sentinel-2

esa

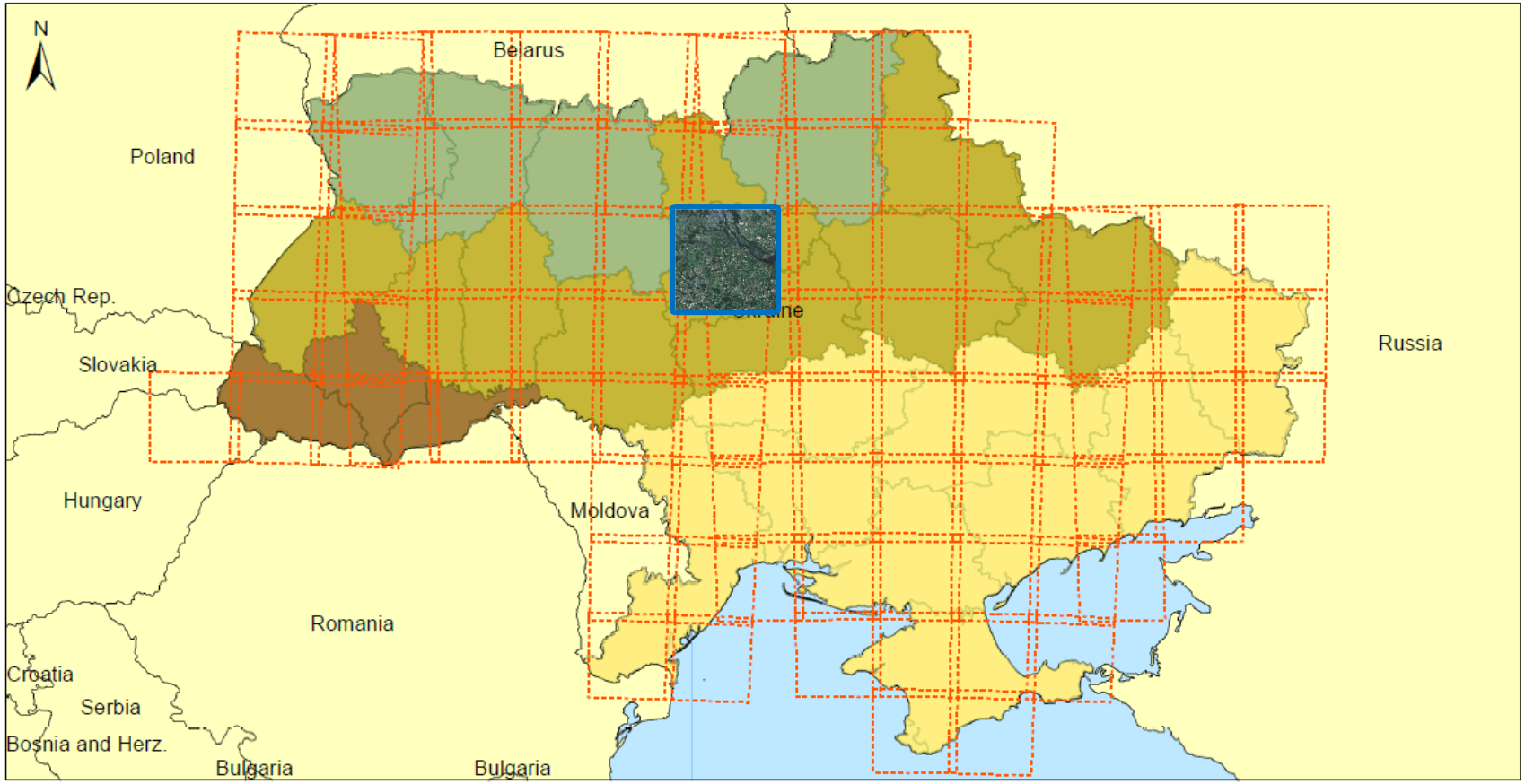
→ AGRICULTURE

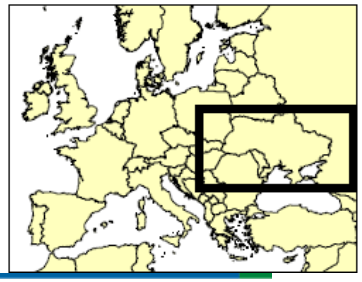
Practical session

Optical agriculture

Pierre Defourny and Nicolas Bellemans

Sentinel-2 data set for the exercise





Area of interest for the demonstration

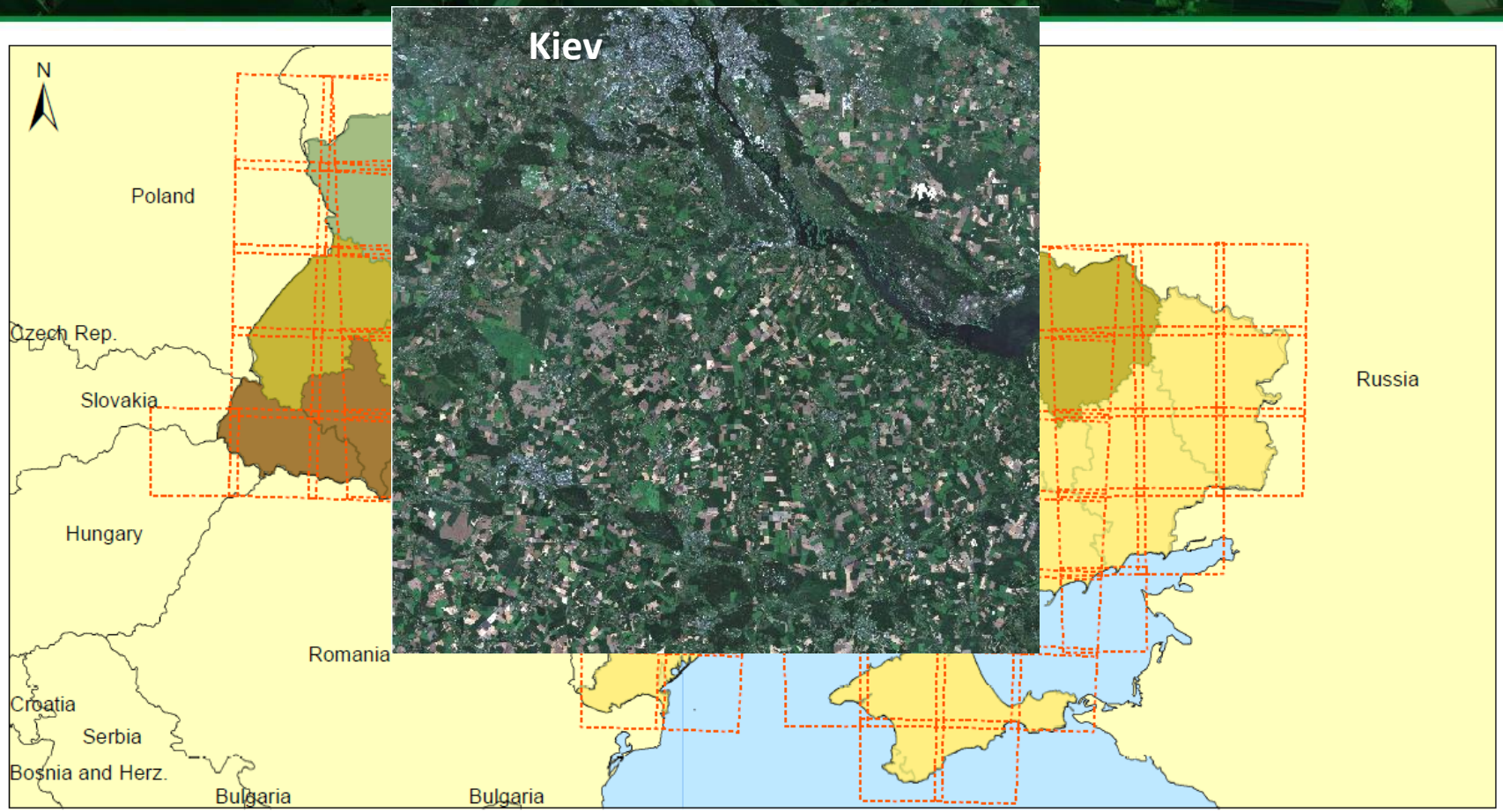
- Sentinel-2 Tiles
- Startum 1: Woodlands
- Stratum 2: Forest and Steppe
- Stratum 3: Steppe
- Stratum 4: Mountains

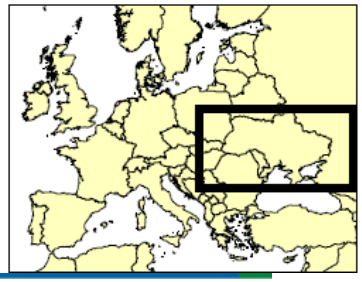
1:10.000.000

Coordinate System : WGS 1984 World Mercator
Projection : Mercator
Datum : WGS 1984
Unit : Meter

0 125 250 500 Kilometers

Sentinel-2 data set for the exercise





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1:10.000.000

Coordinate System : WGS 1984 World Mercator
Projection : Mercator
Datum : WGS 1984
Unit : Meter

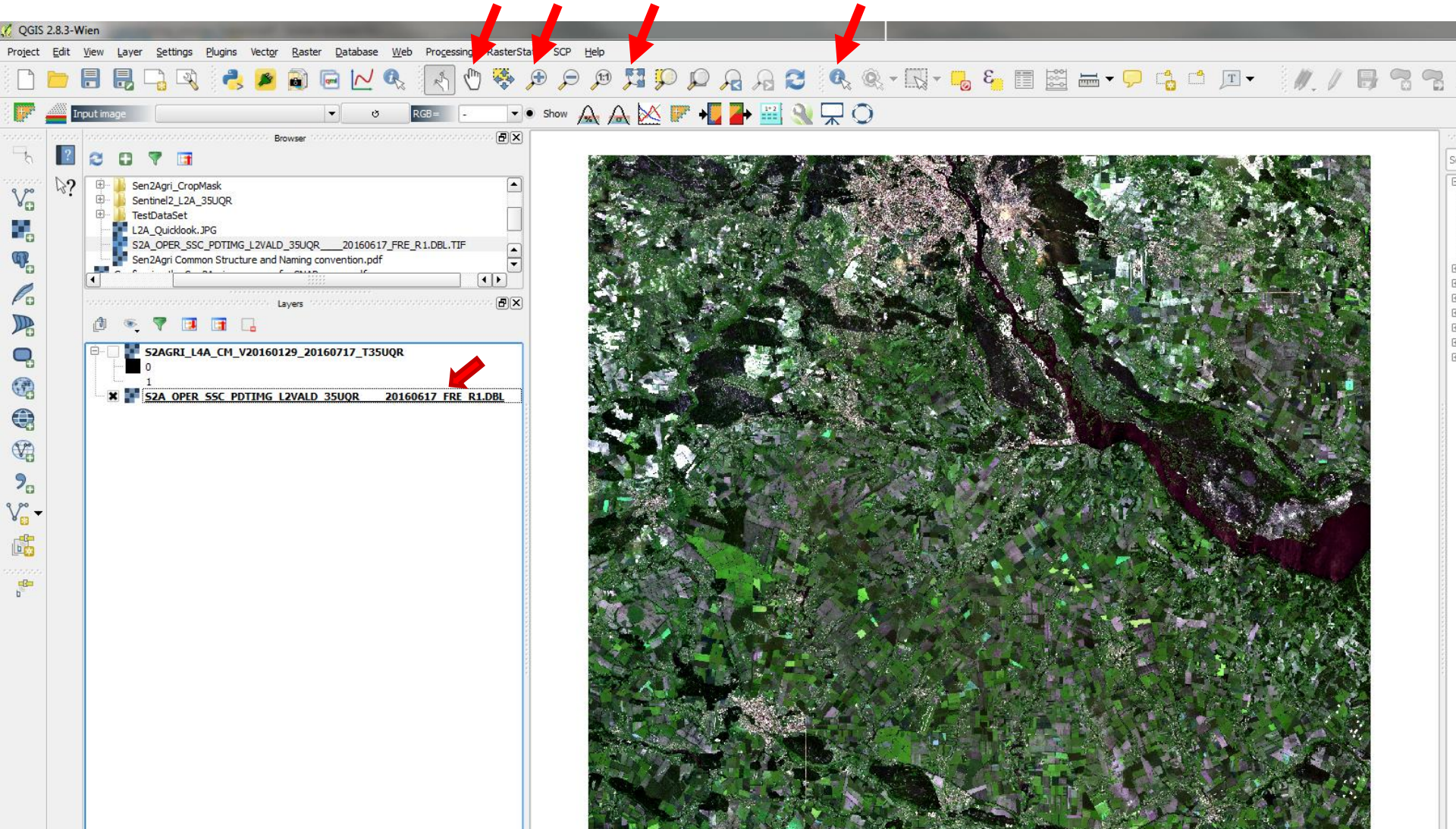
0 125 250 500 Kilometers

1. Explore the image reflectances

- Open Quantum GIS Desktop
- From */01_Exploration/*, load *S2A_L2A_35UQR_20160617_10M.TIF (R-G-B-NIR)*

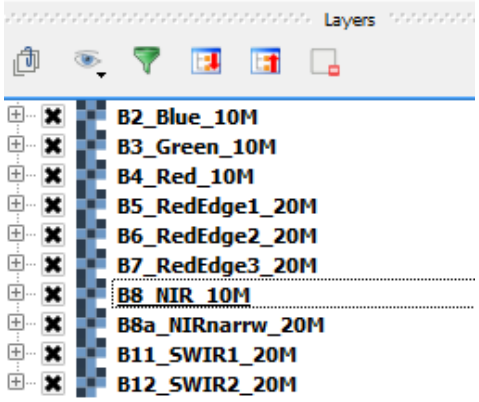
Display Surface reflectance image in the background

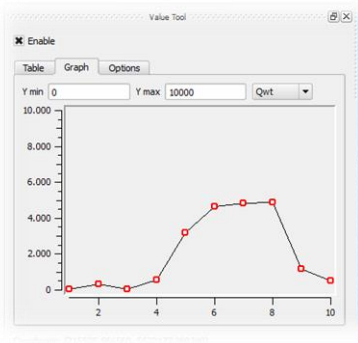
These icons allow you to explore the product easily



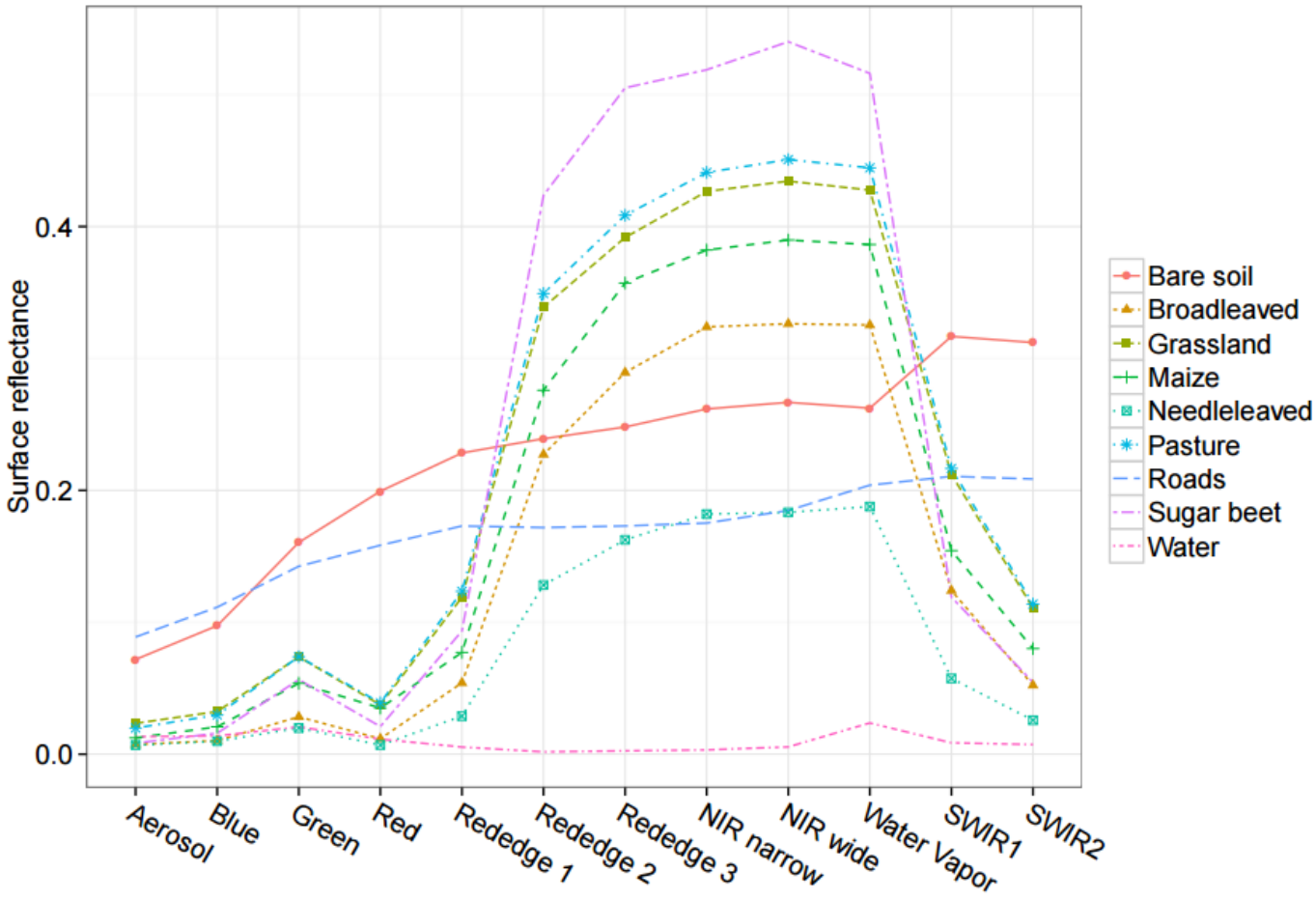
Explore the spectral profile

- Install Value Tool Plugin (`Plugins > Manage and Install Plugins`)
- From */01_Exploration/*, load each band image and class them by order.
- Select the band of interest
- Explore the diversity of spectral profiles by enabling the Graph function of *Value Tool* plugin



