGIS could be necessary to complete the SCP installation); it is possible to deactivate the other SCP installed in the QGIS repository;



CAPITOLO 26

Pre processing

Which image bands should I use for a semi-automatic classification?

In general, it is preferable to avoid thermal infrared bands. If you are using Landsat 4, 5 or 7 you should select bands: 1, 2, 3, 4, 5, 7 avoiding band 6 that is thermal infrared; for Landsat 8 you should select bands: 2, 3, 4, 5, 6, 7. Landsat 8 band 1 is generally avoided because it is very similar to the blue band and it is mainly used for coastal aerosol study. Landsat thermal infrared band is excluded from classifications because values are mainly related to object temperature.

For Sentinel-2 images you can use bands: 2, 3, 4, 5, 6, 7, 8, 8A, 11, 12.

Which Landsat bands can be converted to reflectance by the SCP?

All Landsat 1,2, and 3 MSS and Landsat 4, 5, 7, and 8 images downloaded from http://earthexplorer.usgs.gov/ and processed with the Level 1 Product Generation System (LPGS) can be converted to reflectance automatically by the SCP; products generated by the LPGS have a MTL file included that is required for the conversion. Since version 3.1.1 the *SCP* can also convert images from the Global Land Cover Facility (images available for free from ftp://ftp.glcf.umd.edu/glcf/Landsat/). In particular, images having an old format of the MTL file (or a .met file) can be processed through the automatic conversion to reflectance and the DOS correction. However, some images do not have the required information and cannot be processed. Also, notice that some images available from the Global Land Cover Facility are already converted to reflectance. For this process, image bands must be renamed in order to remove the final 0 if present (e.g. rename B10 to B1).

Can I apply the conversion to Sentinel-2 images download from the web?

Yes, you can convert also images downloaded from the web (actually the conversion is recommended). You should move all the bands (.jp2 files) and if available the .xml file whose name contains `MDT_SAFL1C` in the same directory. Then select this directory in *Sentinel-2 conversion* (pagina 80). Images are converted to reflectance.

How are converted Sentinel-2 images that have different resolutions?

During the conversion to reflectance, pixels of 20m bands are split in 4 pixels of 10m whose values are the same as the original 20m pixel. The purpose of this operation is to allow for the calculation between all the bands, without changing original values.

Can I apply the Landsat conversion and DOS correction to clipped bands?

Yes, you can clip the images before the conversion to reflectance and then copy the MTL file (contained in the Landsat dataset) inside the directory with the clipped bands. If you want to apply the DOS correction (which is an image based technique) you should convert the original Landsat bands (the entire image) and then clip the conversion output (i.e. bands converted to reflectance).

Can I apply the DOS correction to bands with black border (i.e. with NoData value)?

If you want to apply the DOS correction to an entire band which has NoData values (the black border with value = 0) then you have to check the checkbox `Use NoData value` and set the value to 0. This is because DOS is an image based technique, and NoData values must be excluded from the calculation.

How to remove cloud cover from images?

DOS1 correction does not remove clouds from the image. However, Landsat 8 images include Band 9 that identifies clouds (see this NASA site). You can use this band for the creation of a mask.

For other Landsat satellites, clouds can be masked using the approach described this paper.

Also, see the following video-tutorial.

How do I create a virtual raster manually in QGIS?

In order to create a multi-spectral virtual raster in QGIS:

1. from the menu `Raster` select `Miscellaneous > Build Virtual Raster (catalog)`;
2. click the button `Select...` and select all the Landsat bands (in numerical order);
3. select the output file (for instance `rgb.vrt`); check `Separate` (bands will be separated) and click `OK`.

After pan-sharpening of Landsat 8 images, why NIR bands still have 30m resolution?

Landsat 8 panchromatic band doesn't acquire in the Near Infrared (NIR) region (see *Satellite Landsat* (pagina 143)). Therefore, the pan-sharpening process can't improve the resolution of NIR and SWIR bands (see *Pan-sharpening* (pagina 148)), which appear to have 30m resolution. However, raster all pan-sharpened rasters have 15m resolution to allow raster calculation.

CAPITOLO 27

Processing

I get classification errors. How can I improve the accuracy?

