TRAINING KIT – LAND08

DEFORESTATION MONITORING WITH SENTINEL-2

Case Study: Paraquay, 2016-2018

Research and User Support for Sentinel Core Products

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1 Introduction

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation.

Deforested areas in Gran Chaco region, Credits: https://www.hu-berlin.de

Our study area for this exercise will be the part of the Gran Chaco forest in Paraguay. The Gran Chaco is a sparsely populated, hot and semi-arid lowland region of the Río de la Plata basin, laying partly in Bolivia, Paraguay, Argentina and Brazil. What has once been the largest continuous tropical forest on our planet has become the hotspot of deforestation in the last decade due to industrial scale cattle farming and soy production. It is estimated that one 1 hectare of forest is cleared every minute resulting in the destruction of this unique environment.

There is number of methods used for monitoring deforestation with satellite data. However, visual interpretation by a human operator is still broadly used and most accurate, many semi-automatic and automatic methods exist. Vast majority of these methods is based on classification algorithms. In the previous webinar (LAND07), you have heard about supervised classification method called "**Random Forest Classifier",** today we will use a very different method called "**Support Vector Machine**" (SVM).

2 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is LAND08. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the RUS portal and open a User Service request from Your RUS service → Your dashboard.

2.1 Data used

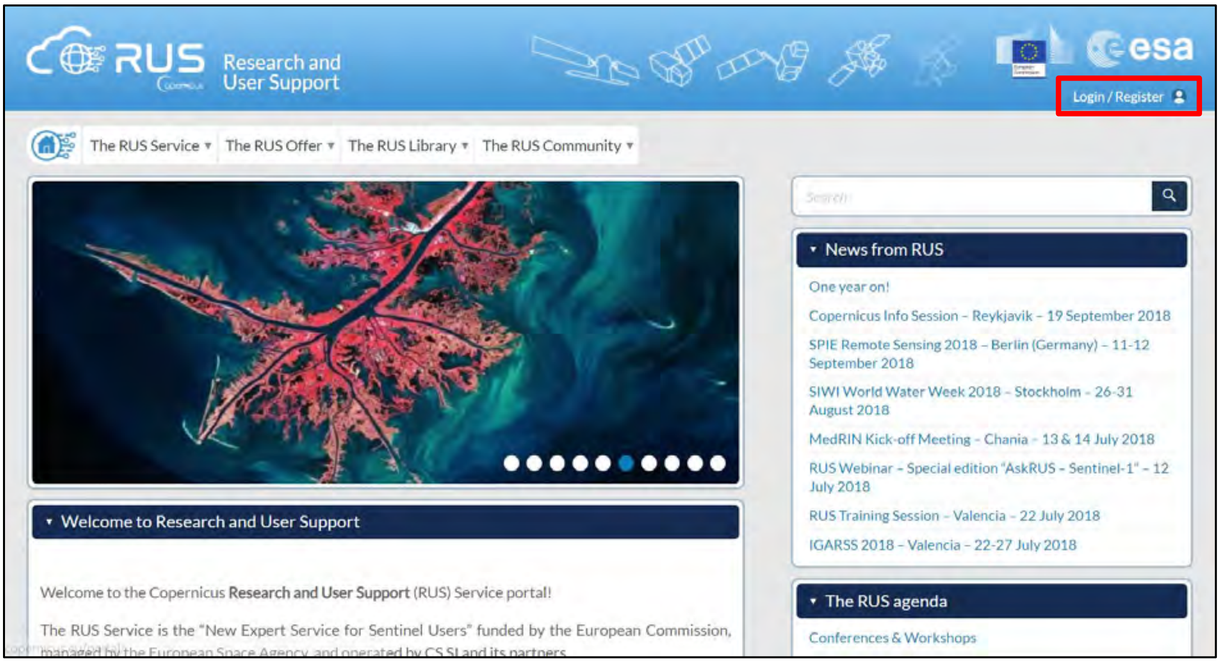
- Three cloud-free Sentinel-2 Level-1C tile (Tile ID: T20KQB) [downloadable @ https://scihub.copernicus.eu/]
    - *S2A_MSIL1C_**20160813**T141052_N0204_R110_**T20KQB**_20160813T141049*
    - *S2B_MSIL1C_**20170823**T141039_N0205_R110_**T20KQB**_20170823T141404*
    - *S2A_MSIL1C_**20180813**T141051_N0206_R110_**T20KQB**_20180813T174352*

2.2 Software in RUS environment

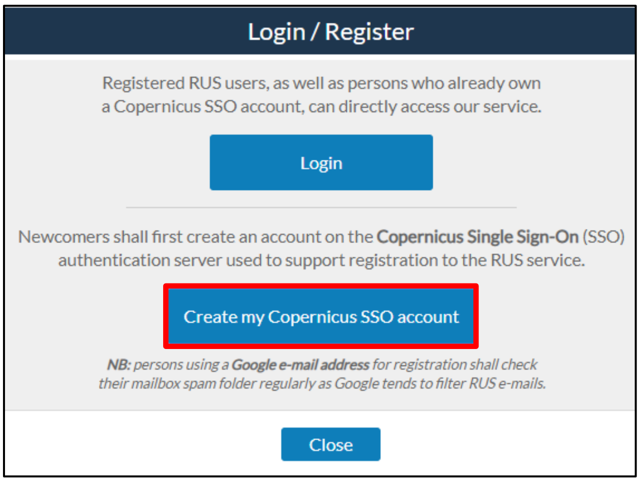
Internet browser, SNAP + Sentinel-2 Toolbox, Sen2Cor, QGIS

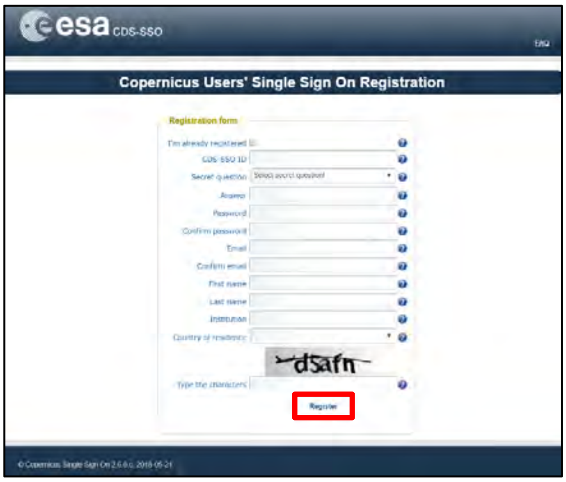
3 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website (www.rus-copernicus.eu) and click on ***Login/Register*** in the upper right corner.