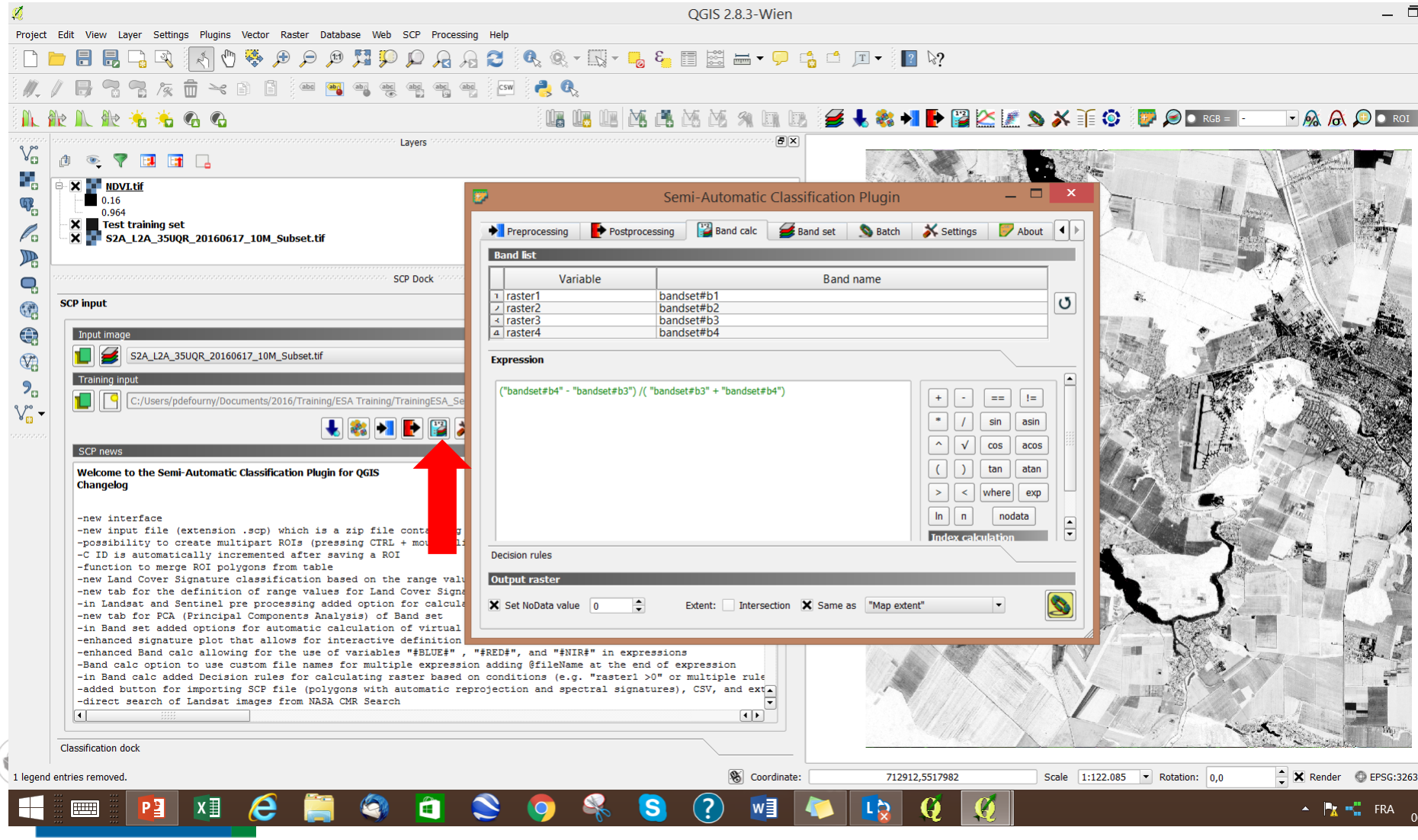


Explore the image reflectances



Compute a Vegetation Index

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



2. Perform a land cover classification

- Open Quantum GIS Desktop
- Install *Semi-Automatic Classification Plugin*
- From the menu `All`, select the *Semi-Automatic Classification* Plugin and click the button `Install plugin`;

- 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 SCPinstallation);

Supervised Classification

*A semi-automatic classification (more appropriately named **supervised classification**) is an image processing methods that allows for the identification of land type according to their spectral signatures. There are several kinds of classification algorithms, but the general purpose is to produce a thematic map of the land cover. SCP allows an interactive approach of the concept.*

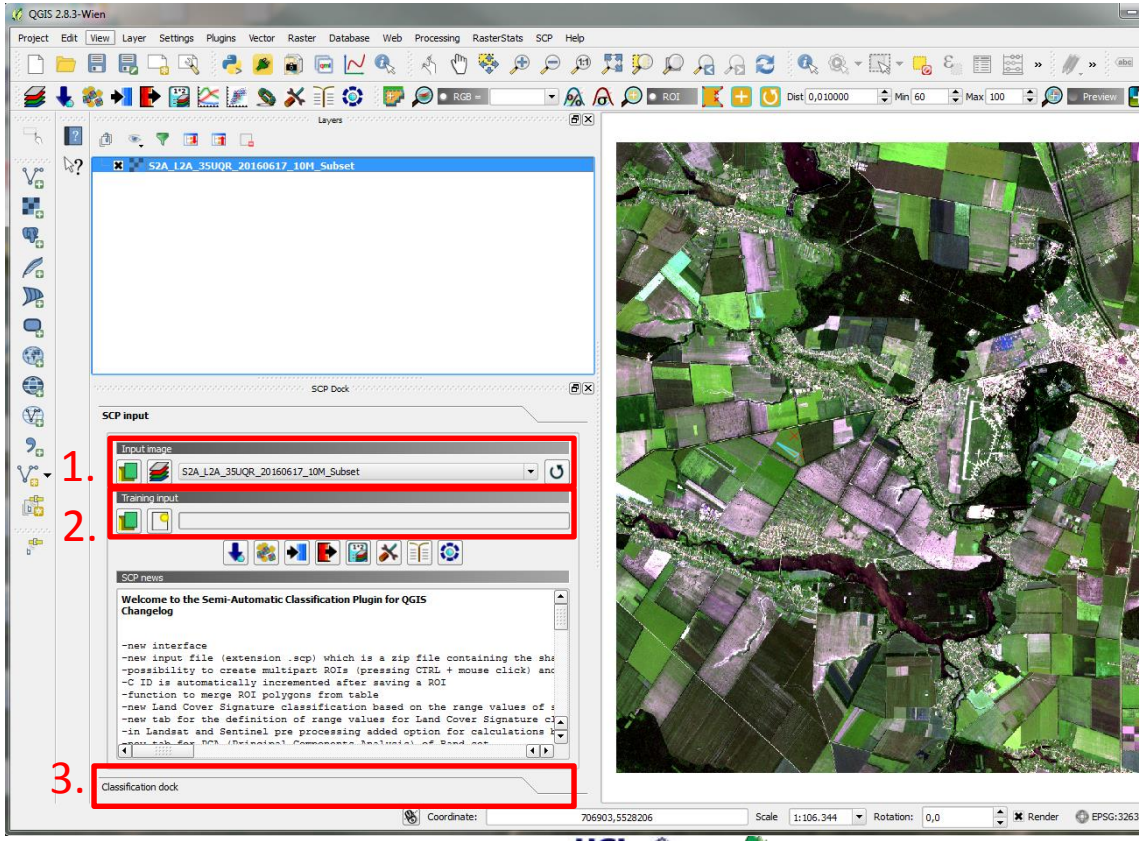
1. Load the input raster in SCP

`02_Classification/S2A_L2A_35UQR_20160617_10M_Subset.tif`

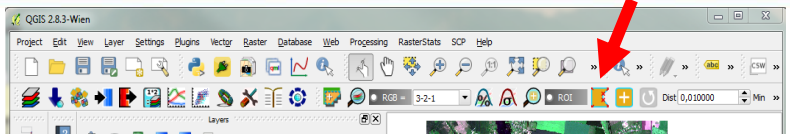
2. Create a new Training Input that will contain the ROIs

3. Create your Training Areas (ROIs)

4. Perfom the classification

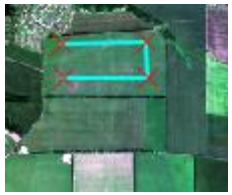


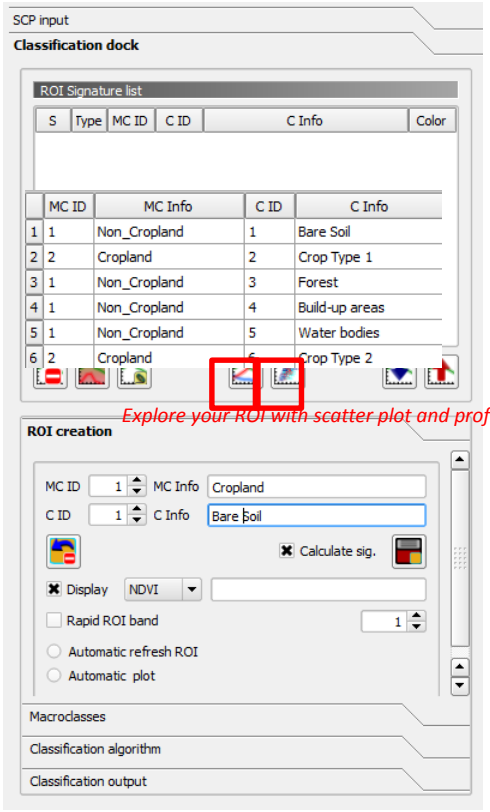
Your First Land Cover Classification



3. Create your Training Areas (ROIs)

- In order to **create manually a ROI** inside the dark area, click the button in the `Working toolbar` (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. You create a orange semi-transparent polygon, which is a temporary polygon
- Region growing algorithm can be also used to delineate your polygon.
- It is required to define the **Classes and Macroclasses** for each polygon. Macroclasses can be defined in the Macroclasses tab.
- You can save each Training shapefile : Click the button Save ROI





→ Create multiple polygon encompassing the diversity of landcover

Water bodies, bare soils, Crops, Build-up areas, Forests, grasslands

ROI nomenclature

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.

Macroclass name	Macroclass ID	Class name	Class ID
Vegetation	1	Grass	1
Vegetation	1	Trees	2
Built-up	2	Road	3

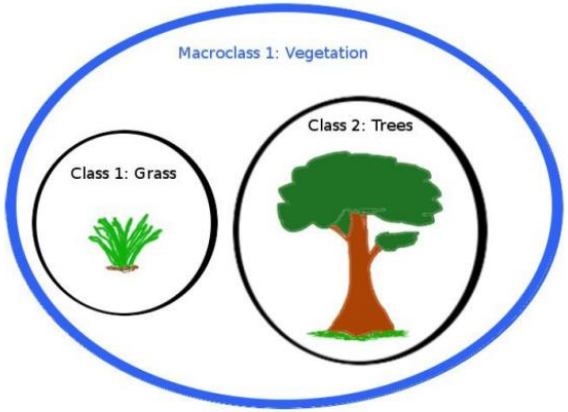
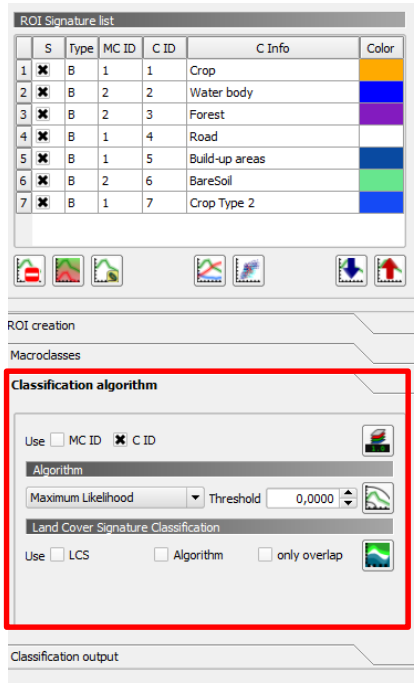


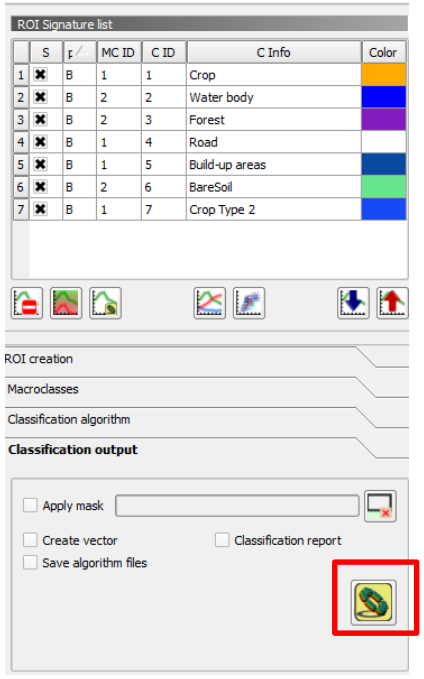
Fig. 7.1: *Macroclass example*

Your First Land Cover Classification

More details and tutorials in the SCP manual (available in 00_Documentation)

4. Perform a classification

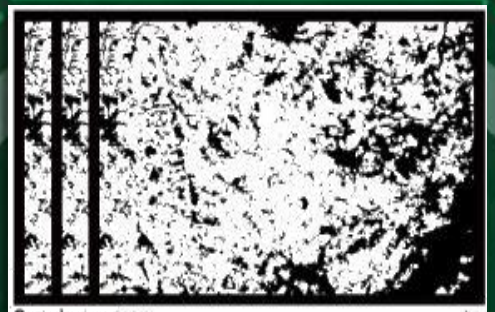




3. Sen2-Agri products exploration

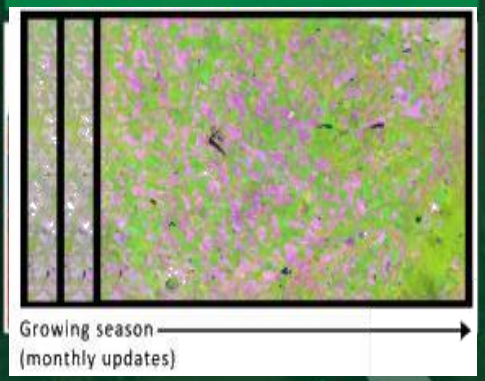
DYNAMIC CROPLAND MASK

Binary map identifying annually cultivated land at 10m updated every month



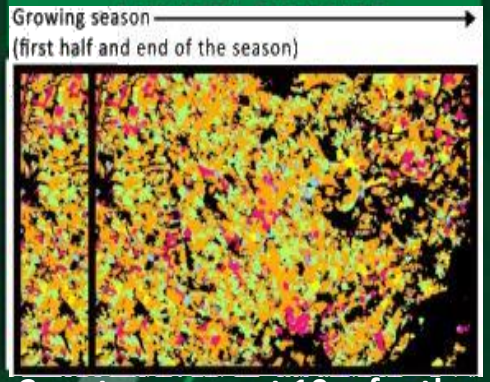
Monthly cloud free surface reflectance composite at 10-20m

CLOUD FREE SURFACE REFLECTANCE COMPOSITES



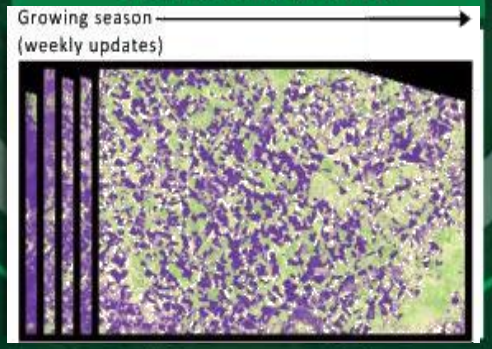
Open source toolbox
Capacity building and training

CULTIVATED CROP TYPE MAP



Crop type map at 10m for the main regional crops including irrigated/rainfed discrimination

VEGETATION STATUS



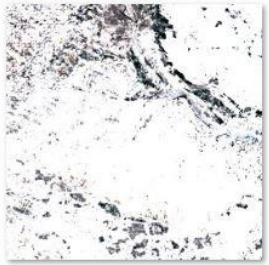
Vegetation status map at 20m delivered every 10 days (NDVI, LAI, pheno index)

Sen2-Agri Product Types

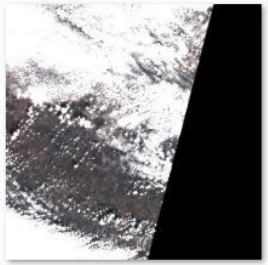
Name	High-level Description	Production & Distribution
Level-1C	Top-of-atmosphere reflectance in cartographic geometry	Systematic generation and on-line distribution (ESA)
Level-2A	Bottom-of-atmosphere reflectance with snow, water, cloud and cloud shadow masks	Sentinel-2 for Agriculture system through MACCS algorithm (CNES)
Level-3A	Monthly composite product	Sentinel-2 for Agriculture System
Level-3B Level-3C Level-3D	Vegetation status map at 20m delivered every 10 days (NDVI, LAI, pheno index). Monodate – Multidate - Fitted	Sentinel-2 for Agriculture System
Level-4A	Dynamic binary map identifying annually cultivated land at 10m updated every month started from the middle of the season	Sentinel-2 for Agriculture System
Level-4B	Crop type map at 10m for the main regional crops including irrigated/rainfed discrimination	Sentinel-2 for Agriculture System

Sentinel-2 2016 time series

over 35UQR tile in Ukraine


S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160129.DBL


S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160218.DBL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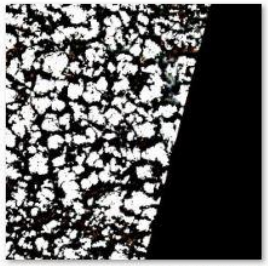