Several materials have similar spectral signatures (e.g. soil and built-up, or forest and other types of dense low vegetation), which can cause classification errors if ROIs, and spectral signatures thereof, are not acquired correctly. In order to improve the results, you can try to collect more ROIs over these areas, in order to train the algorithm for these very similar areas, also, display the spectral signatures of these areas in *Spectral Signature Plot* (pagina 123) to assess their similarity. You can also use a *Signature threshold* (pagina 72) for these signatures in order to reduce the variability thereof (only pixels very similar to the input signatures will be classified). The *Land Cover Signature Classification* (pagina 156) is also useful for classifying specific materials that can be spectrally similar to other ones.

Is it possible to use the same training input for multiple images?

Yes, it is possible if all the images have the same number of bands. However, if images are acquired in different months, land cover changes (especially of vegetation state) will affect the spectral signature (i.e. the same pixel has different spectral signature in different periods). Atmospheric effects could also affect the images differently. That could reduce classification accuracy. Therefore, it is suggested to collect always the ROIs and spectral signatures for every image.

What is the difference between classes and macroclasses?

Please see *Classi e Macroclassi* (pagina 153).

Can I use SCP with images from drones or aerial photographs?

Yes, you can use them if they have at least 4 bands. With less than 4 bands, semi-automatic classification algorithms are unable to classify the land cover correctly. Alternative classification methods exist, such as object oriented classification, which is not implemented in SCP.

Why using only Landsat 8 band 10 in the estimation of surface temperature?

Several methods were developed for estimating surface temperature. The method described in the tutorial for temperature estimation requires only one band. Moreover, USGS recommends that users refrain from relying on Landsat 8 Band 11 data in quantitative analysis of the Thermal Infrared Sensor data (see Changes to Thermal Infrared Sensor (TIRS) data by USGS).

CAPITOLO 28

Warnings

Warning [12]: The following signature will be excluded if using Maximum Likelihood. Why?

The ROI is too small (or too homogeneous) for the *Maximum Likelihood* (pagina 154) algorithm because that ROI has a singular covariance matrix. You should create larger ROIs or don't use the Maximum Likelihood algorithm in the classification process.

CAPITOLO 29

Errors

How can I report an error?

If you found an error of the Semi-Automatic Classification Plugin please follow these steps in order to collect the required information (log file):

1. close QGIS if already open;
2. open QGIS, open the Plugin tab *Debug* (pagina 120) and check the checkbox *Records events in a log file* ;
3. click the button *Test dependencies* in the tab *Debug* (pagina 120) ;
4. **load the data in QGIS (or open a previously saved QGIS project) and repeat all the steps that cause the error in the Pl**

    - if the issue could be related to the image data, please use this sample dataset ;

5. if an error message appears (like the one in the following image), copy the whole content of the message in a text file;
6. open the tab *Debug* (pagina 120) and uncheck the checkbox *Records events in a log file*, then click the button and save the **log file** (which is a text file containing information about the Plugin processes);
7. open the **log file** and copy the whole content of the file;
8. join the Facebook group or the Google+ community , create a new post and copy the error message and the **log file** (or attach them).

Virtual raster creation issues. Why?

The automatic creation of the virtual raster after Landsat conversion to reflectance is not required for the classification. Errors could happen if the output destination path contains special characters (such as accented letters) or spaces; try to rename directories (e.g. rename `new directory` to `new_directory`). If you still get the same error you can create a virtual raster manually.