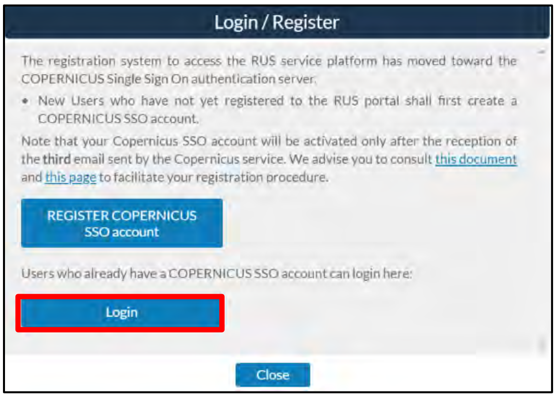
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.

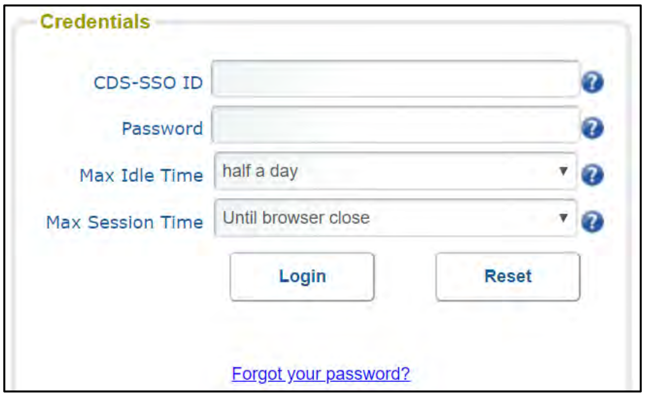




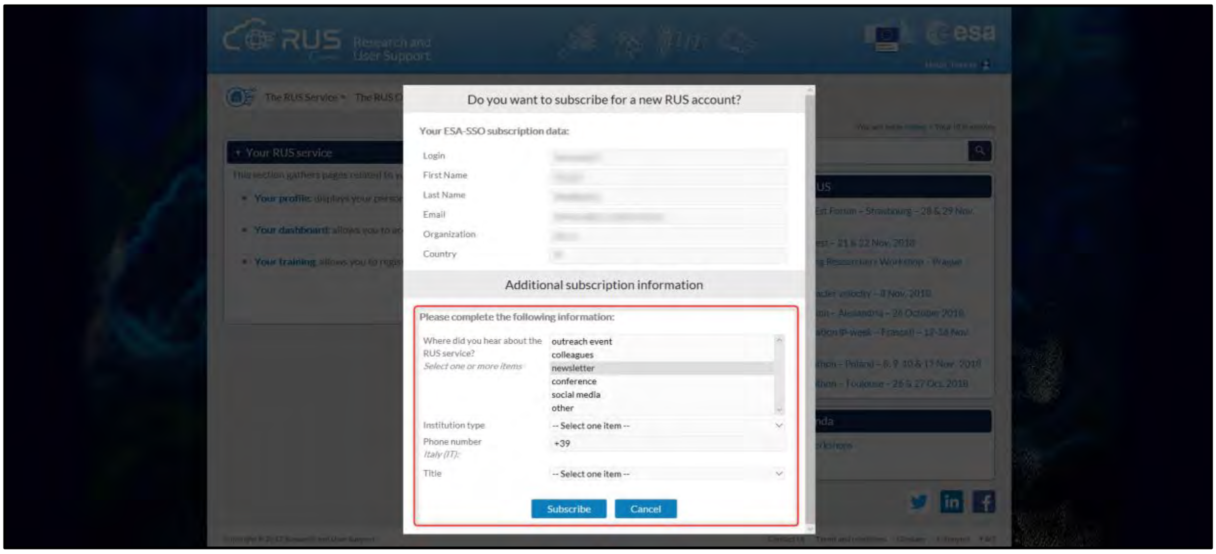
Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

You can now return to https://rus-copernicus.eu/, click on ***Login/Register***, choose ***Login*** and enter your chosen credentials.



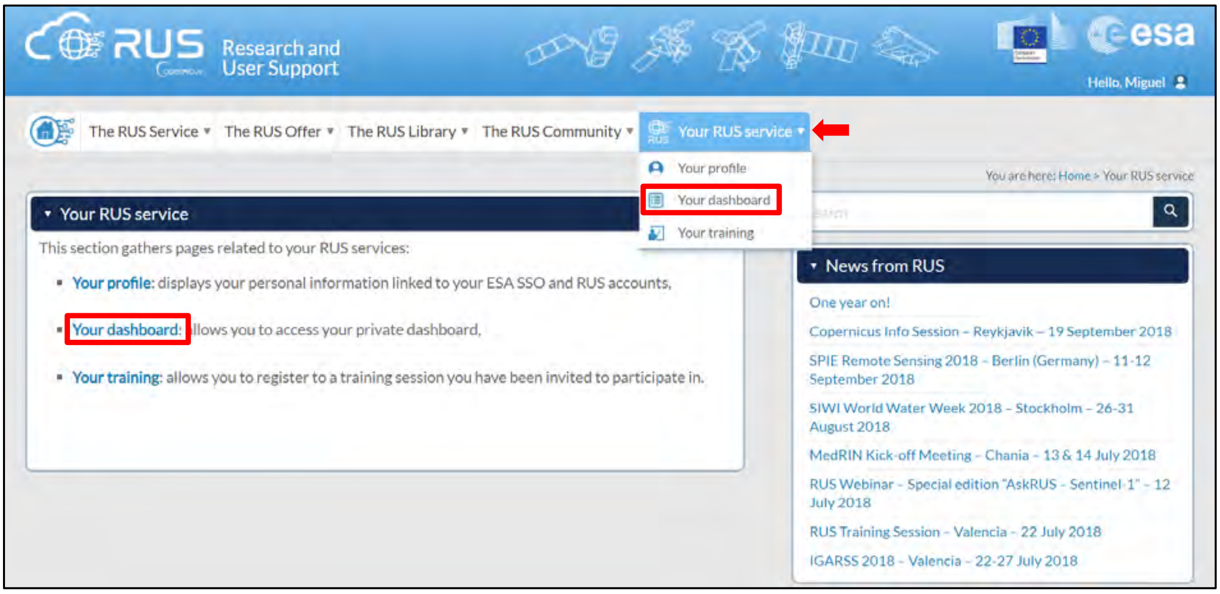


Upon your first login you will need to enter some details. You must fill all the fields.