S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160521.DBL


S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160610.DBL

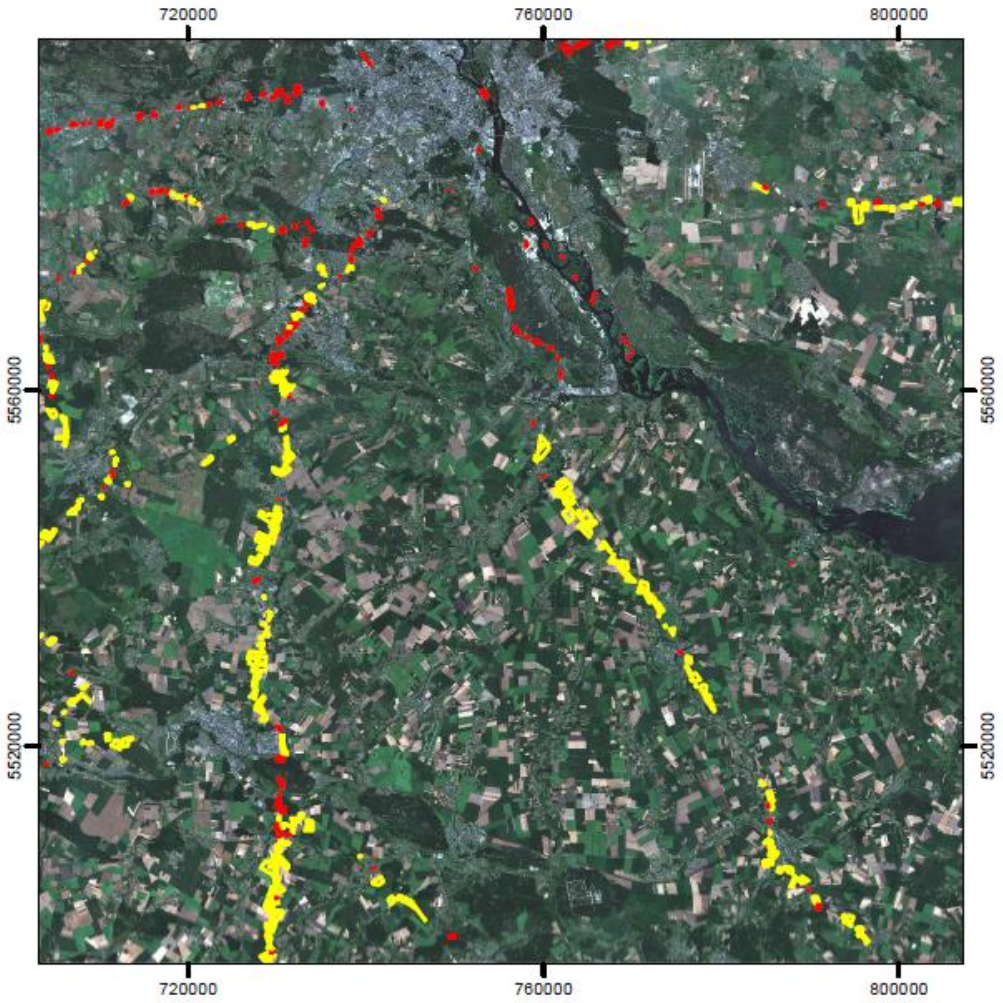

S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160617.DBL

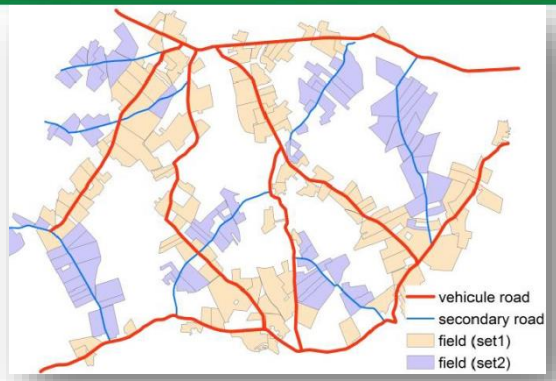

S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160620.DBL

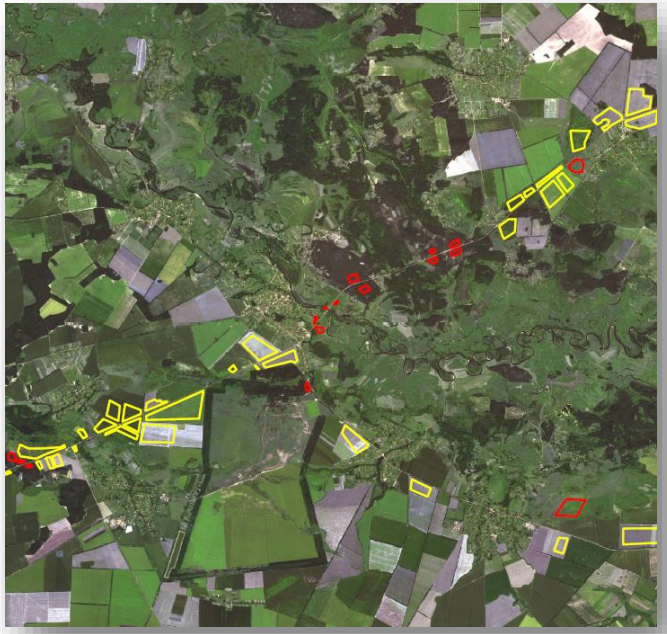

S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160630.DBL


S2A_OPER_SSC_PDTQLK_L2VALD_35UQR__20160717.DBL

Sampling strategy for crop Type and cropland mapping







sentinel-2

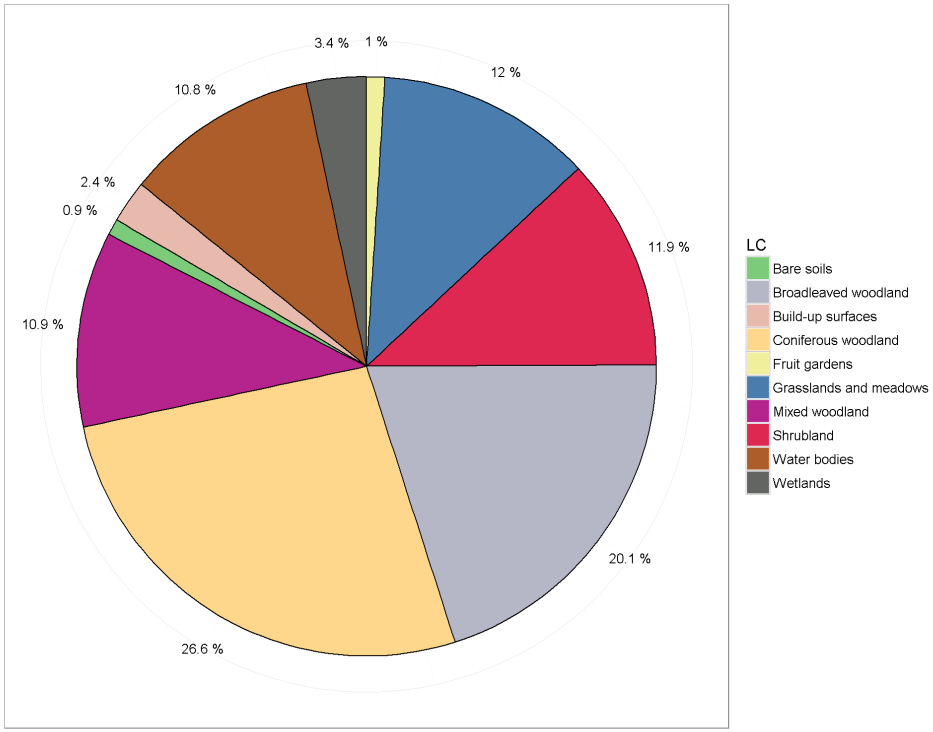
→ AGRICULTURE

Structure of the in situ data set

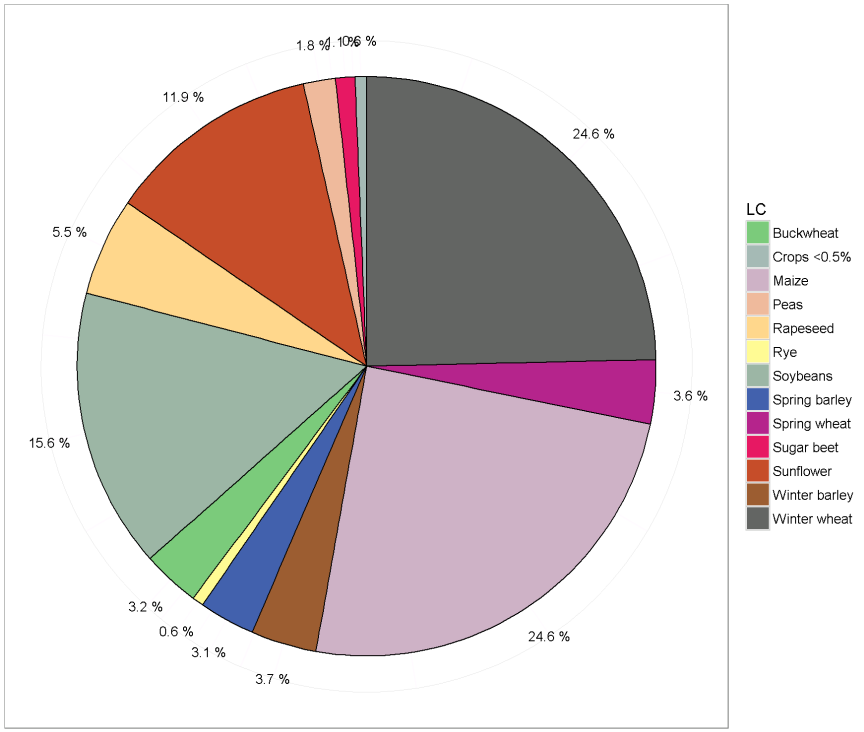
Attribute table - TDS_35UQR :: Features total: 517, filtered: 517, selected: 0

	ID	CROP	LC	CODE	IRRIGATION
132	1556.00	1	Soya beans	41	0
133	1557.00	0	Grassland and m...	2001	0
134	1558.00	0	Shrub land	4001	0
135	1559.00	1	Winter wheat	111	0
136	1560.00	0	Shrub land	4001	0
137	1561.00	0	Shrub land	4001	0
138	1562.00	0	Water bodies	8001	0

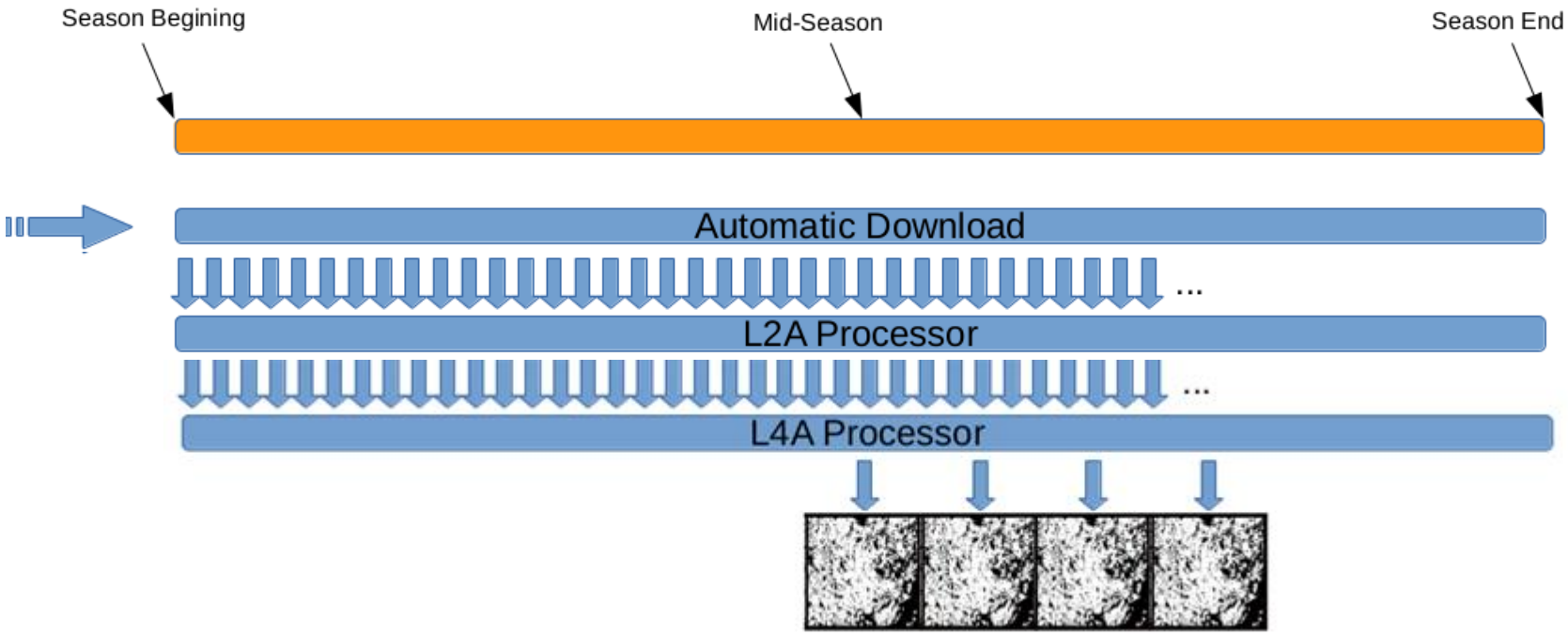
Ukraine_SiteTest_TDS - Non-Cropland area
Total area = 1034 ha

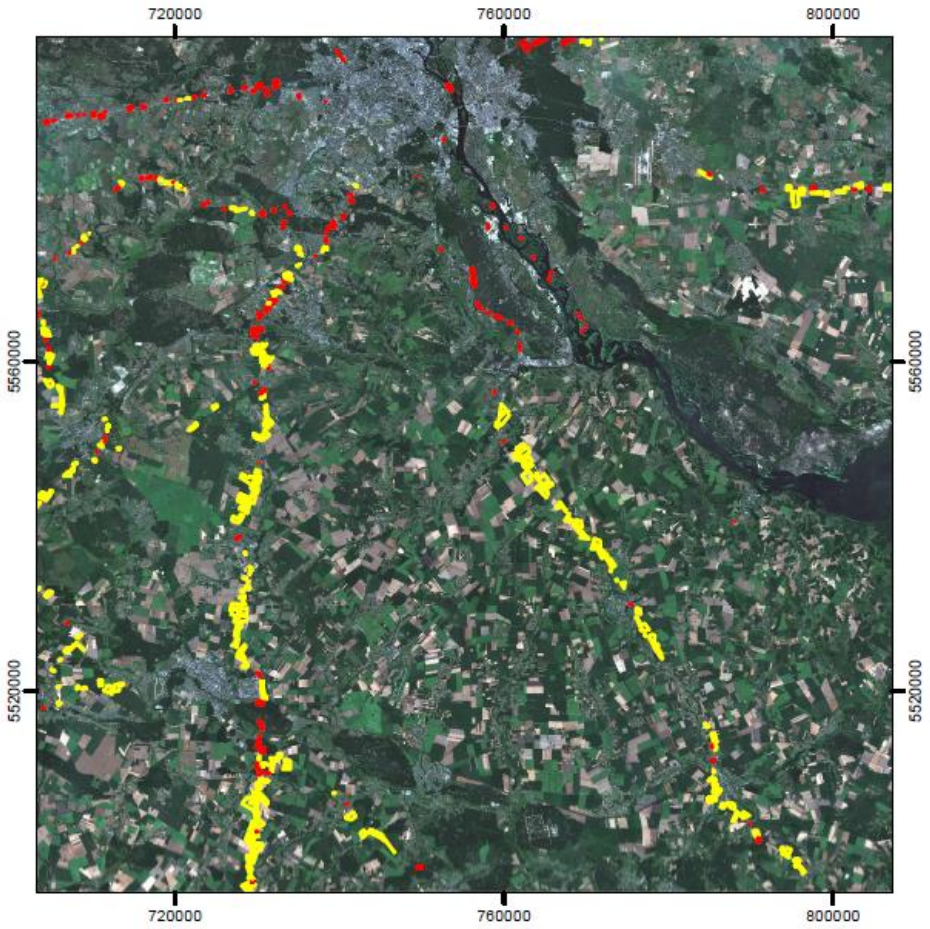


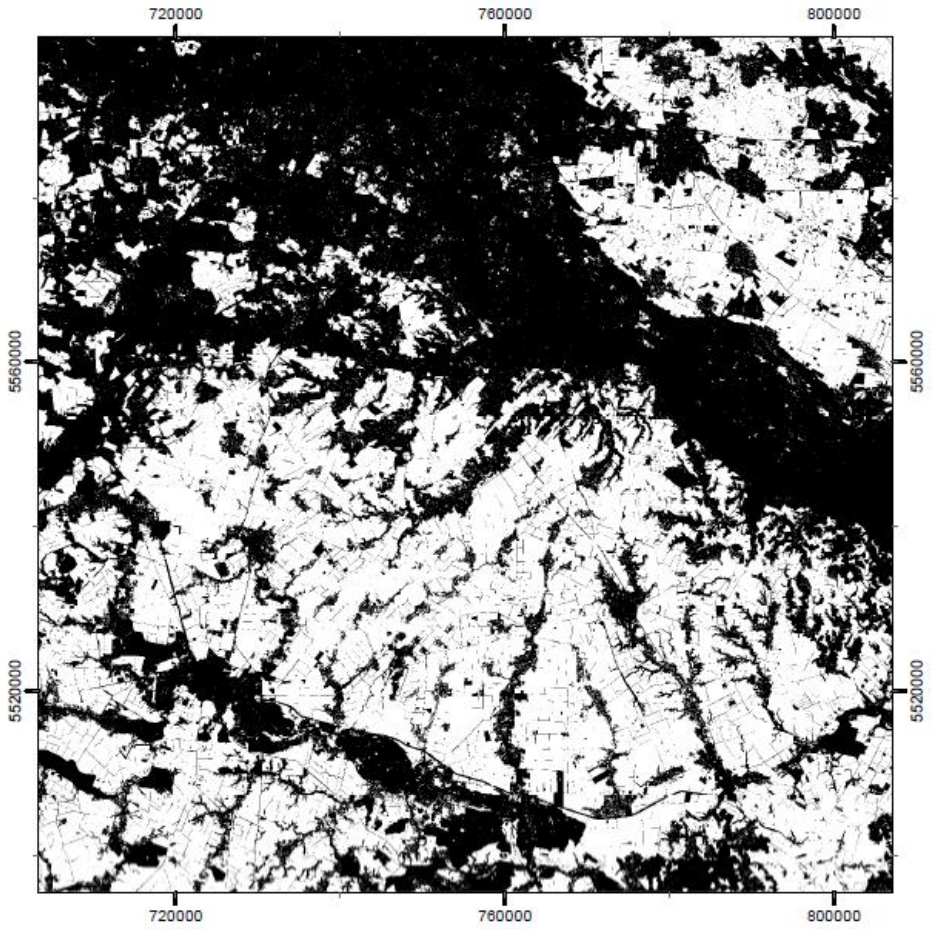
Ukraine_SiteTest_TDS - Cropland area
Total area = 6395 ha



Crop Mask (L4A)