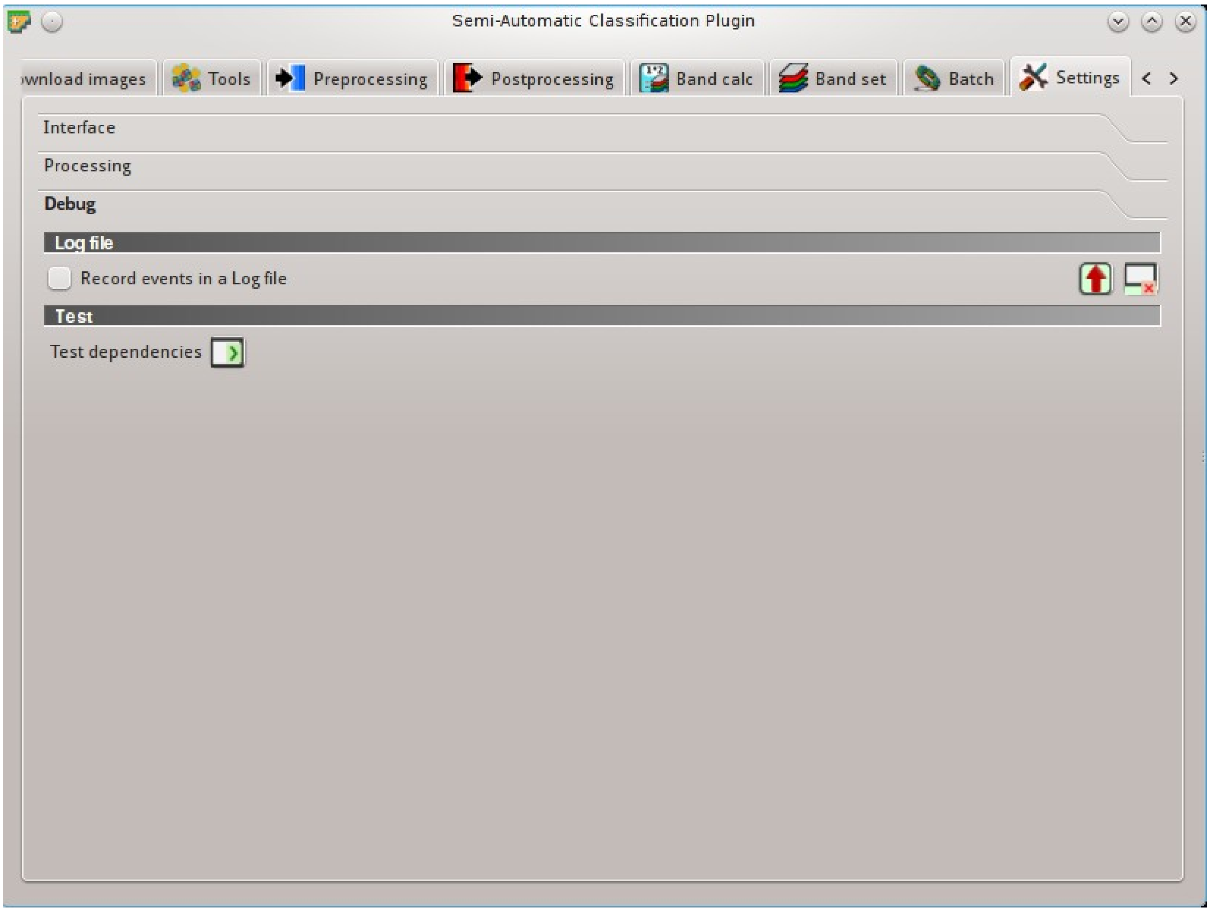


Fig. 29.1: *Debug*

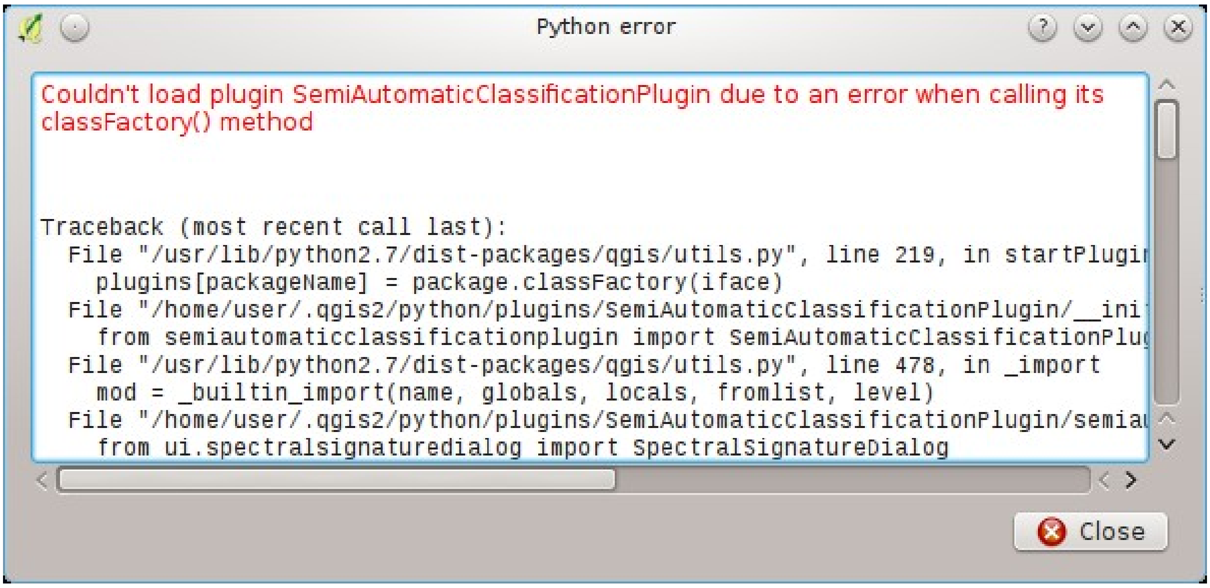


Fig. 29.2: *Error message*

Error [26] 'The version of Numpy is outdated'. Why?

QGIS 32bit could have an older version of Numpy as default; in order to update Numpy:

1. download this file (which is based on WinPython installer and PyParsing);
2. extract the file with 7-zip;
3. copy the content of the extracted directory inside the directory `apps\Python27\Lib\site-packages` inside the QGIS installation directory (e.g. `C:\Program Files (x86)\QGIS Chugiak\apps\Python27\Lib\site-packages`) overwriting the files `pyparsing`, `numpy`, `matplotlib`, and `scipy`.

Alternatively, you should be able to install QGIS and Numpy with the OSGEO4W advanced installer.

Error 'Plugin is damaged. Python said: ascii'. Why?

It could be related to a wrong installation. Please, uninstall QGIS and install it again with administrative rights. Delete also the directory .qgis2 in your user directory. Then run QGIS 2 and try to install the plugin following the *Plugin Installation* (pagina 7) guide.

Also, it could be related to the user name containing special characters. Please try the installation creating a new user without special characters (e.g. `user`).

Also, if the error message contains something like: `sfnt4 = sfnt4.decode('ascii').lower()`

it could be related to a known issue of Matplotlib (a Python library); in order to solve this, you should (as reported at stackoverflow):

1. open in a text editor the file font_manager.py which is inside the directory `C:\PROGRA~1\QGISCH~1\apps\Python27\lib\site-packages\matplotlib\`
2. **search for the line** `sfnt4 = sfnt4.decode('ascii').lower()`
3. **and replace it with the line** `sfnt4 = sfnt4.decode('ascii', 'ignore').lower()`

Alternatively, try to install QGIS through the OSGEO4W installer, which includes an updated Matplotlib version.

Error [50] 'Internet error'. Unable to download Sentinel-2 images. Why?