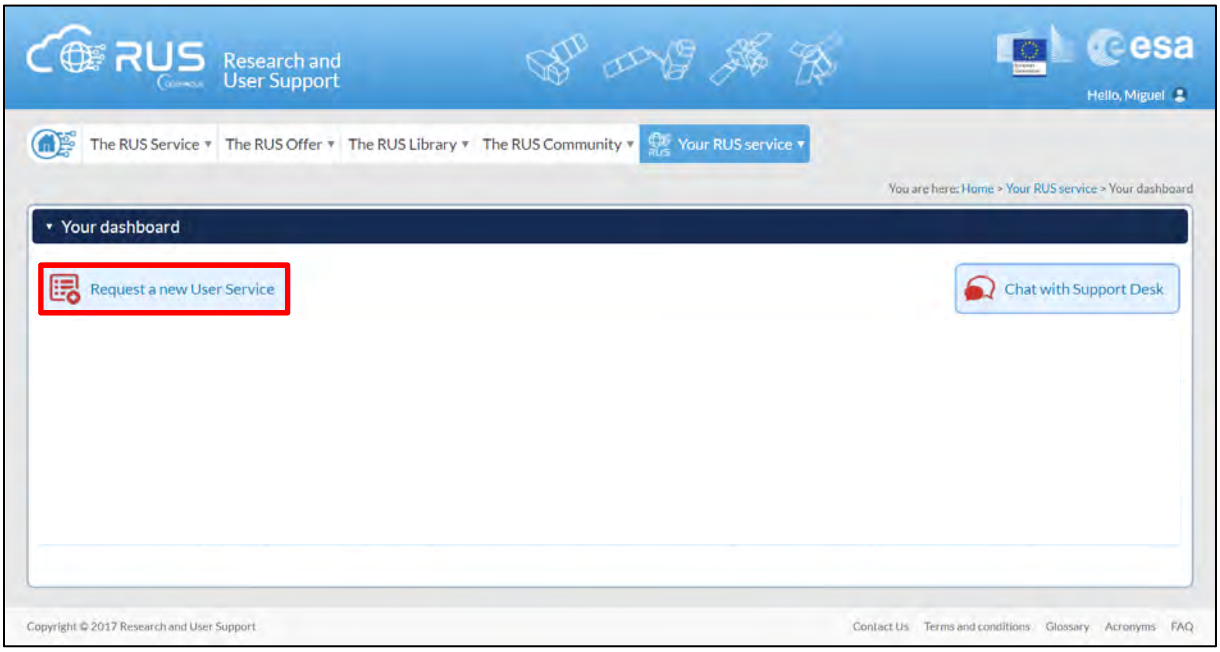


4 Request a RUS Copernicus Virtual Machine

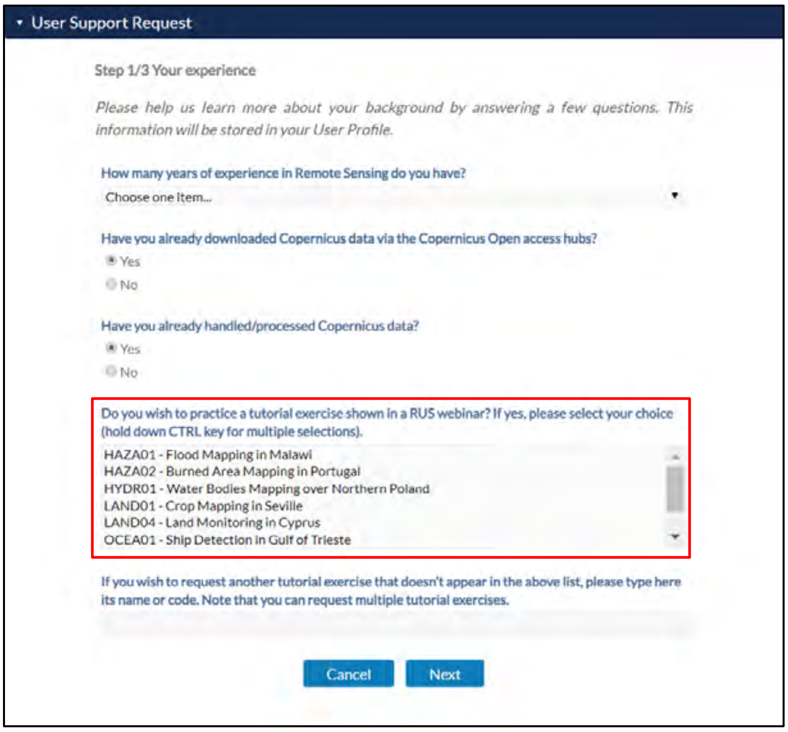
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service* → *Your Dashboard***.