2016 Calibration data survey

- Non-cropland samples
- Cropland samples

2016 Crop Mask

- Non-Cropland
- Cropland

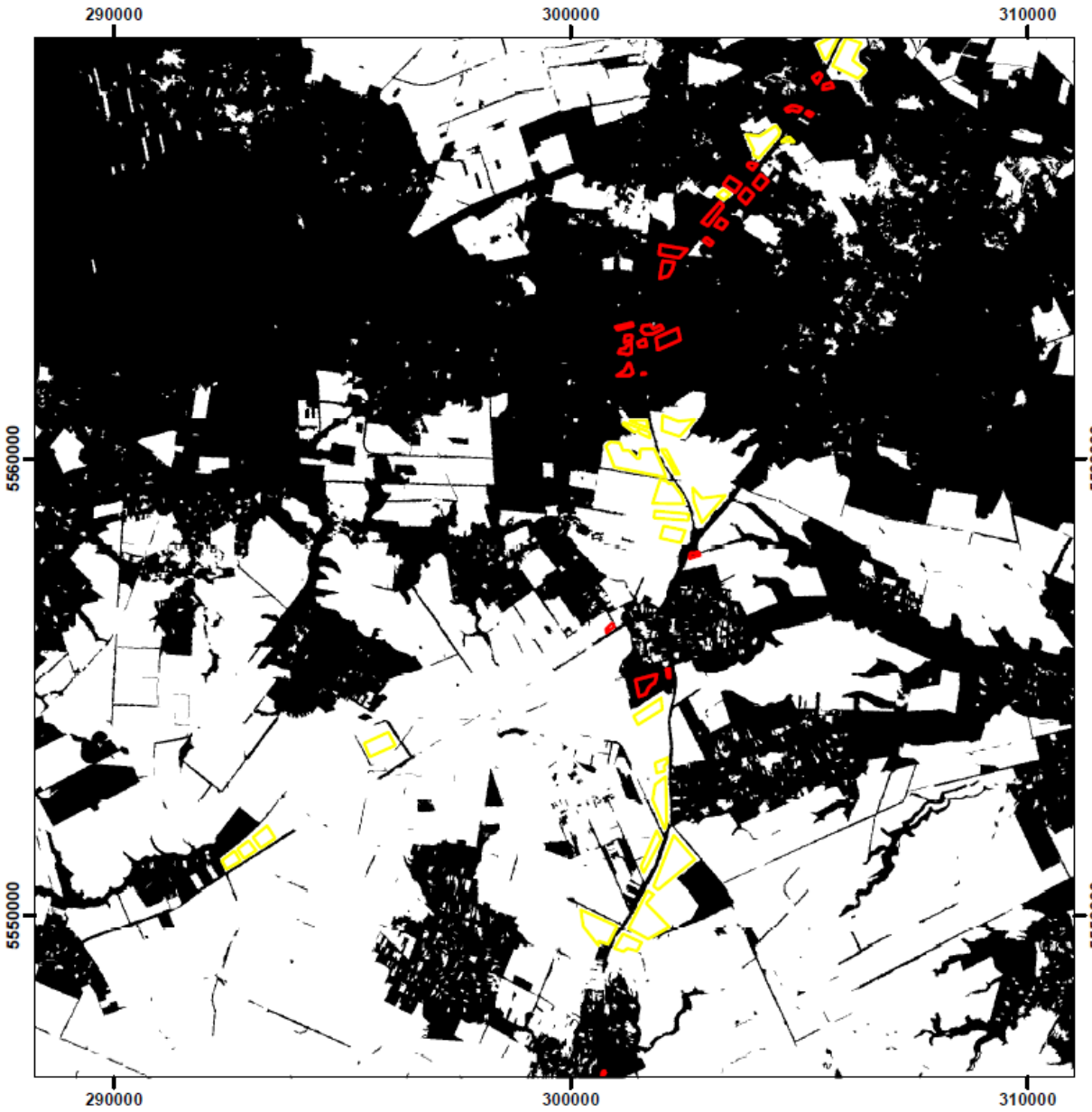
N

Coordinate System : WGS 1984 UTM Zone 35N
Projection : Transverse Mercator
Datum : WGS 1984
Unit : Meter

Sources: Sentinel-2 background image Tile 35UQR from 17-07-2016 (ESA, Copernicus Sentinel data 2016) ;
In situ data collected by Space Research Institute of the National Academy of Science & State Space Agency, Ukraine

1:800.000

0 5 10 20 Kilometers



Calibration in-situ data set

- Non-cropland samples
- Cropland samples

Binary Crop mask

- Non-Cropland
- Cropland

1:130.000

N

Coordinate System : WGS 1984 UTM Zone 35N
Projection : Transverse Mercator
Datum : WGS 1984
Unit : Meter

Sources: In situ data collected by Space Research Institute of the National Academy of Science & State Space Agency, Ukraine

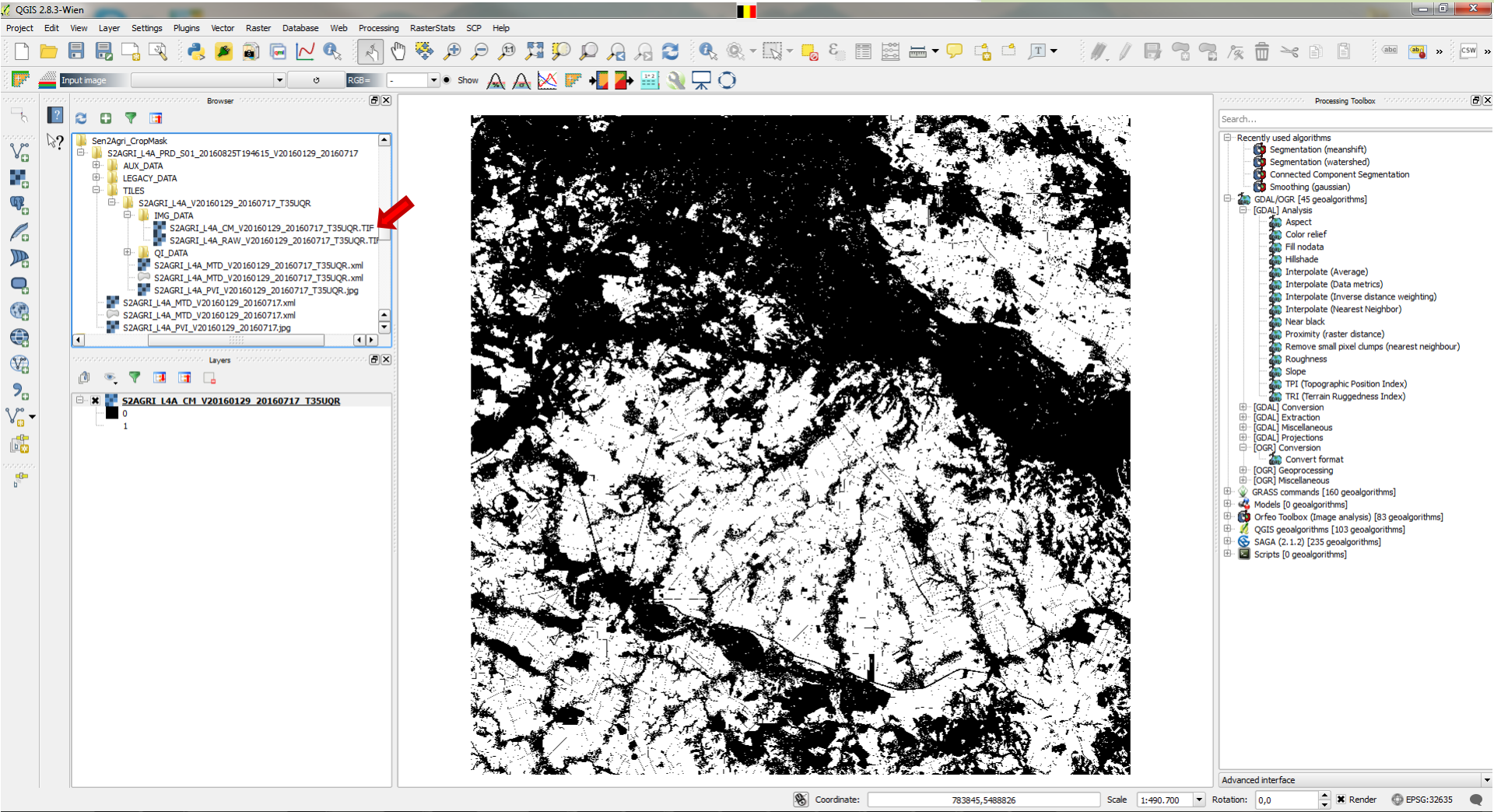
0 2 4 8 Kilometers

Product exploration and manipulation

Consult the **Product sheets** and the **Product data structure summary**

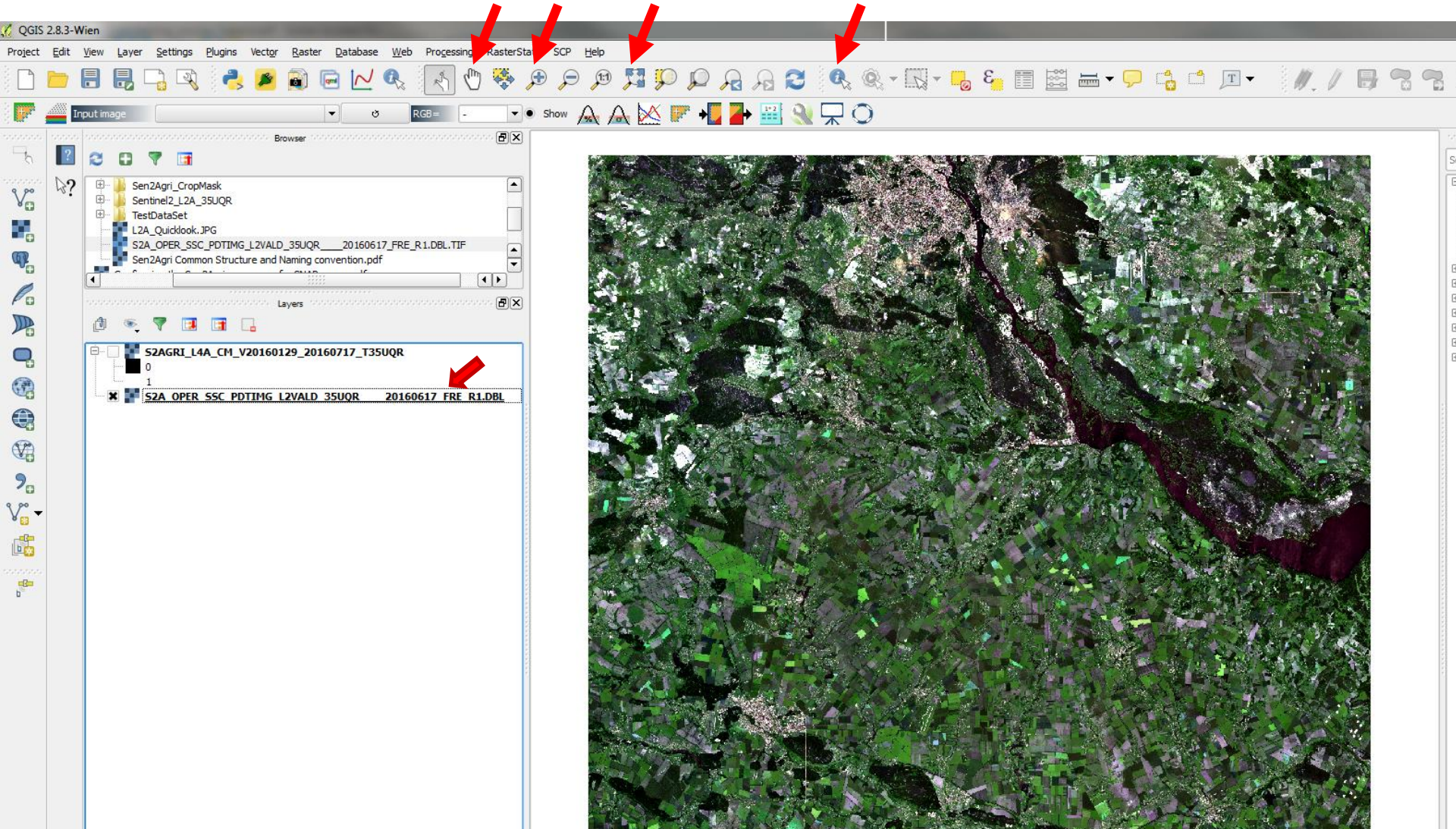
Let’s explore the Cropland mask product

Binary mask : 0 = non-cropland
1 = Cropland

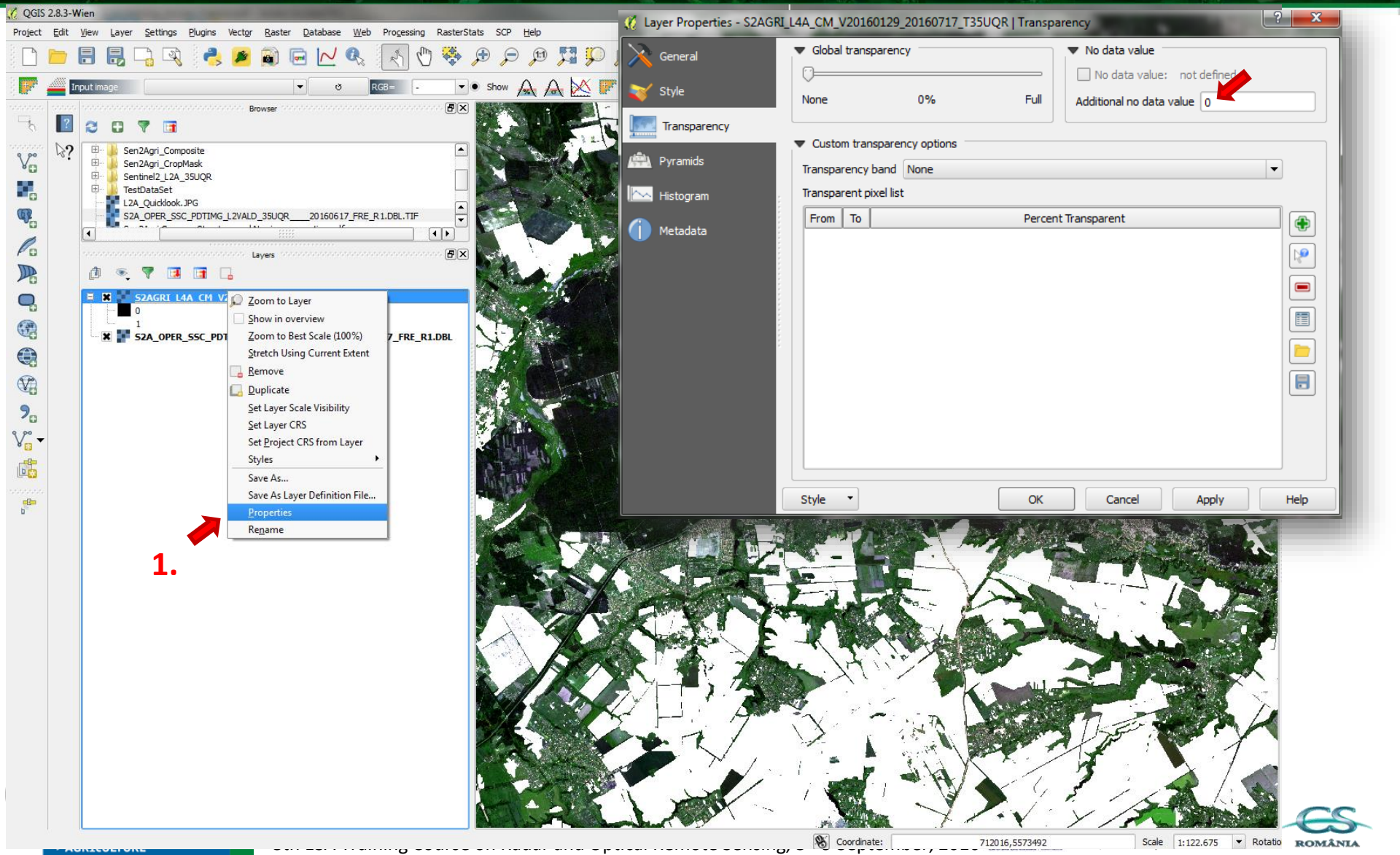


Display Surface reflectance image in the background

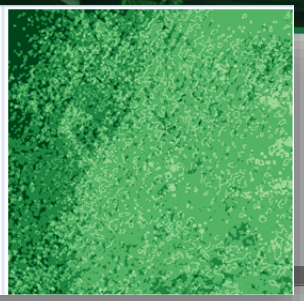
These icons allow you to explore the product easily