The error message usually includes some information about the issue. First, check the user name and password.

Also, there could be an interruption of the service. For Sentinel-2 images please check this website https://scihub.copernicus.eu/news/ for messages about the state of the service.

In case you still get the same error, please follow these steps *How can I report an error?* (pagina 267).

Error [56] 'SSL connection error'. Unable to download Sentinel-2 images. Why?

First, check the user name and password.

This issue could be related to SSL protocols (TLS v1.1 and TLS v1.2) required for Sentinel-2 download. As described here https://docs.python.org/2/library/ssl.html the protocols TLS v1.1 and TLS v1.2 are available only in Python 2.7.9+ with openssl version 1.0.1+. QGIS could have a previous version of Python where TLS v1.1 and TLS v1.2 are not available. Therefore the Sentinel-2 download process fails.

A temporary solution for Windows OS:

Warning: this could break other QGIS functions, but fortunately you can install multiple versions of QGIS.

1. Close QGIS if open
2. Download and install Python for 32bit or for 64bit according to the installed version of QGIS
3. Copy and replace `C:\python27\python.exe` to `"QGIS installation folder"\bin\` (e.g. `C:\Program Files (x86)\QGIS Chugiak\bin\`)
4. Copy and replace `C:\python27\pythonw.exe` to `"QGIS installation folder"\bin\`
5. Copy and replace all the content of `C:\python27\` to `"QGIS installation folder"\apps\python27\`
6. Now start QGIS and if everything went well you should be able to search and download Sentinel-2 images using SCP

In case you still get the same error, please follow these steps *How can I report an error?* (pagina 267).

This plugin is broken 'matplotlib requires pyparsing >= 1.5.6'. Why?

It is related to this issue https://hub.qgis.org/issues/14952 which should affect QGIS 32bit only. The installation of QGIS 64bit should work. As a solution you can install a previous version of QGIS 2.8 32bit .

Error installing the plugin, possible missing dependencies. Why?