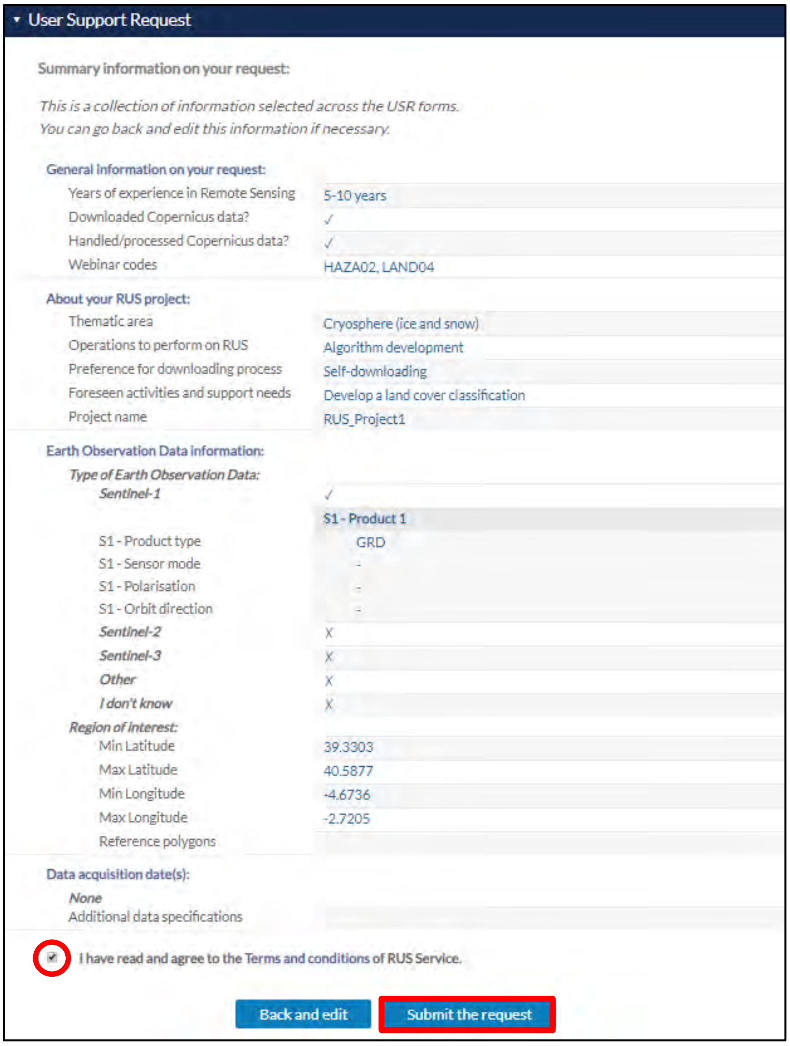
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



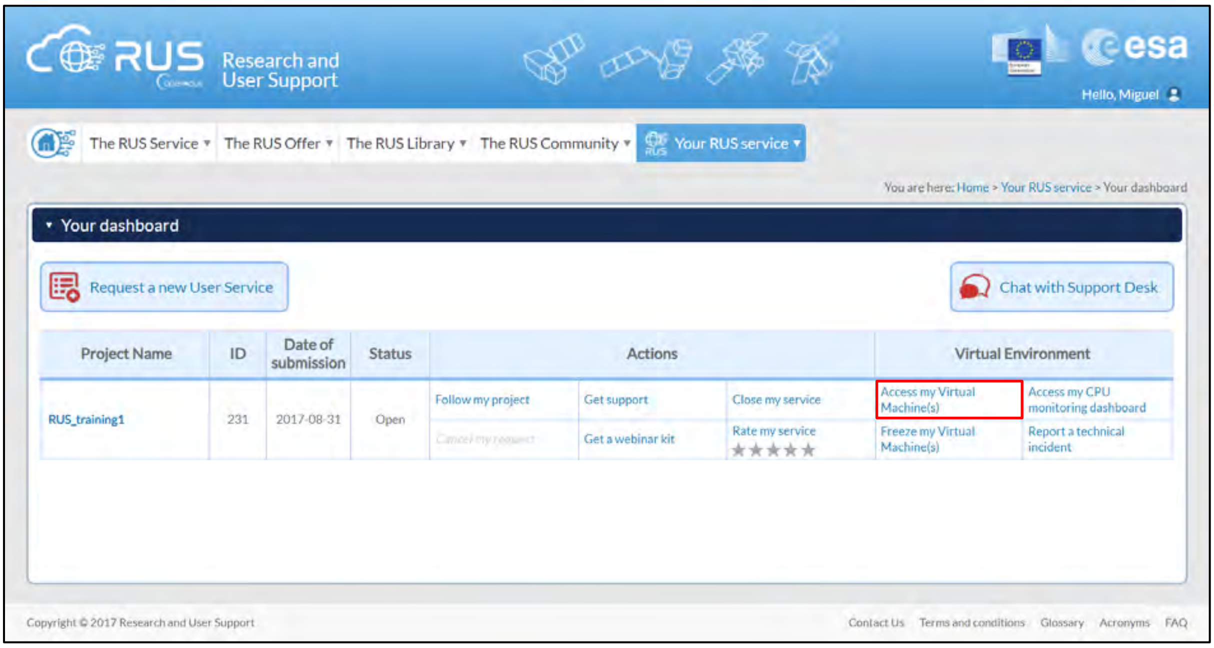
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.



Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to ***Your RUS Service → Your Dashboard*** and click on ***Access my Virtual Machine***.



Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.

This is the remote desktop of your Virtual Machine.