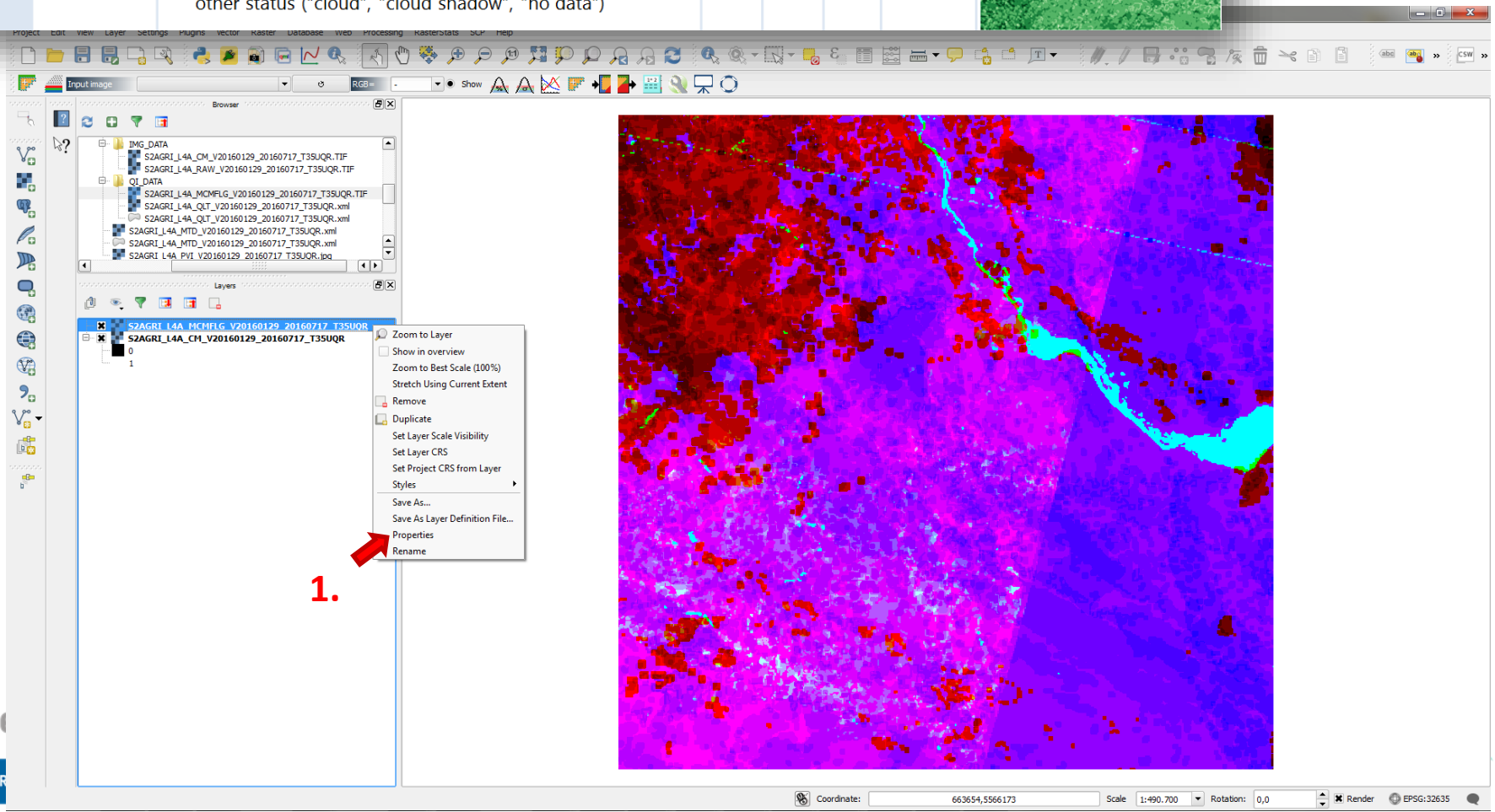


Set transparency to no crop pixels



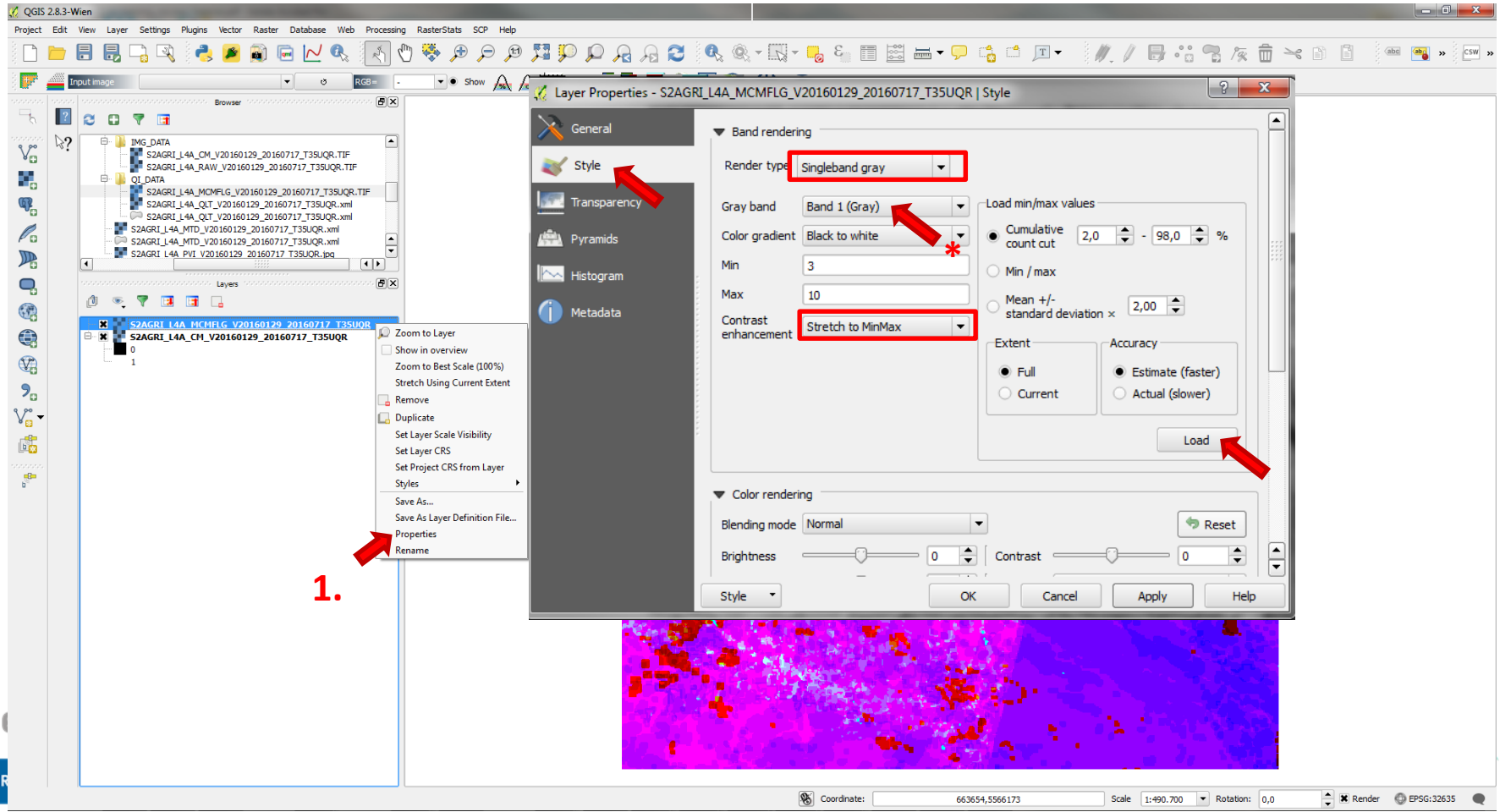
Check the quality indicator masks

/QI_DATA	MCMFLG	Status of the pixel during the period used to generate the map Band 1 = number of dates which are associated with the "land" status Band 2 = number of dates which are associated with the "water" status Band 3 = number of dates which are associated with the "snow" status Band 4 = number of dates which are associated with the other status ("cloud", "cloud shadow", "no data")	10	4	16	GEOTIFF	

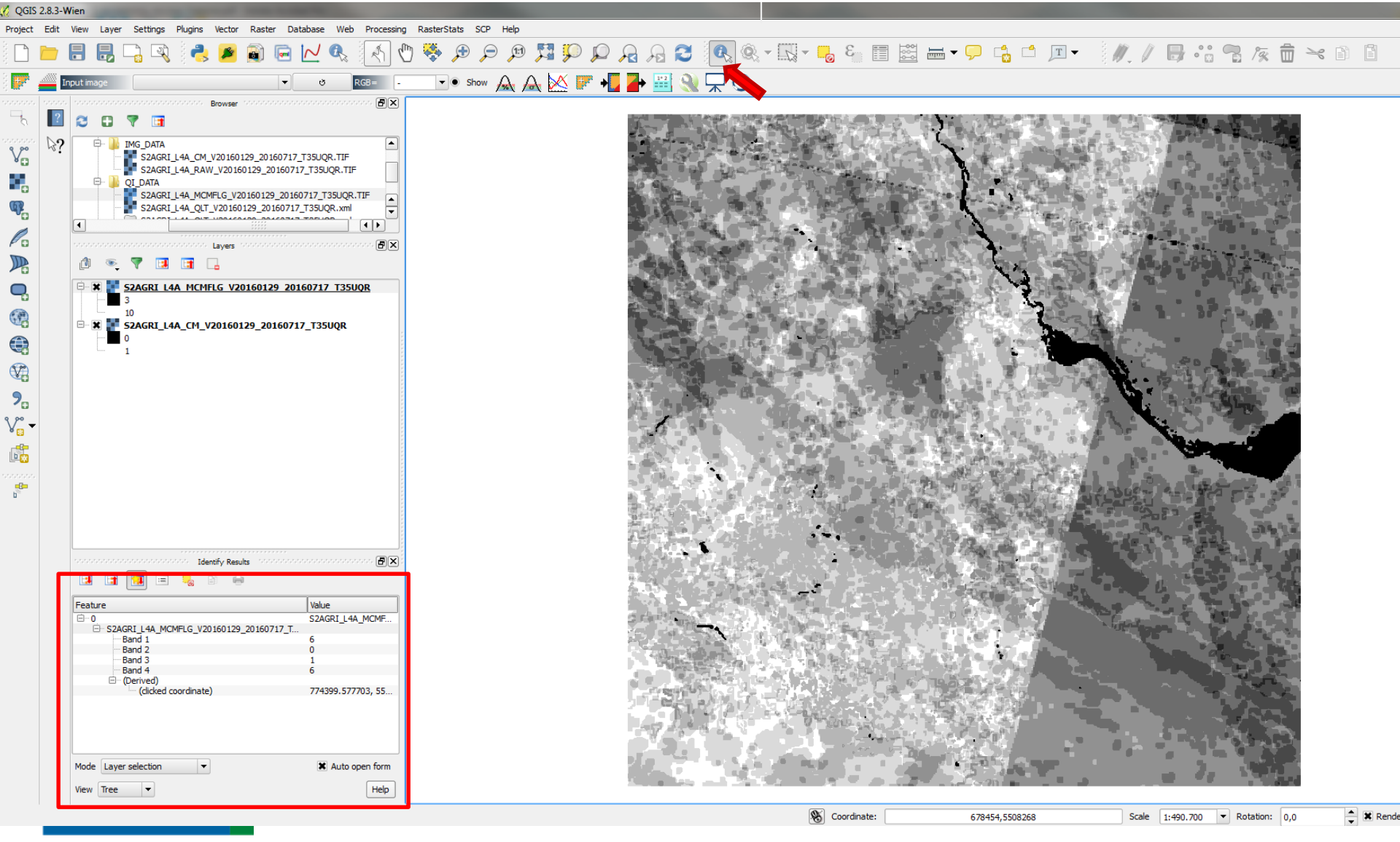


Check the quality indicator masks

*Select band 1 if you want to know the number of dates associated to the land status (i.e. without any cloud, water, snow or cloud shadow)



How many cloud free dates are used for the classification ?



How accurate is my cropland mask ?

Have a look on the delivered quality metrics (**QI_DATA > S2AGRI_L4A_QLT_….xml**)

From \S2AGRI_L4A_PRD_S01_20160825T194615_V20160129_20160717\TILES\S2AGRI_L4A_V20160129_20160717_T35UQR\QI_DATA

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        </ReferenceLabels>
        <ProducedLabels>
            <ColumnLabel>0</ColumnLabel>
            <ColumnLabel>1</ColumnLabel>
        </ProducedLabels>
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            <Row>
                <Column>20445</Column>
                <Column>12</Column>
            </Row>
            <Row>
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                <Column>94969</Column>
            </Row>
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    </ConfusionMatrix>
    <QualityMetrics>
        <Precision class="0"> 0.755655</Precision>
        <Recall class="0"> 0.999413</Recall>
        <F-score class="0"> 0.860607</F-score>
        <Precision class="1"> 0.999874</Precision>
        <Recall class="1"> 0.934918</Recall>
        <F-score class="1"> 0.966306</F-score>
        <Kappa> 0.827716</Kappa>
        <Accuracy> 0.94573</Accuracy>
    </QualityMetrics>
</CropMask>
```

Confusion matrix

2/3 of the data set = calibration
1/3 of the data set = validation

Quality metric : Precision – Recall – F-Score – Kappa – OA

Some words about the quality metrics

1.1 Overall accuracy

The Overall Accuracy (OA) is calculated as the total number of correctly classified pixels (diagonal elements of the confusion matrix) divided by the total number of test pixels:

$$OA = \frac{\sum_{i=1}^{r} n_{ii}}{\sum_{i=1}^{r}\sum_{j=1}^{r} n_{ij}}$$

1.1 F-Score

The F-Score (also known as F-1 score or F-measure) is the harmonic mean of the Precision and Recall and reaches its best value at 1 and worst score at 0:

$$FScore = 2x\frac{Precison * Recall}{Precision + Recall}$$

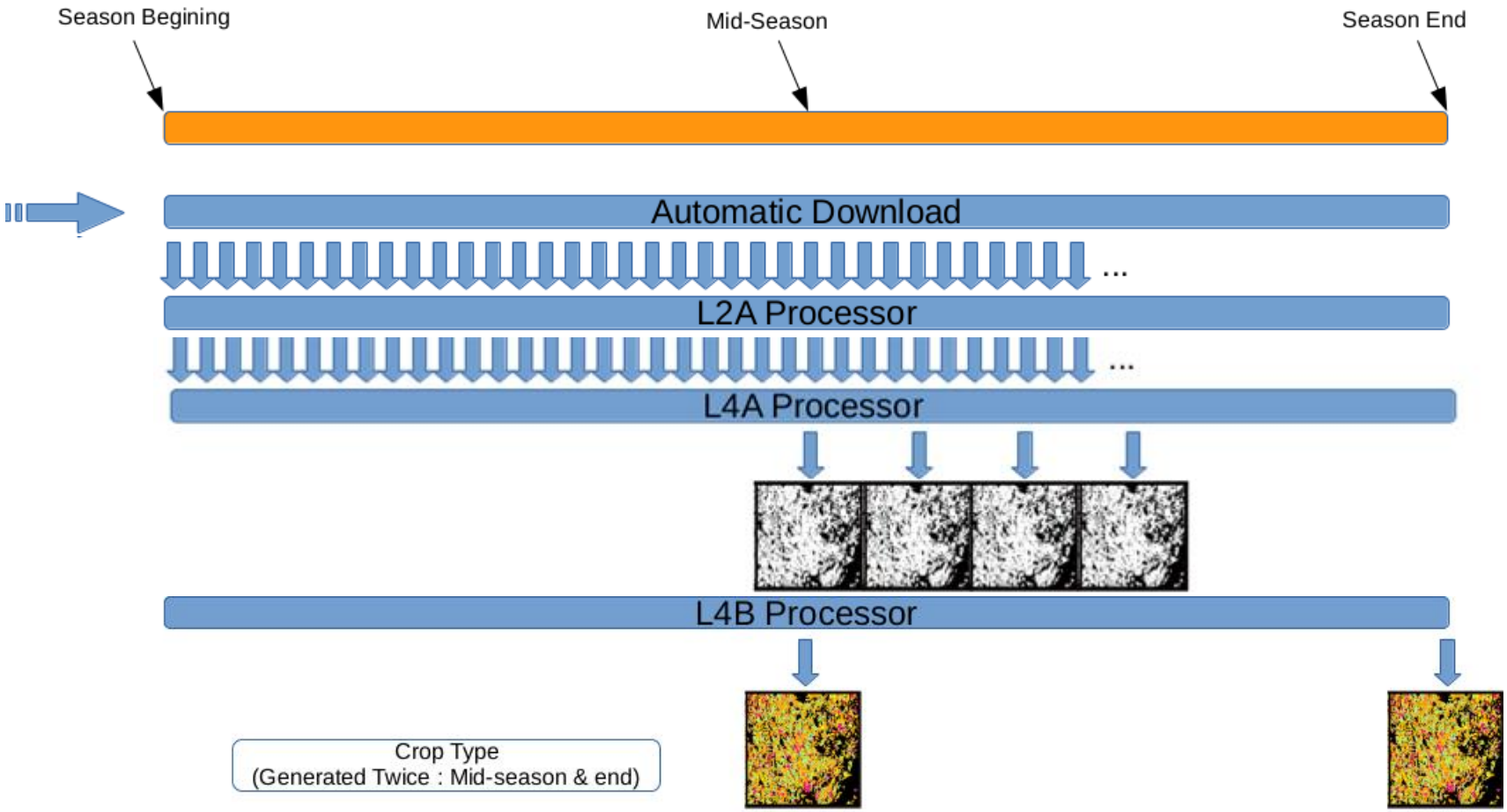
Precision or User's Accuracy (UA) for the class *i* it is the fraction of correctly classified pixels with regard to all pixels classified as this class *i* in the classified image:

$$UA_i = \sum_{j=1}^{r} \frac{n_{ii}}{n_{ij}}$$

Recall or Producer's Accuracy (PA) for the class *i* it is the fraction of correctly classified pixels with regard to all pixels of that ground truth class *i*:

$$PA_i = \sum_{j=1}^{r} \frac{n_{ii}}{n_{ji}}$$

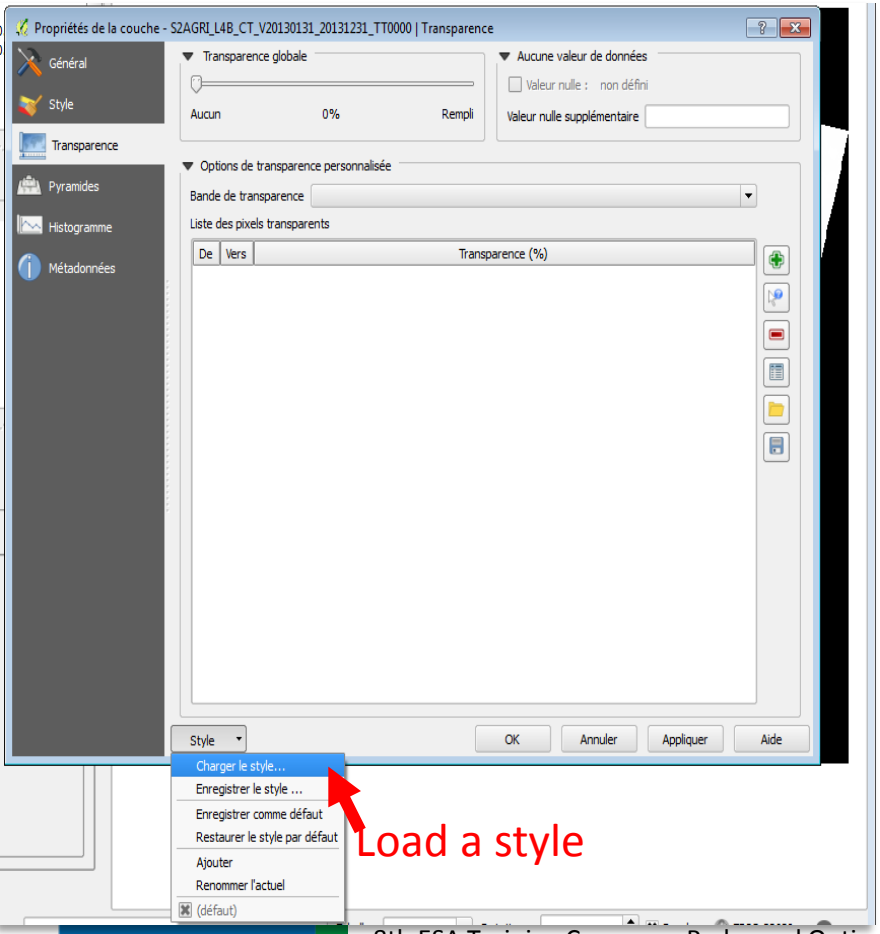
Crop Type (L4B)



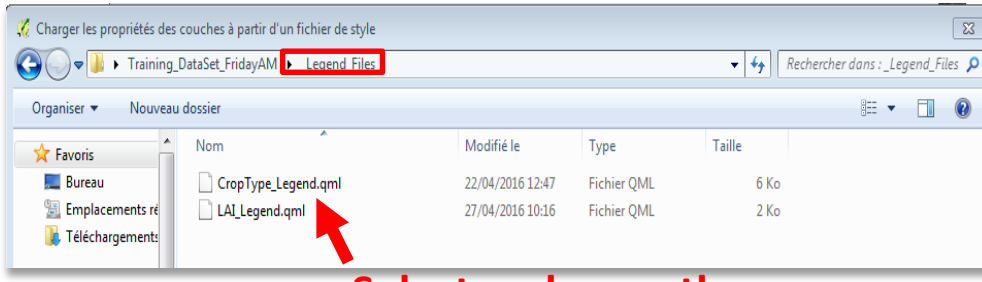

330000
340000
5540000
5530000
5520000

1. Introduction to the product

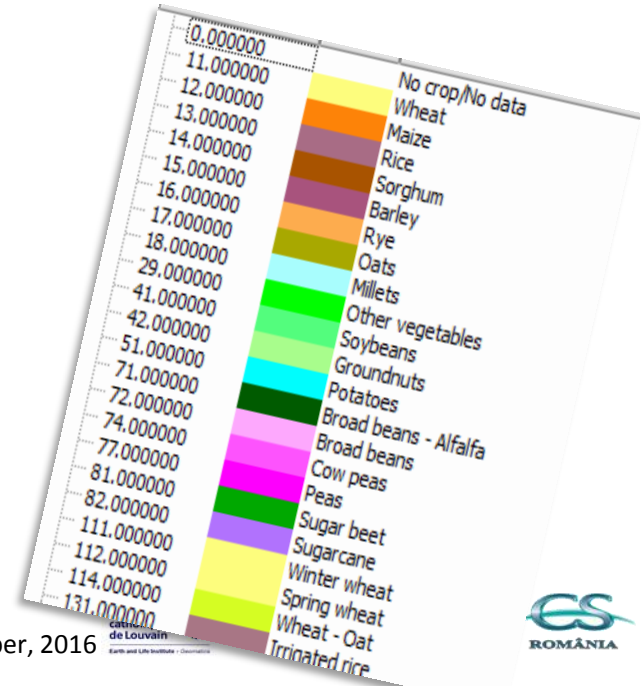
- Open and display a crop type image
- Assign a style



Load a style



Select and open the croptype legend



- Set transparency to no crop pixels
- Visual analysis of the image
- Display monthly color composite image in the background
- Overlay ground data used for the calibration and validation: add *TDS_35UQR.shp*

How accurate is my Croptype map?

Have a look on the delivered quality metrics (QI_DATA > S2AGRI_L4B_**QLT**_....xml)