The plugin requires the installation of GDAL, NumPy, SciPy and Matplotlib, which should be installed along with QGIS. If the plugin installation fails, and you get a message about possible missing dependencies, you should try to install or update QGIS and the required dependencies. Notice that in order to avoid this error, python dependencies should not be installed through Anaconda.

CAPITOLO 30

Various

What can I do with the SCP?

SCP allows for the **land cover classification** of remote sensing images through *Supervised Classification* (pagina 151). You can produce a land cover raster using one of the *Classification Algorithms* (pagina 154) available in SCP. These algorithms require spectral signatures or ROIs as input (for definitions please read *Breve Introduzione al Telerilevamento (Remote Sensing)* (pagina 139)) that define the land cover classes to be identified in the image.

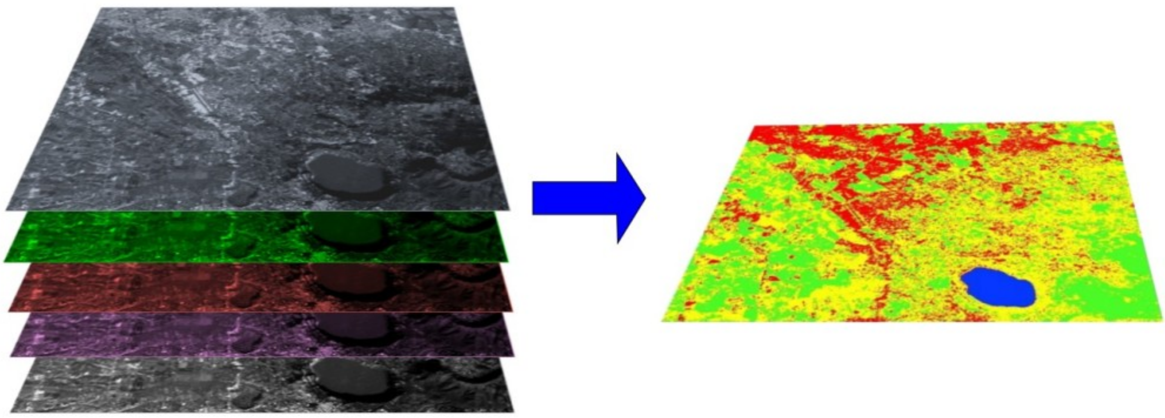


Fig. 30.1: *A multispectral image processed to produce a land cover classification*
`(Landsat image provided by USGS)`

SCP can work with **multispectral images** acquired by satellites, airplanes, or drones. Also, *SCP* allows for the direct search and download of free images (see *Download images* (pagina 51)). You cannot use orthophotos with less than 4 bands, SAR data, and LIDAR data with SCP.

Input image in *SCP* is called *Band set* (pagina 110), which is used as input for the classification. *SCP* provides several tools for the *Preprocessamento* (pagina 77) of downloaded images, such as the conversion to reflectance and manipulation of bands.

Classification results can be assessed with the tools *Accuracy* (pagina 91) and *Classification report* (pagina 94). Also, rasters can be manipulated using *Postprocessamento* (pagina 91) tools such as *Classification to vector* (pagina 96), *Reclassification* (pagina 96), *Edit raster* (pagina 99) directly, *Classification sieve* (pagina 101), *Classification erosion* (pagina 104), and *Classification dilation* (pagina 104).

The *Spectral Signature Plot* (pagina 123) and *Scatter Plot* (pagina 129) allow for the **analysis of spectral signatures and ROIs**. Also, several *Tools* (pagina 65) are available for easing the ROI creation and editing spectral signatures.

Raster calculation is available through the seamless integration of the tool *Band calc* (pagina 104) with bands in the *Band set* (pagina 110), calculating mathematical expressions and spectral indices. Also, an output raster can be calculated based on *Decision rules* (pagina 108).

The tool *Batch* (pagina 114) allows for the automatic execution of several *SCP* functions using a scripting interface.

See the *Tutorials di Base* (pagina 173) for more information and examples.

How to contribute to SCP

You can contribute to *SCP* by fixing and adding functionalities (see *Where is the source code of SCP?* (pagina 274)), or translating the user manual (see *How can I translate this user manual to another language?* (pagina 273)).

Also, you can donate to this project at the following link https://fromgistors.blogspot.com/p/donations.html .