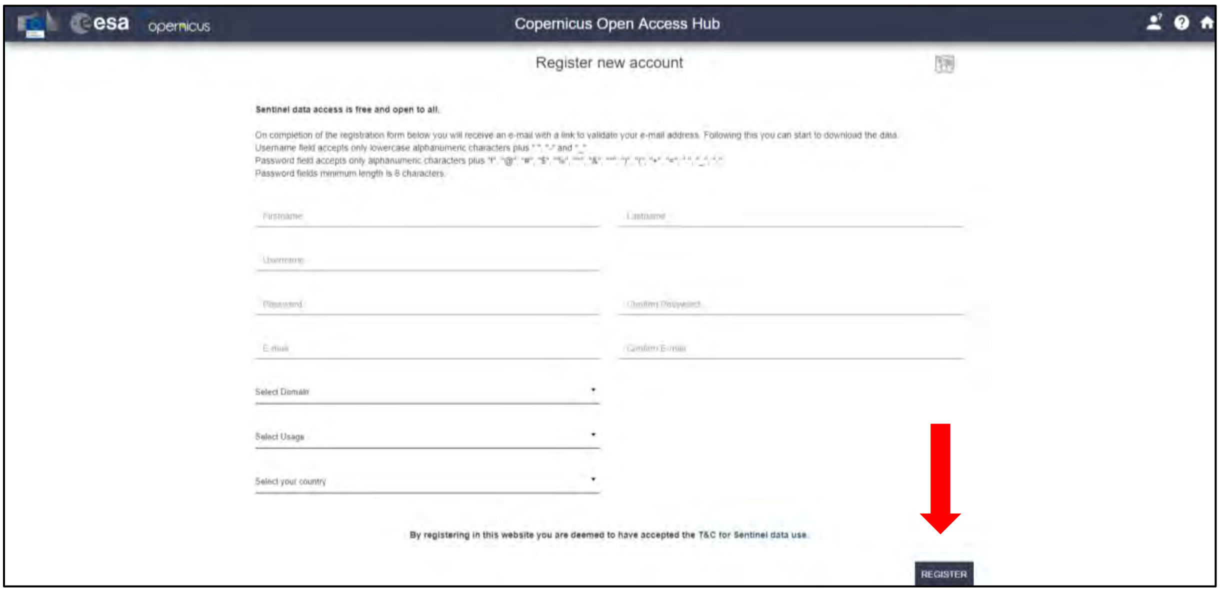
5 Step-by-step

5.1 *Data download - ESA SciHUB*

In this step, we will download a Sentinel-2 scene from the Copernicus Open Access Hub using the online interface (**Applications → Network → Firefox Web Browser** or click the link below).

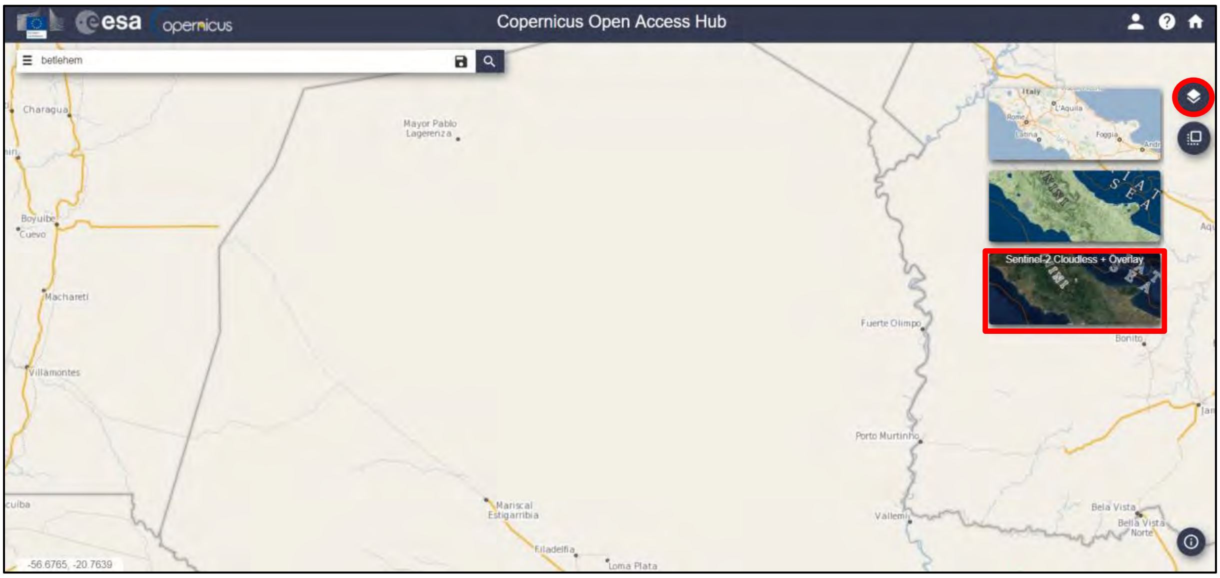
Go to https://scihub.copernicus.eu/

Go to “**Open HUB**”, if you do not have an account please register by going to “**Sign-up**” in the LOGIN menu in the upper right corner.



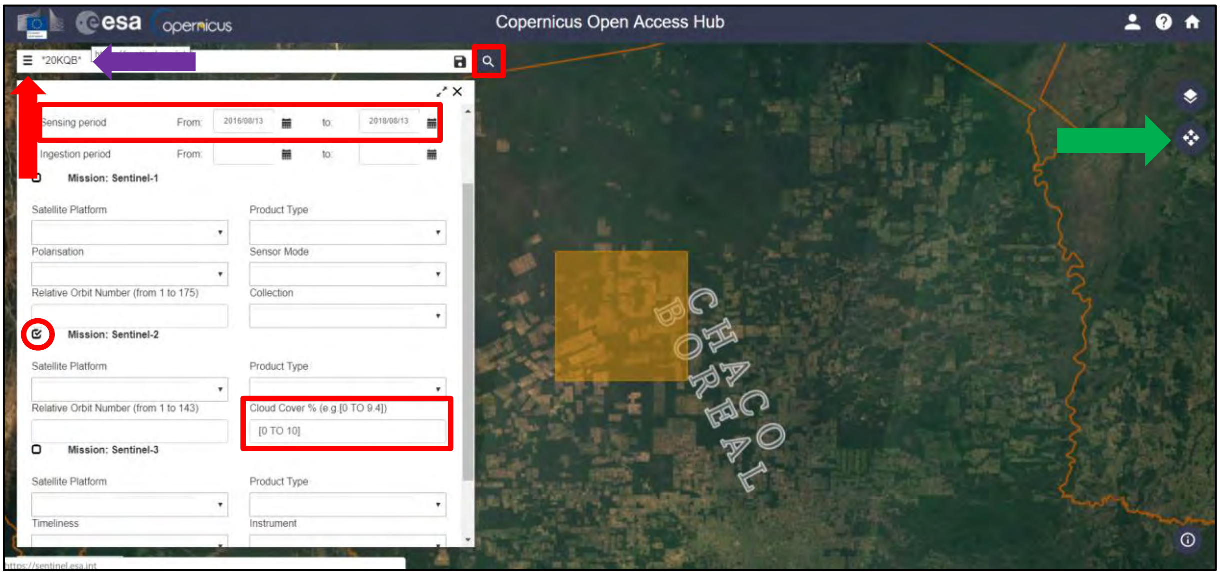
After you have filled in the registration form, you will receive an activation link by e-mail. Once your account is activated or if you already have an account, “**LOGIN**”.