```
<?xml version="1.0" encoding="UTF-8"?>
<CropType xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  - <ConfusionMatrix>
    - <ReferenceLabels>
        <RowLabel>11</RowLabel>
        <RowLabel>12</RowLabel>
        <RowLabel>72</RowLabel>
        <RowLabel>114</RowLabel>
        <RowLabel>225</RowLabel>
        <RowLabel>791</RowLabel>
      </ReferenceLabels>
    - <ProducedLabels>
        <ColumnLabel>0</ColumnLabel>
        <ColumnLabel>11</ColumnLabel>
        <ColumnLabel>12</ColumnLabel>
        <ColumnLabel>72</ColumnLabel>
        <ColumnLabel>114</ColumnLabel>
        <ColumnLabel>225</ColumnLabel>
        <ColumnLabel>791</ColumnLabel>
      </ProducedLabels>
    - <Data>
      - <Row>
          <Column>655</Column>
          <Column>17894</Column>
          <Column>0</Column>
          <Column>0</Column>
          <Column>167</Column>
          <Column>0</Column>
          <Column>5</Column>
        </Row>
      - <Row>
          <Column>0</Column>
          <Column>124</Column>
          <Column>466</Column>
          <Column>0</Column>
          <Column>0</Column>
          <Column>0</Column>
          <Column>0</Column>
        </Row>
      - <Row>
          <Column>11</Column>
          <Column>119</Column>
          <Column>13</Column>
          <Column>0</Column>
          <Column>4</Column>
          <Column>0</Column>
          <Column>9</Column>
        </Row>
```

Code of the crop (Jecam guidelines)

Confusion matrix