Free and valuable resources about remote sensing and GIS

The following links are valuable resources:

- The Landsat 8 Data Users Handbook by USGS;
- The Landsat 7 Science Data Users Handbook by NASA;
- Remote Sensing Note by JARS.
- Webinar: Fundamentals of Remote Sensing by NASA.
- Webinar: NASA Remote Sensing for Land Management by NASA.
- Webinar: Creating and Using Normalized Difference Vegetation Index (NDVI) from Satellite Imagery by NASA.
- Webinar: Remote Sensing of Forest Cover and Change Assessment for Carbon Monitoring by NASA.
- Webinar: Introduction to Remote Sensing for Conservation Management by NASA.

Other tutorials about SCP, also in languages other than English?

There are several tutorials about *SCP* on the internet. Following an incomplete list of these resources:

- French: Suivre l'impact des feux de forêts par imagerie satellite avec le plugin Qgis SCP;
- German: 2015 Jakob Erfassung von Landnutzungsveränderungen mit FOSS Image Processing Tools;
- Italian: Classificazione e Mosaico di Varie Immagini Landsat;
- Korean: QGIS Semi-Automatic Classification Plugin;
- Portuguese: Classificacao supervisionada de imagens Sentinel-2 com QGIS e SCP;
- Portuguese: Avaliação do erro de uma imagem de satélite usando o QGIS e o SCP;
- Portuguese: Conversão Sentinel-2 para refletância com QGIS SCP;

- Portuguese: Criar composições coloridas no QGIS com SCP;
- Portuguese: Corte de imagem Sentinel-2 usand QGIS e SCP;
- Portuguese: Classificação Supervisionada de Imagens Orbitais com o Semi-Automatic Classification Plugin;
- Portuguese: Tutorial Classificação e caracterização de imagens de satélites;
- Portuguese: Aprendizagem Supervisionada usando o SCP no QGIS;
- Portuguese: Classificação supervisionada utilizando o QGIS e SCP;
- Russian: Landsat Semi-Automatic Classification Plugin QGIS;
- Spanish: Ejercicio Clasificación Semiautomática Plugin (SCP);
- Spanish: Aplicaciones de Teledetección con el QGIS y el plugin Semi-Automatic Classification;
- Spanish: Descarga de Landsat 8, 7, 5 y 4 Semi Automatic Classification Plugin Qgis 2.8;
- Swedish: Landsat 8 och fjärranalys med QGIS;
- Ukrainian: Semi-Automatic Classification 5.0;
- Ukrainian: ;

How can I translate this user manual to another language?

It is possible to easily translate the user manual to any language, because it is written in reStructuredText as markup language (using Sphinx). Therefore, your contribution is fundamental for the translation of the manual to your language. The following guide illustrates the main steps for the translation, which can be performed:

- using the free online service Transifex;
- using the gettext .po files.

Before translating, please read this document from the QGIS translation guide, which helps you understand the reStructuredText.

Method 1. Translation using the free online service Transifex

This is probably the easiest way to translate the manual using an online service.

1. Join the Semi-automatic Classification Manual project

   Go to the page https://www.transifex.com/semi-automatic-classification/semi-automatic-classification-plugin-manual and click the button `Help translate`. You can sign in using your Google or Facebook account, or with a free registration.

2. Select your language

   Select your language and click the button `Join team`. If your language is not listed, click the button `Request language`.

3. Translation

   There are several files to be translated, which refer to the sections of the SCP documentation. To translate the SCP interface you should select the file `semiautomaticclassificationplugin.ts`.

Method 2. Translation using the gettext .po files

In order to use this method, you should be familiar with GitHub. This translation method allows for the translation of the PO files locally.

1. Download the translation files

Go to the GitHub project https://github.com/semiautomaticgit/SemiAutomaticClassificationManual_v4/tree/master/locale and download the .po files of your language (you can add your language, if it is not listed), or you can fork the repository. Every file .po is a text file that refers to a section of the User Manual.

2. Edit the translation files

   Now you can edit the .po files. It is convenient to edit those file using one of the following programs: for instance Poedit for Windows and Mac OS X, or Gtranslator for Linux or OmegaT (Java based) for Windows, Linux and Mac OS X. These editors allow for an easy translation of every sentence in the User Manual.

Where is the source code of SCP?

You can find the source code of SPC is at the following link https://github.com/semiautomaticgit/SemiAutomaticClassificationPlugin