Then navigate to the north of Paraguay, approximately as indicated on map below and switch the base layer to Sentinel-2 cloudless overlay.



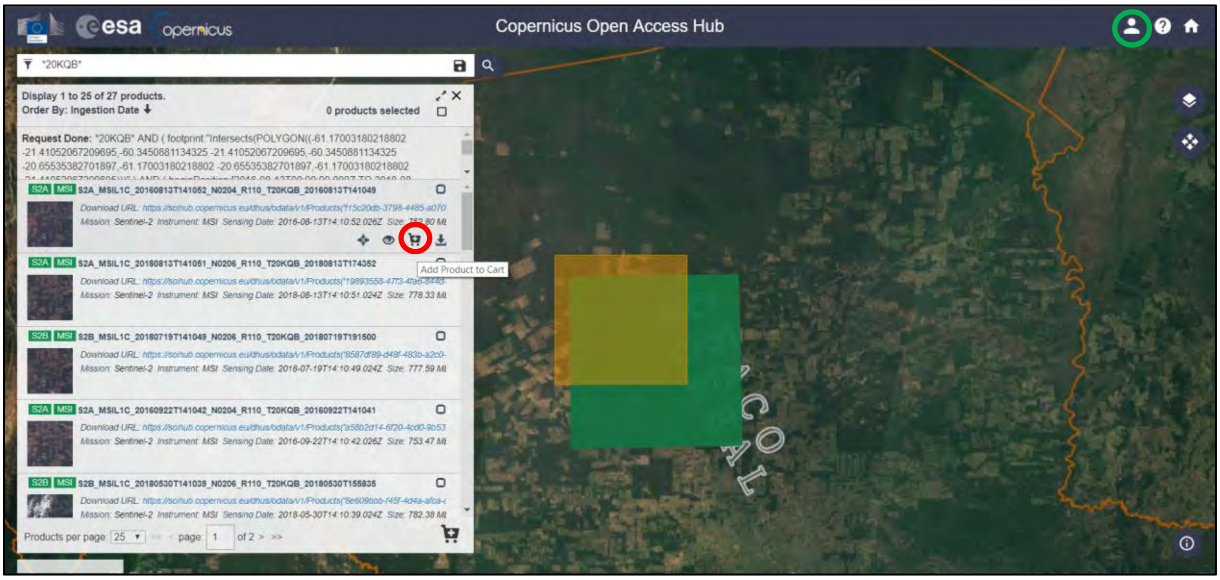
Now we have two options either we can switch to the rectangle-drawing mode (**Green arrow**) and draw search polygon over our study area (**approximate area – orange rectangle**) or we can specify the Sentinel-2 tile we are looking for in the Search text box (**Purple arrow**). The tile identification consists of UTM zone number and 3 letter code. We can find it in the name of any product from the same location we already have. For us the code is **20KQB**. We enter it to the search filed as ***20KQB***.

Sensing period: From 2016/08/13 to 2018/08/13
Check Mission: Sentinel-2
Cloud Cover %: [0 TO 10]

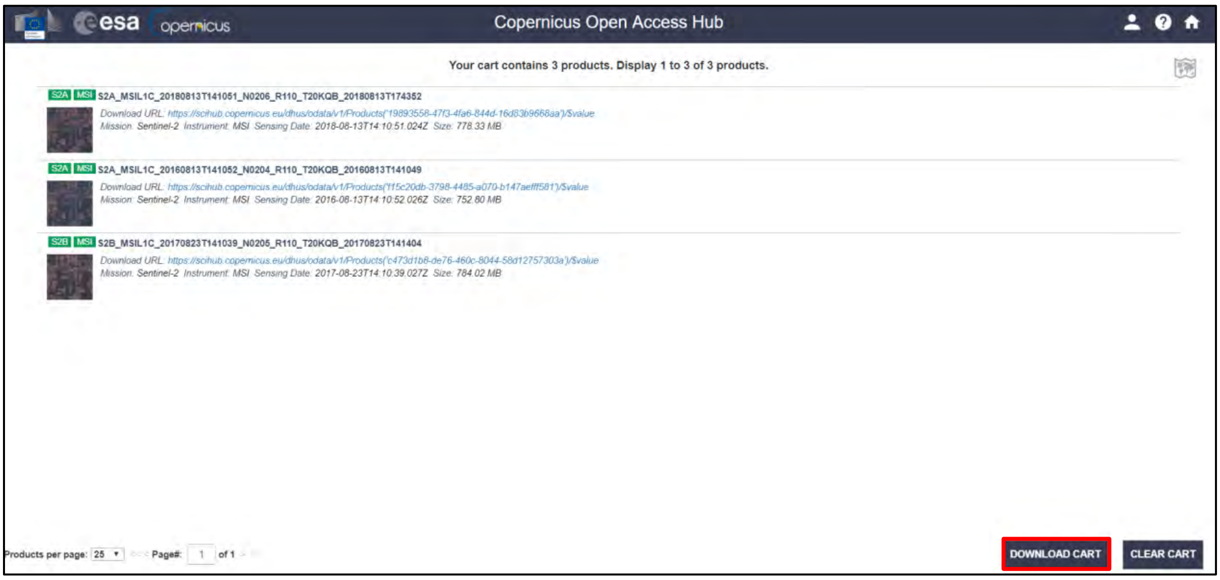


Then click **Search** . In our case, the search returns 27 results as we are looking at long time period. Now let's find following three products and add them to cart using the symbol as shown below:

*S2A_MSIL1C_**20160813**T141052_N0204_R110_T20KQB_20160813T141049*
*S2B_MSIL1C_**20170823**T141039_N0205_R110_T20KQB_20170823T141404*
*S2A_MSIL1C_**20180813**T141051_N0206_R110_T20KQB_20180813T174352*



Once all our data are in the cart, click on the **Profile** icon in the upper right corner (marked with green circle above) and go to **Cart**. You should now have three products in your cart. Click **Download Cart**.