```
    </ConfusionMatrix>
  - <QualityMetrics>
      <Precision class="11"> 0.89287</Precision>
      <Recall class="11"> 0.990479</Recall>
      <F-score class="11"> 0.939145</F-score>
      <Precision class="12"> 0.968815</Precision>
      <Recall class="12"> 0.789831</Recall>
      <F-score class="12"> 0.870215</F-score>
      <Precision class="72"> 0</Precision>
      <Recall class="72"> 0</Recall>
      <F-score class="72"> 0</F-score>
      <Precision class="114"> 0.687956</Precision>
      <Recall class="114"> 0.167854</Recall>
      <F-score class="114"> 0.269864</F-score>
      <Precision class="225"> 1</Precision>
      <Recall class="225"> 1</Recall>
      <F-score class="225"> 1</F-score>
      <Precision class="791"> 0.935115</Precision>
      <Recall class="791"> 0.856643</Recall>
      <F-score class="791"> 0.894161</F-score>
      <Kappa> 0.480783</Kappa>
      <Accuracy> 0.890488</Accuracy>
    </QualityMetrics>
</CropType>
```

Quality metric : Precision – Recall – F-Score – Kappa – OA

2. Simple processing

2.1 ***Filtering of crop type image***

- Remove all patches below , for instance

  `Processing -> ToolBox -> GDAL/OGR -> Sieve`

  Input Layer: the crop type image

  Threshold: 25 (the minimum size if the patches to be kept) = 25 pixels of 10x10 m = 0,25 h

  Pixel connection: 8 (consider all neighbours of a pixel)

- Compare to unfiltered crop type image

2.2 ***Create and display a single crop image***

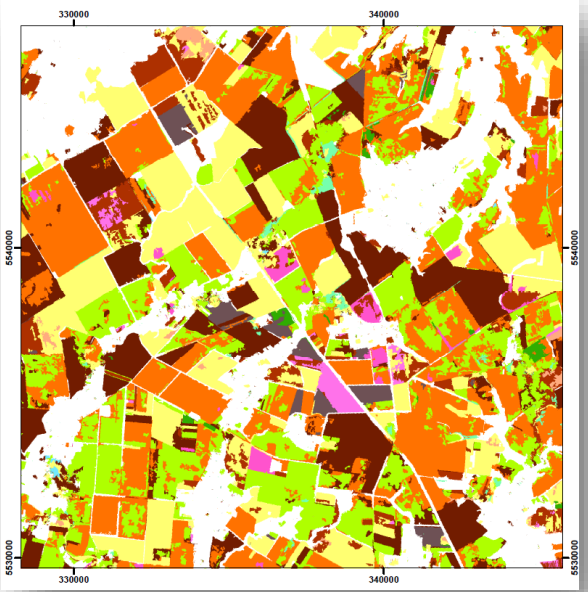
- Find the class number you wish to consider

  `Raster-> Raster Calculator`

  "S2AGRI L4B CT V20160129 20160717 T35UQR" = 12

  12 is the number of the crop type class

- Define a style



Crop type : Qgis processing

2.3 ***Group crops per categories***

- Gather summer crops and winter crops in two classes
  - Creates a txt file

    12 14 41 438 = 1 *(summer crops are grouped under class #1)*

    11 15 77 11 435 =2 *(winter crops are grouped under class #2)*

    - = 3 *(other classes are grouper under class #3)*

  - `Processing -> ToolBox -> GRASS -> Raster -> r.reclass`
  - `Set a style`

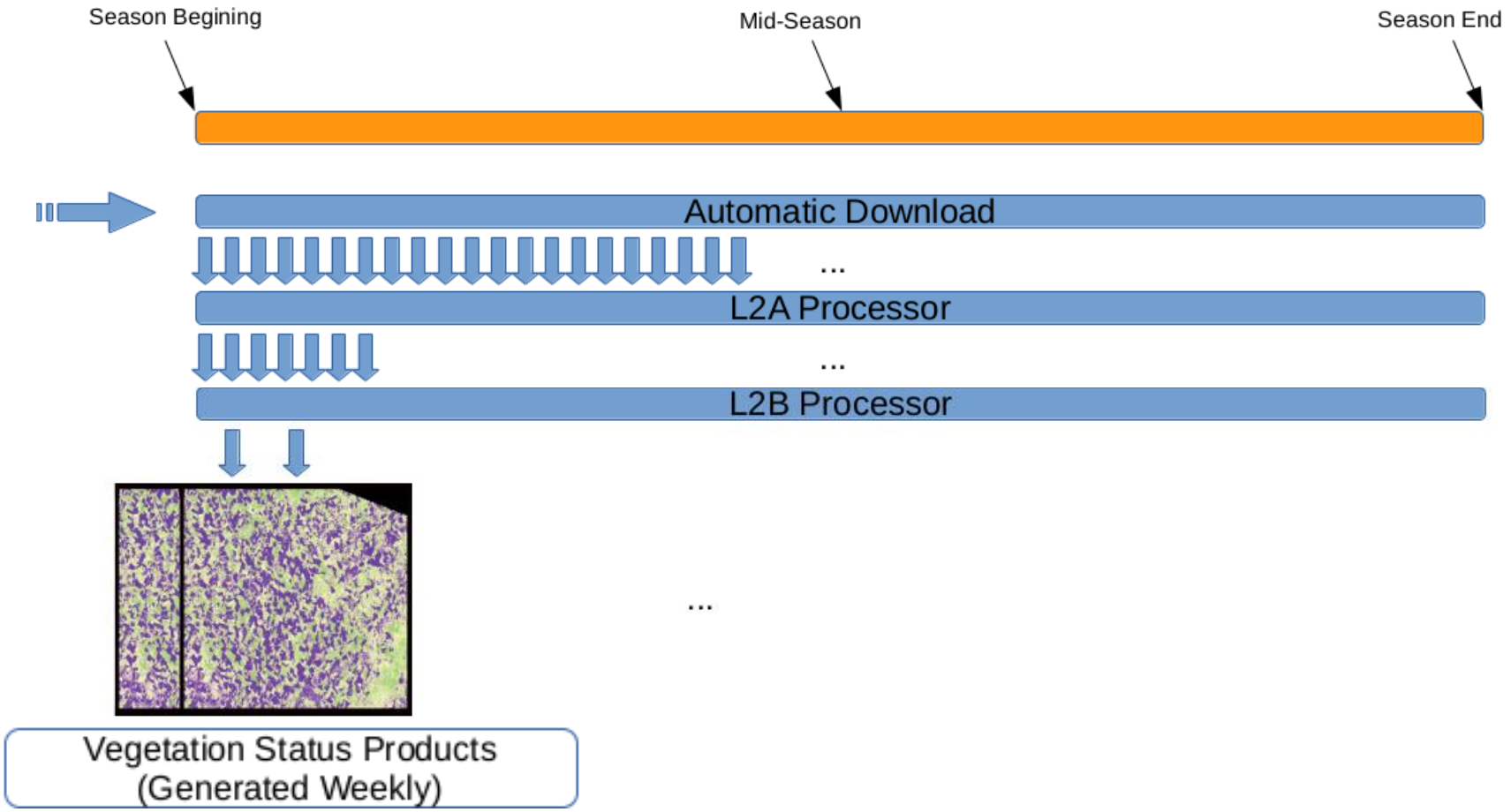
- OR Gather potentially irrigated crops
  - Creates a txt file

    12 41 = 1 (maize and soybean crops are grouped under class #1)

    * = NULL (other classes as no data)

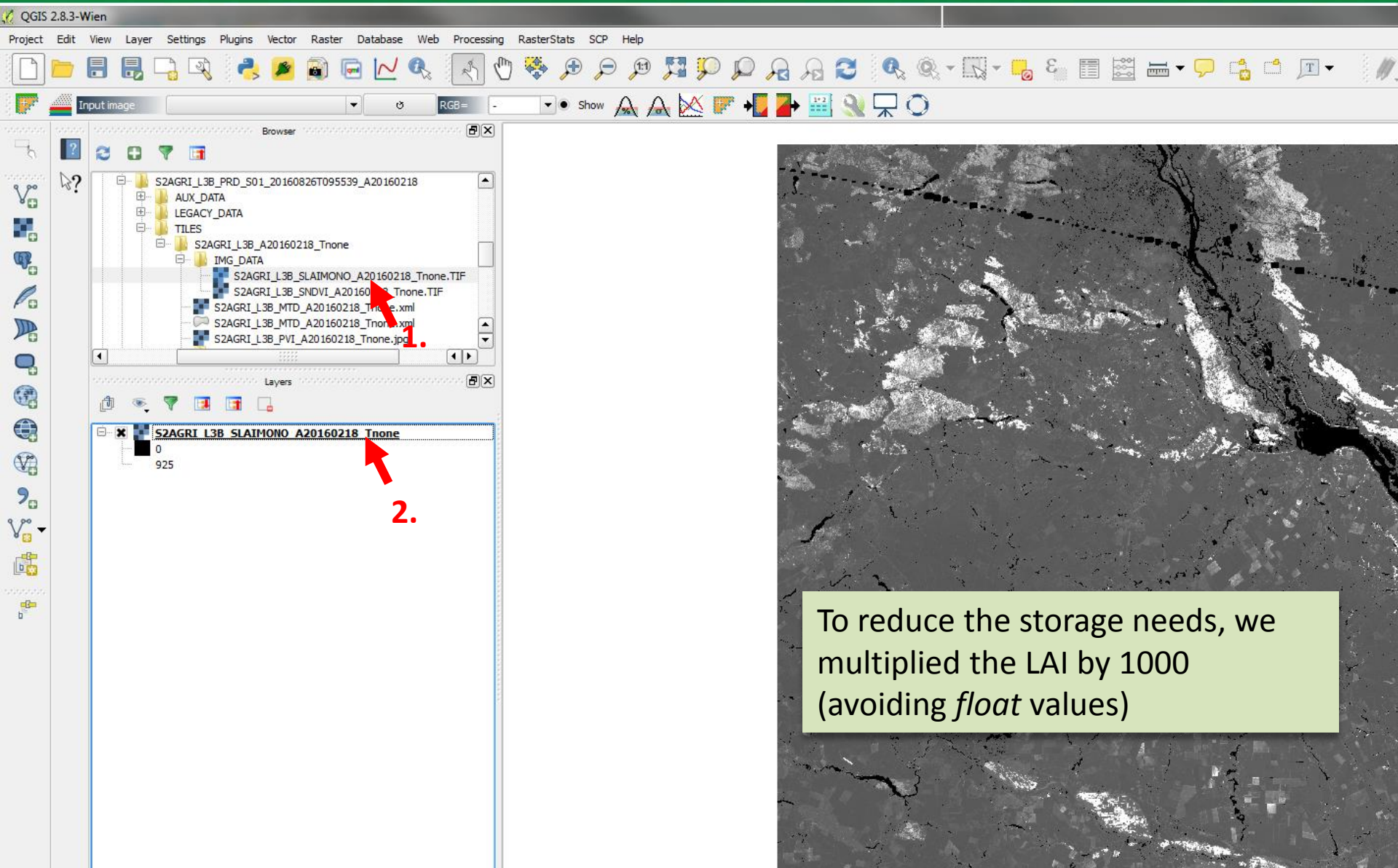
  - `Processing -> ToolBox -> GRASS -> Raster -> r.reclass`
  - `Set a style`

Vegetation Status



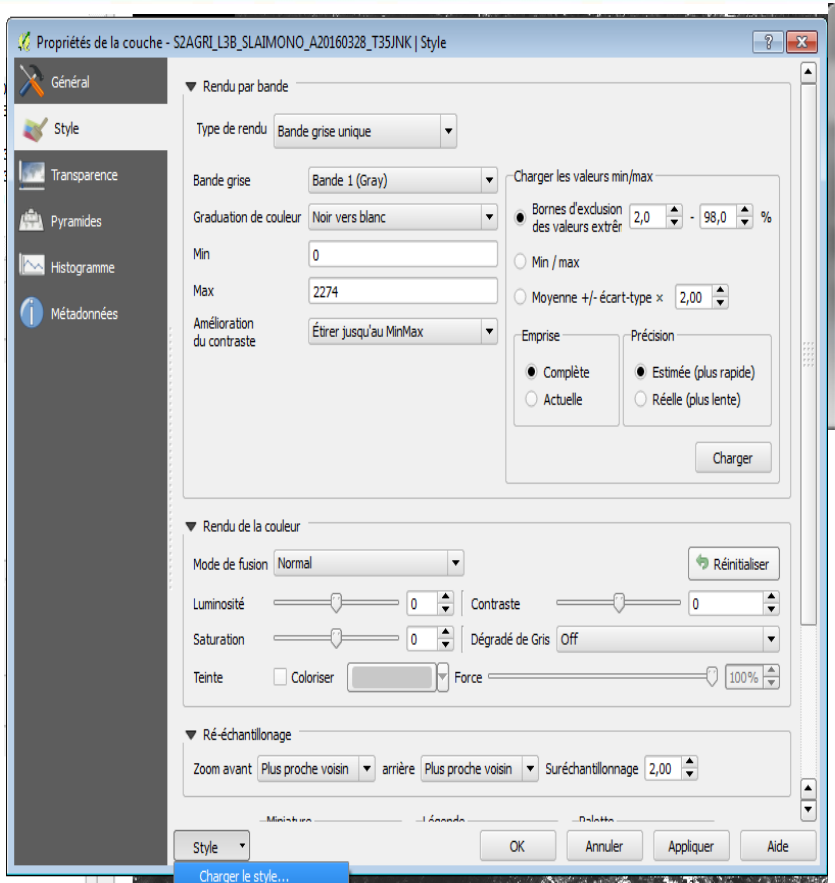
Display the LAI monodate (SLAIMONO) (1)

1. Add the LAI *.TIF* product from *TILES>IMG_DATA>S2AGRI_L3B_SLAIMONO… . TIF*

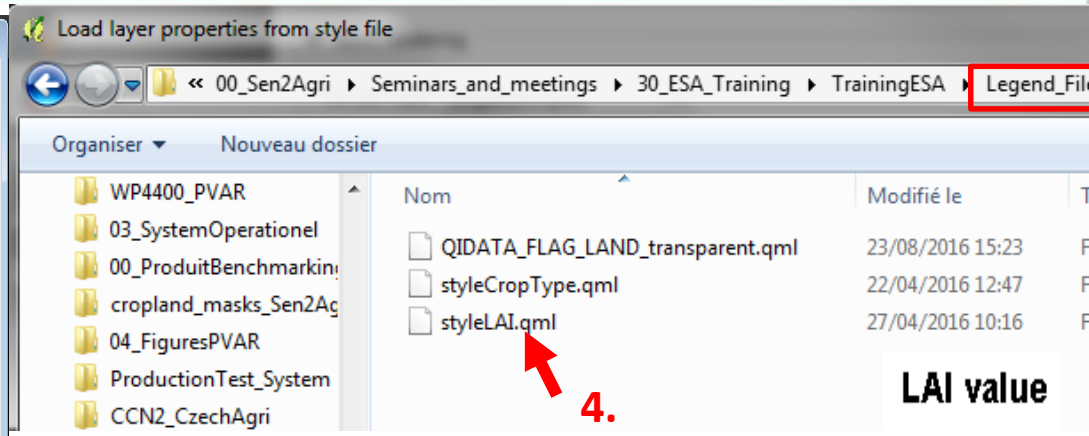


To reduce the storage needs, we multiplied the LAI by 1000 (avoiding *float* values)

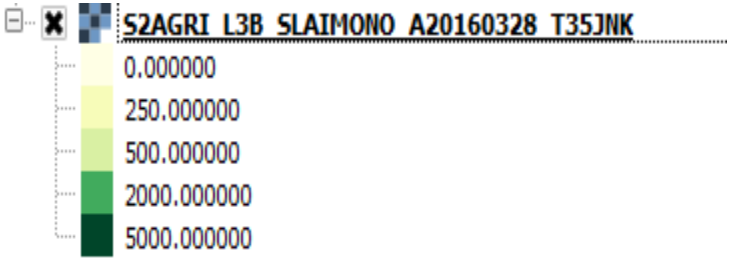
Display the LAI monodate (SLAIMONO) (2)

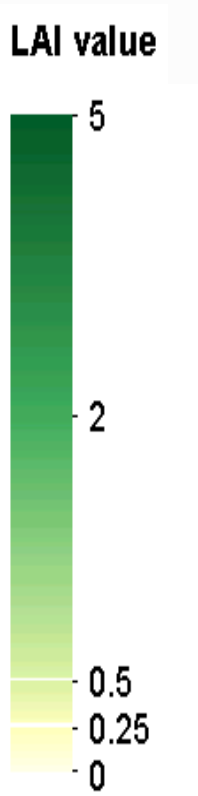


3. Load a style



4.





QGIS 2.8.3-Wien

Project Edit View Layer Settings Plugins Vector Raster Database Web Processing RasterStats SCP Help

Input image RGB= Show

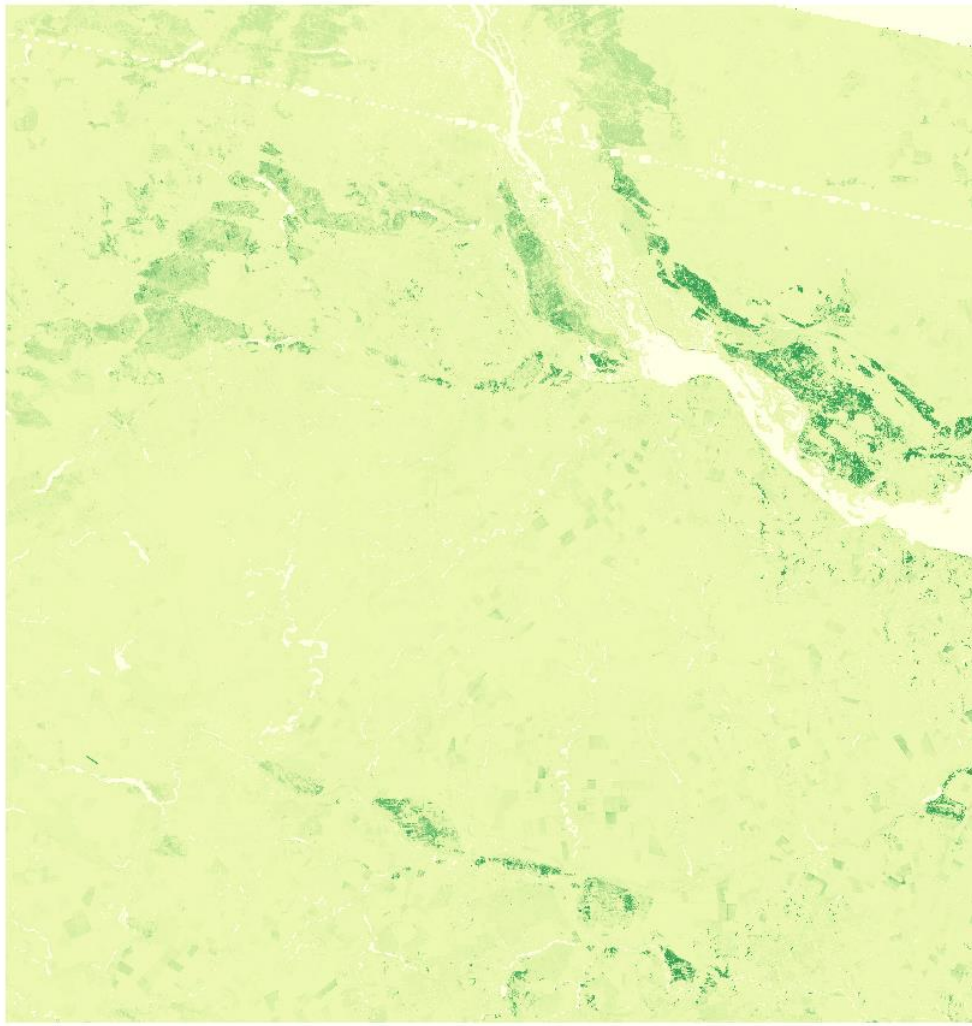
Browser

- Sen2Agri_CropMask
- Sen2Agri_CropType
- Sen2Agri_VegetationStatus
  - S2AGRI_L3B_PRD_S01_20160826T095539_A20160218
  - S2AGRI_L3B_PRD_S01_20160826T101417_A20160329
    - AUX_DATA
    - LEGACY_DATA
    - TILES
    - S2AGRI_L3B_MTD_A20160329.xml
    - S2AGRI_L3B_MTD_A20160329.xml
    - S2AGRI_L3B_PVI_A20160329.jpg

Layers

S2AGRI_L3B_SLAIMONO_A20160218_Tnone

- 0.000000
- 250.000000
- 500.000000
- 2000.000000
- 5000.000000



Lets continue exploring

1. Display the corresponding L2A images

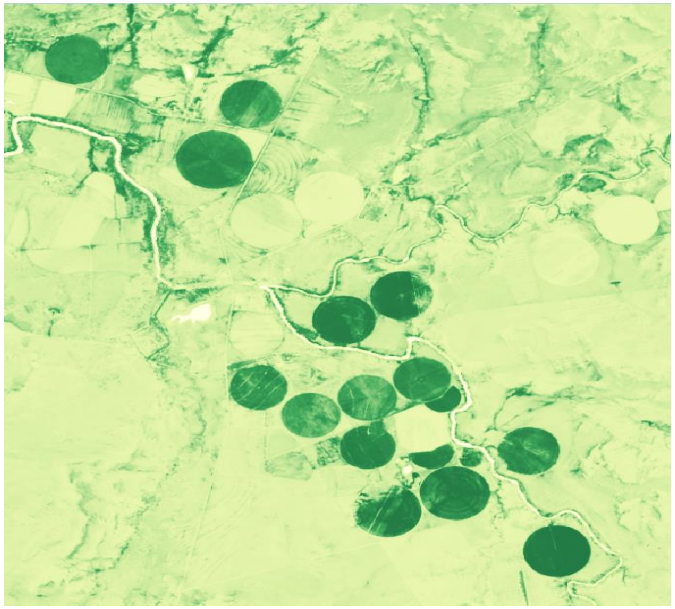
2. Display le **QI « MLAIERR »** giving you the error on the LAI estimation for each pixel

   > 0 : the model over-estimate the real value

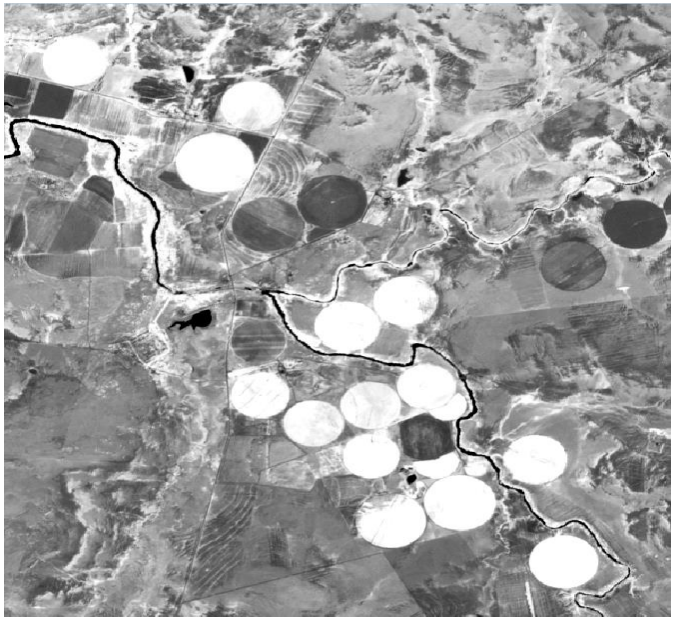
   < 0 : the model under-estimate the real value

3. Display the **NDVI** product

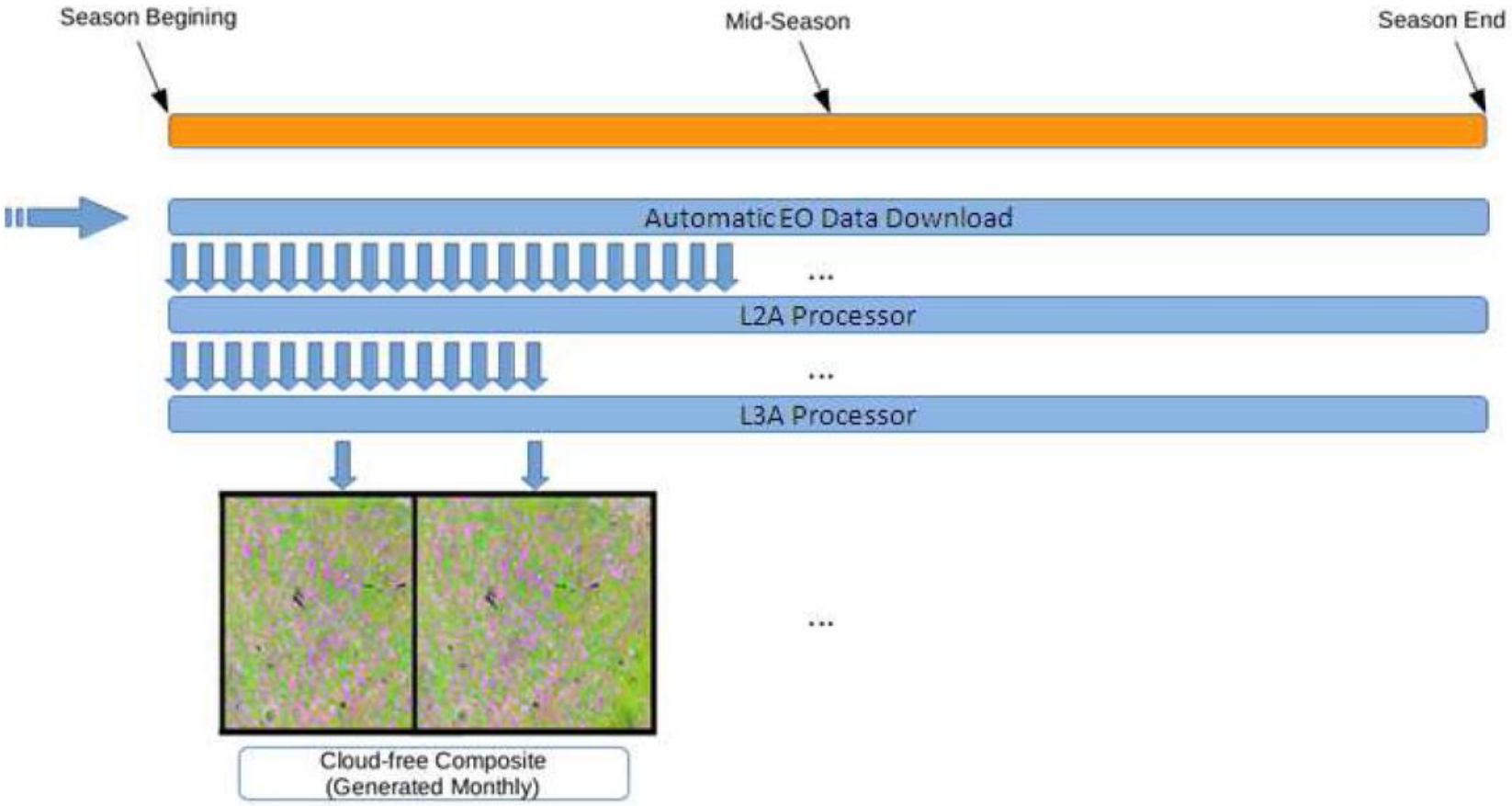
Mono-date LAI



NDVI



Cloud free composite



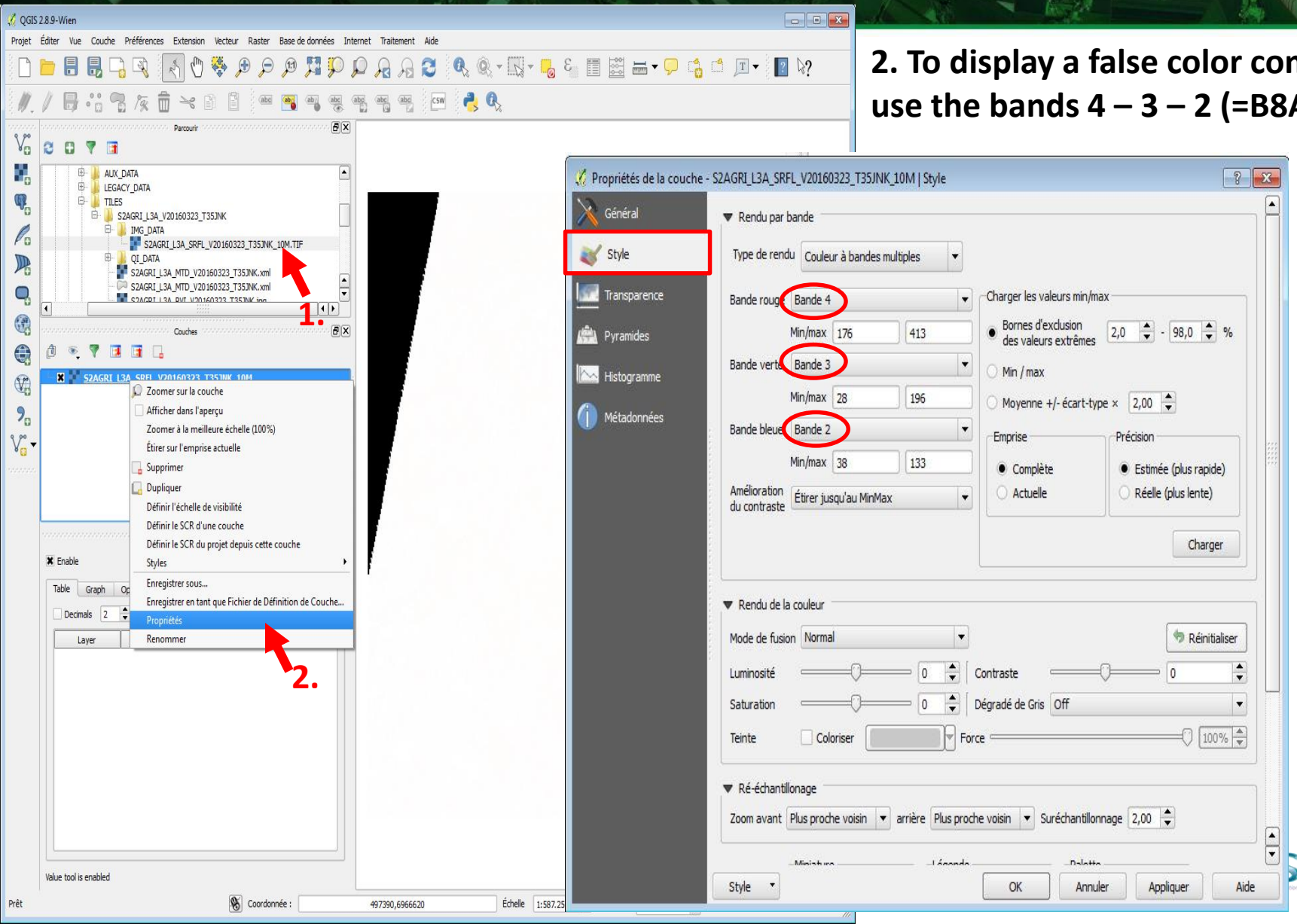
Let's explore the **monthly cloud composite**

1. Explore the folders of the product to be more familiar with the structure and the available information
2. Open the L3A products over one tile
   a. Display a true color composite (bande 3-2-1) and/or
   b. Display a false color composite (bande 4-3-2)
3. Open the **QI « MFLG »** allowing to identify the final status of the pixel over the period.
4. Open the **xml** « Image Processing Parameters » (*AUX_DATA > S2AGRI_L3A_IPP_*) Typically using NotePad++, Internet Explorer, Google Chrome or Firefox.
   - Look at the information about the L2A products used the generate the composite
   - Display one or two L2A images
5. Afficher le **QI « MDAT »** qui donne la moyenne des dates utilisées pour chaque pixel

Display the Monthly composite (1)

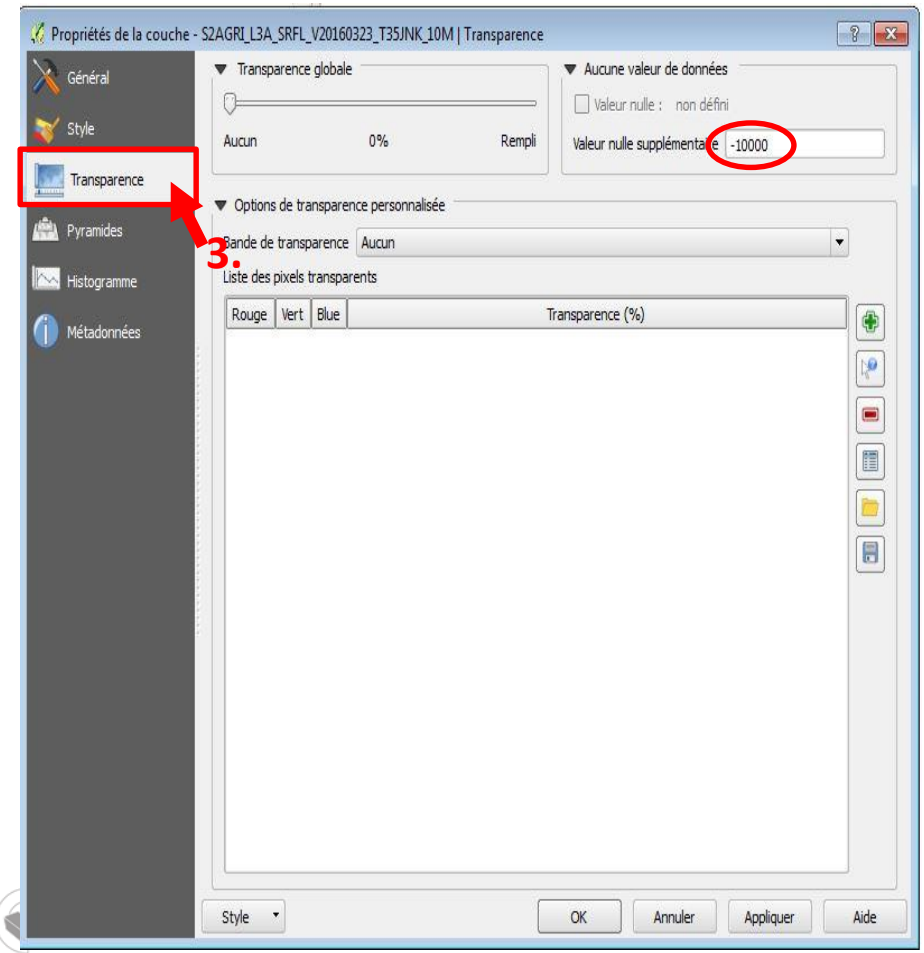
1. Add the L3A *.TIF* product from *TILES>IMG_DATA>S2AGRI_L3A_SRFL… .TIF*

2. To display a false color composite, use the bands 4 – 3 – 2 (=B8A, B4, B3)

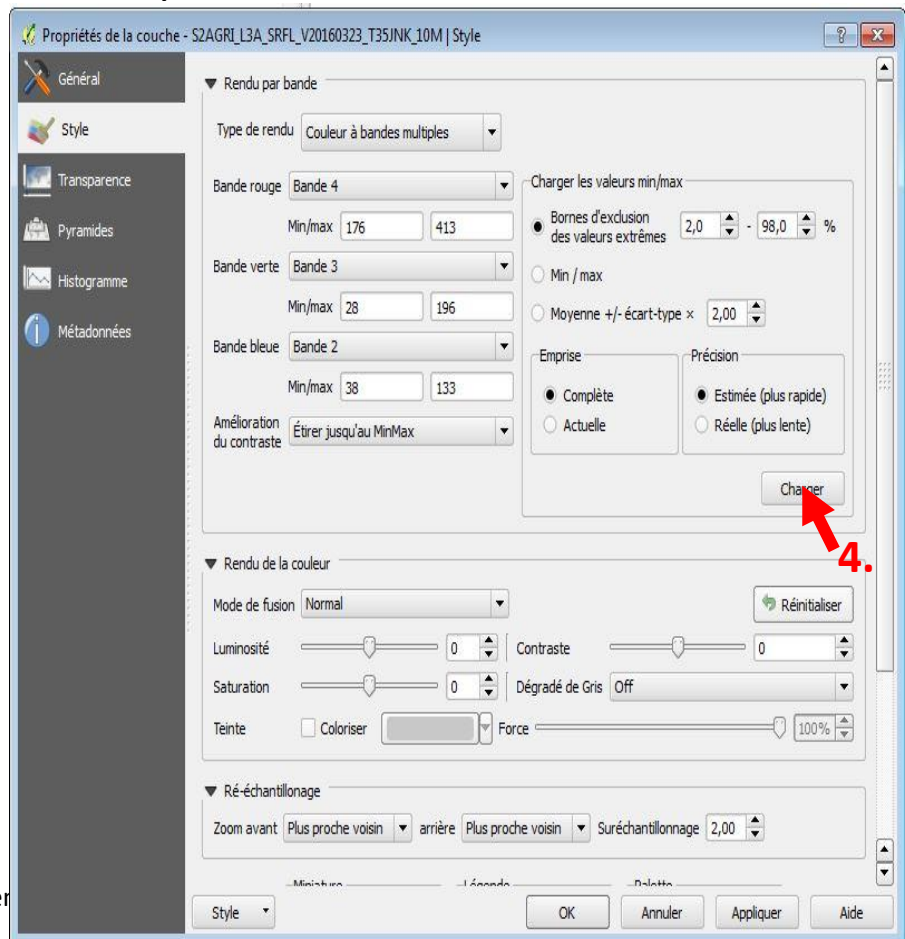


Display the Monthly composite (2)

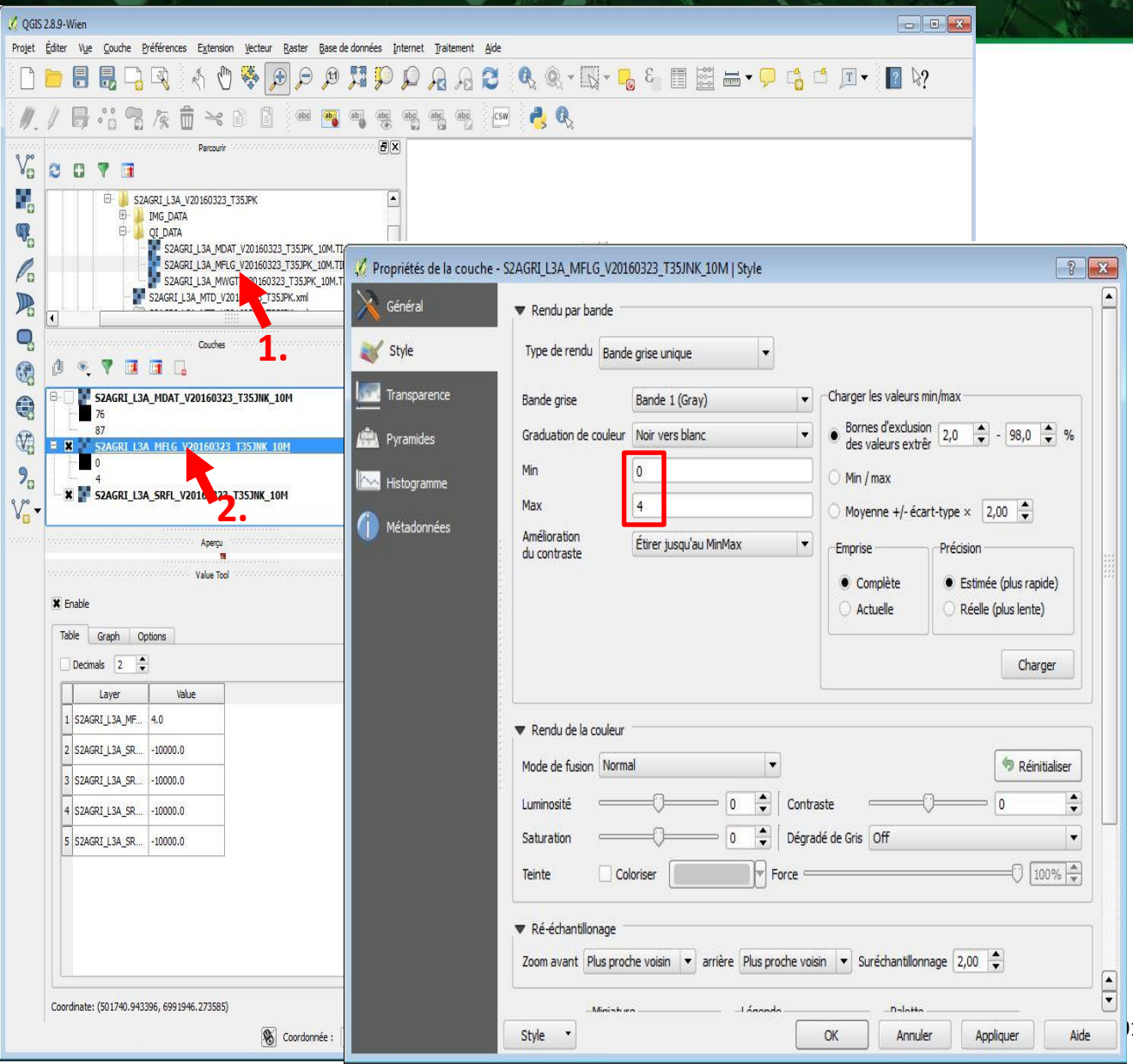
3. Go to *Transparency* property to set the -10000 value as transparent > Click Apply



4. Go back to style property to improve the color stretching by clicking on the *Load* option



Display the flag mask(QI>MFLG)



Indicates the status of the pixel

0 = No data

1 = Cloud or cloud shadow

2 = Snow

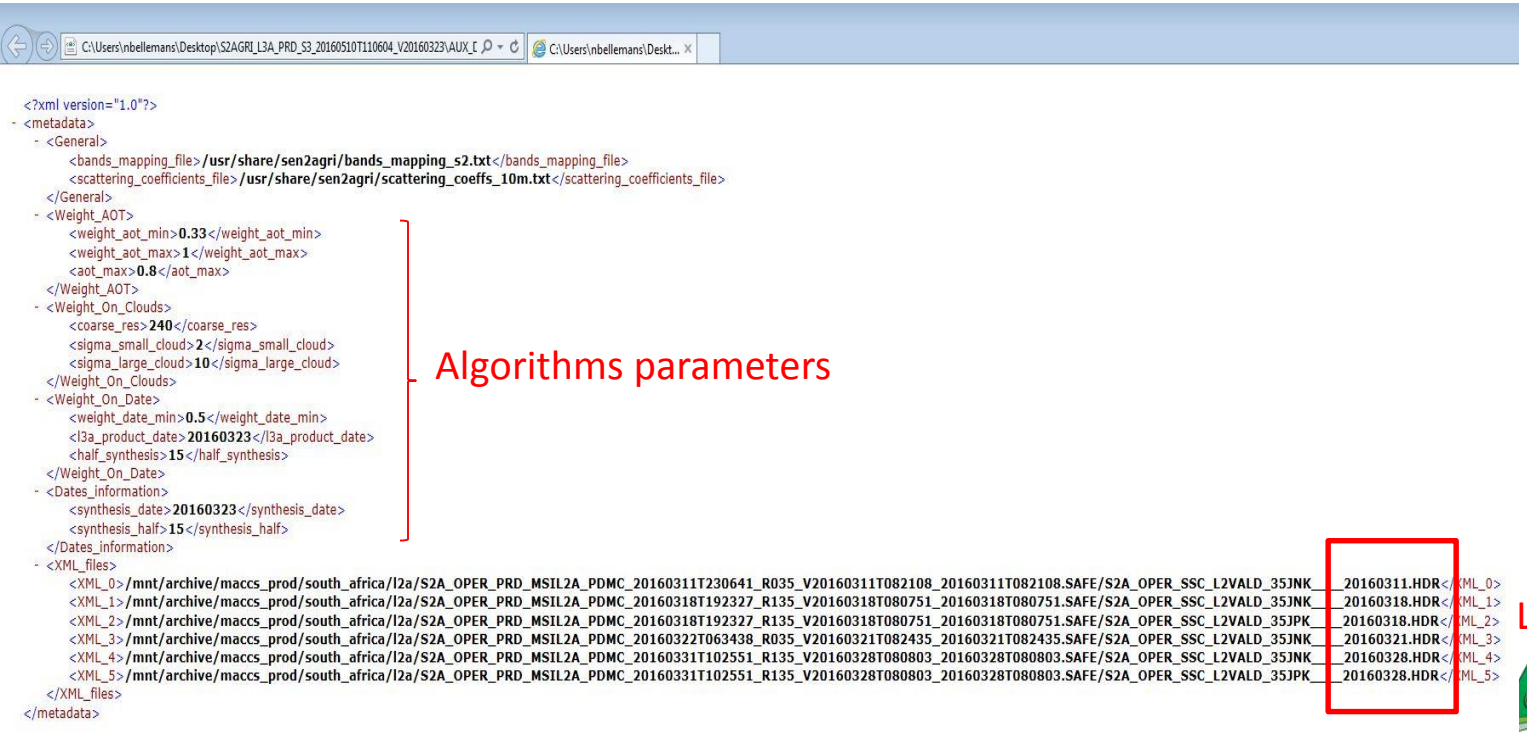
3 = Water

4 = Land valid pixel

What are the L2A acquisitions used to generate this cloud free composite ?

Information contains in the Image Processing Parameters .xml file

AUX_DATA > S2AGRI_L3A_**IPP**_V20160323.xml → Easy to open/visualize with Internet Explorer, Google Chrome, Firefox, NotePad++,…

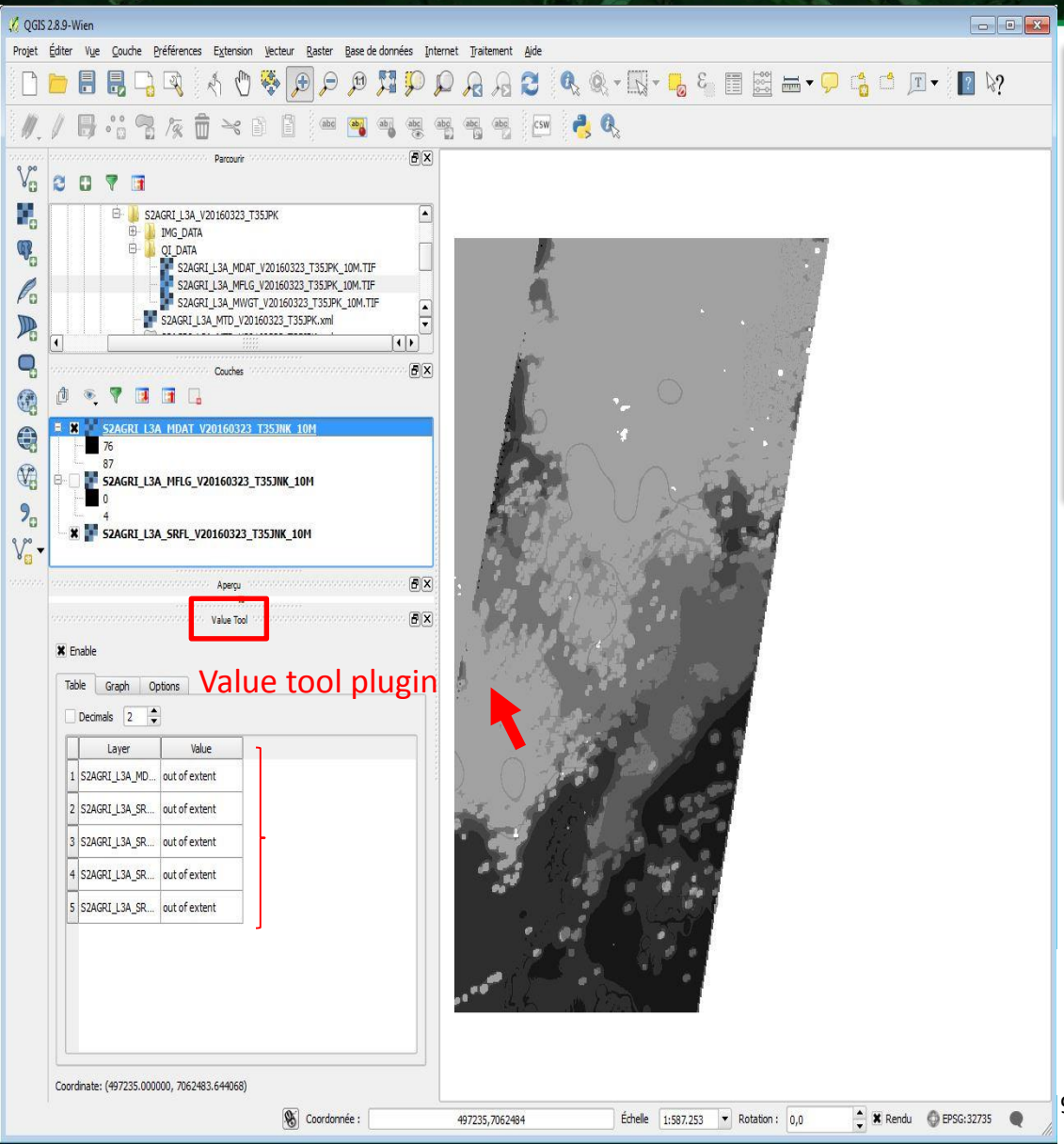