A ***products.meta4*** file will be downloaded to your ***/home/rus/*** folder. To download our data, we will use **aria2** tool. To use the tool, we first need to place the ***products.meta4*** file to the folder where we wish our data to be downloaded to:

/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Original/

Let's test our aria2 installation. To do this we open the Command Line (in the bottom of your desktop window), type the following and then press "Enter": `aria2c`

The correct response should be as follows:

If the response is "**-bash aria2c: command not found**" (see NOTE 1).

> NOTE 1: If (**and only if**) the response is "**-bash aria2c: command not found**". Then we have to install the tool, to do this in command line type: `sudo apt-get install aria2`
> When requested type: Y
> Then you can test your installation again.

If you have received the correct response, then we can run the tool by typing following commands in the command line (replace **<username>** and **<password>** with your login credentials for Copernicus Open Access Hub):

First type the following command and press "Enter". It defines our target directory.

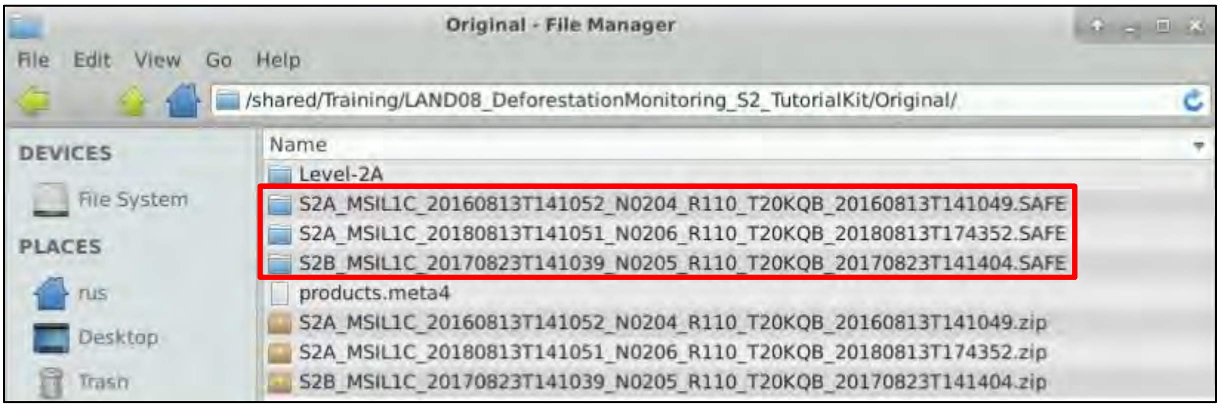
```
cd /shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Original/
```

Then type the following command and after having made the necessary changes press "Enter" to run the download tool (Type the red text all in single line).

```
aria2c    --http-user='<username>'    --http-passwd='<password>'    --check-
certificate=false --max-concurrent-downloads=2 -M products.meta4
```

All three products will be downloaded to the ***Original*** folder two products in parallel automatically (Note that the constraint of maximum two parallel downloads at a time is imposed by the Copernicus Access Hub, if you increase the number the download will fail). This might take some time.

Lastly, navigate to the folder where our data are saved: ***/shared/Training/LAND08_Deforestation Monitoring _S2_TutorialKit/Original*** and unzip all three products by right-clicking each and going to "***Extract Here***".



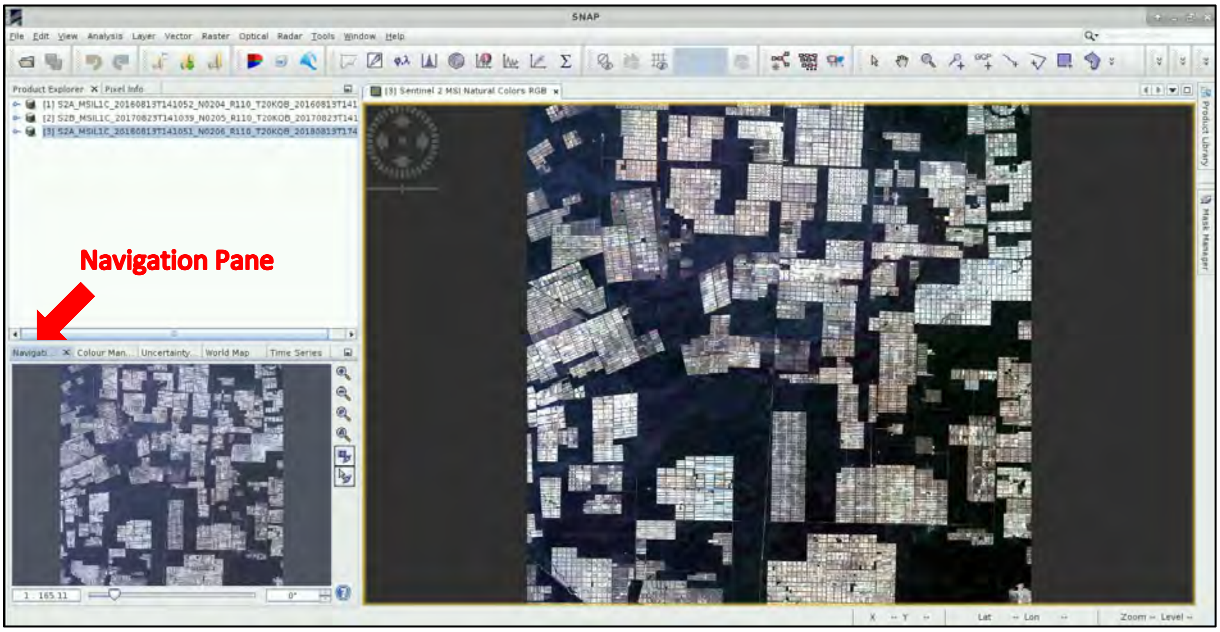
5.2 SNAP – open and explore data

Launch SNAP (icon on desktop). When the SNAP window opens click **Open Product** , navigate to: ***/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Original*** and open the three zipped downloaded S2 products (SNAP can read .ZIP files).