```
<?xml version="1.0"?>
- <metadata>
  - <General>
      <bands_mapping_file>/usr/share/sen2agri/bands_mapping_s2.txt</bands_mapping_file>
      <scattering_coefficients_file>/usr/share/sen2agri/scattering_coeffs_10m.txt</scattering_coefficients_file>
    </General>
  - <Weight_AOT>
      <weight_aot_min>0.33</weight_aot_min>
      <weight_aot_max>1</weight_aot_max>
      <aot_max>0.8</aot_max>
    </Weight_AOT>
  - <Weight_On_Clouds>
      <coarse_res>240</coarse_res>
      <sigma_small_cloud>2</sigma_small_cloud>
      <sigma_large_cloud>10</sigma_large_cloud>
    </Weight_On_Clouds>
  - <Weight_On_Date>
      <weight_date_min>0.5</weight_date_min>
      <l3a_product_date>20160323</l3a_product_date>
      <half_synthesis>15</half_synthesis>
    </Weight_On_Date>
  - <Dates_information>
      <synthesis_date>20160323</synthesis_date>
      <synthesis_half>15</synthesis_half>
    </Dates_information>
  - <XML_files>
      <XML_0>/mnt/archive/maccs_prod/south_africa/l2a/S2A_OPER_PRD_MSIL2A_PDMC_20160311T230641_R035_V20160311T082108_20160311T082108.SAFE/S2A_OPER_SSC_L2VALD_35JNK____20160311.HDR</XML_0>
      <XML_1>/mnt/archive/maccs_prod/south_africa/l2a/S2A_OPER_PRD_MSIL2A_PDMC_20160318T192327_R135_V20160318T080751_20160318T080751.SAFE/S2A_OPER_SSC_L2VALD_35JNK____20160318.HDR</XML_1>
      <XML_2>/mnt/archive/maccs_prod/south_africa/l2a/S2A_OPER_PRD_MSIL2A_PDMC_20160318T192327_R135_V20160318T080751_20160318T080751.SAFE/S2A_OPER_SSC_L2VALD_35JPK____20160318.HDR</XML_2>
      <XML_3>/mnt/archive/maccs_prod/south_africa/l2a/S2A_OPER_PRD_MSIL2A_PDMC_20160322T063438_R035_V20160321T082435_20160321T082435.SAFE/S2A_OPER_SSC_L2VALD_35JNK____20160321.HDR</XML_3>
      <XML_4>/mnt/archive/maccs_prod/south_africa/l2a/S2A_OPER_PRD_MSIL2A_PDMC_20160331T102551_R135_V20160328T080803_20160328T080803.SAFE/S2A_OPER_SSC_L2VALD_35JNK____20160328.HDR</XML_4>
      <XML_5>/mnt/archive/maccs_prod/south_africa/l2a/S2A_OPER_PRD_MSIL2A_PDMC_20160331T102551_R135_V20160328T080803_20160328T080803.SAFE/S2A_OPER_SSC_L2VALD_35JPK____20160328.HDR</XML_5>
    </XML_files>
</metadata>
```

Algorithms parameters

L2A acquisitions used

Display the date mask(QI>MDAT)



Indicates the **weighted average of the dates** used for each pixel

Here :

- 83 = 2016-03-23 = central date
- Pixel value < 83 = higher weight for the dates before the central date
- Pixel value > 83 = higher weight for the dates after the central date

Value tool plugin allows displaying in a table or plot the values from the visible raster layers at the current mouse position