Right-click the product from 2018 and click **Open RGB image window,** a new window will open. From the drop-down menu select:

Profile: Sentinel 2 MSI Natural Colors

Click **OK**. The RGB image will be opened at the **View** window.



5.3 *Atmospheric correction*

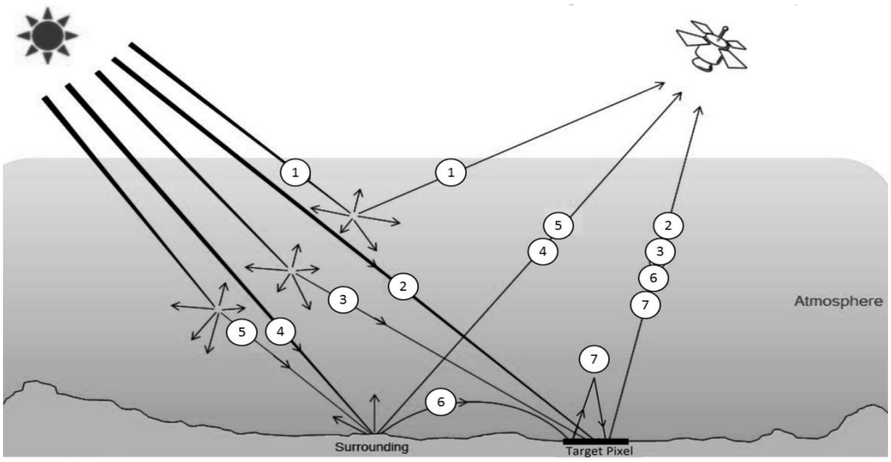
The "Level 1C" data we have downloaded are radiometrically and geometrically corrected (including orthorectification and spatial registration). However, atmospheric correction is applied only to the Level 2A data which are not available for our study site at this time.

> TIP: Level 2A have been systematically produced for newly acquired products over Europe since the spring of 2017, the coverage has been increasing through 2018 to reach global coverage in the beginning of 2019.

Solar radiation reflected by the Earth's surface to satellite sensors is affected by its interaction with the atmosphere. The objective of applying an atmospheric correction is to determine true surface (Bottom-Of-Atmosphere, BOA) reflectance values from the Top-Of-Atmosphere (TOA) reflectance values, by removing atmospheric effects. (See NOTE 1) Atmospheric correction is especially important in cases where multi-temporal images are compared and analysed as it is in our case. [1]

In this tutorial, we will use the Sen2Cor processor. Sen2Cor is a processor for Sentinel-2 Level 2A product generation and formatting; it performs the atmospheric, terrain and cirrus correction of Top-Of-Atmosphere Level 1C input data. Sen2Cor creates Bottom-Of-Atmosphere, optionally terrain and cirrus corrected reflectance images; additional, Aerosol Optical Thickness, Water Vapour, Scene Classification Maps and Quality Indicators for cloud and snow probabilities.

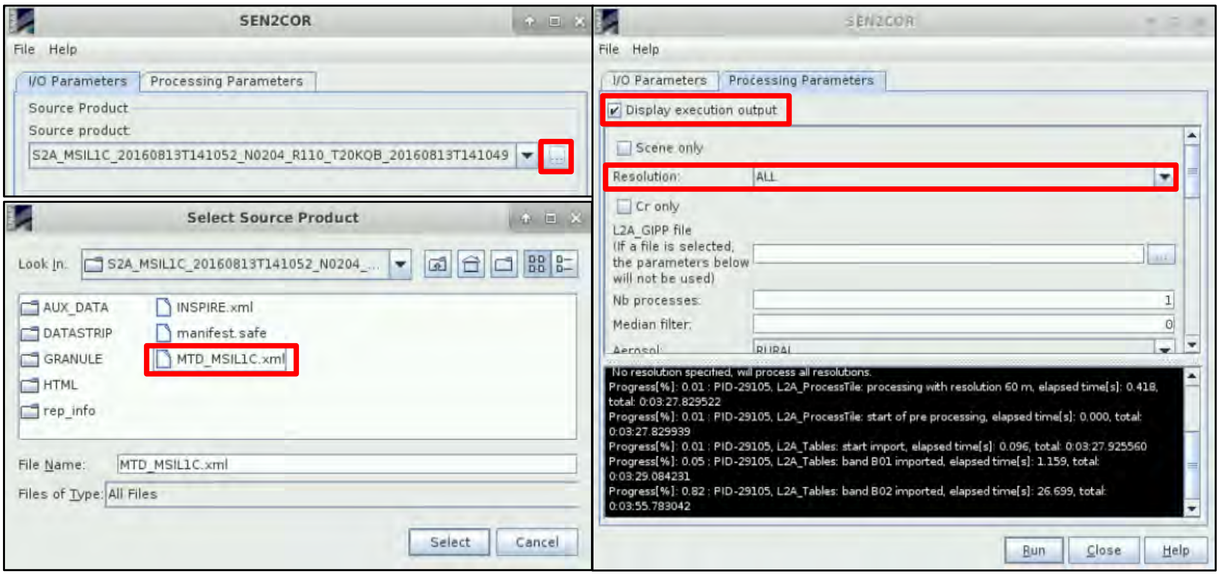
> NOTE 1: The radiance reaching the sensor is a result of following components:
>
> 1. Radiation from the sun and, scattered into the field of view of the sensor by the atmosphere without reaching the surface.
> 2. Direct radiation that goes through the atmosphere without being absorbed or scattered, reaches the sensor after being reflected by the target pixel.
> 3. Radiation scattered by the atmosphere into the target pixel and reflected back towards the sensor.
>
> 4. & 5. Direct or diffuse radiation reflected or scattered by the surrounding areas into the field of view of the sensor. This effect is so called "adjacency effect" or "blurring effect".
>
> 6. Diffuse radiation coming from the adjacent features into the field of view of the sensor.
> 7. So-called trapping effect and it is a part of the radiation reflected from the surface into the air column above the surface being scattered and ultimately reaches the sensor.



Credits: Mousivand et al.. 2015[1]

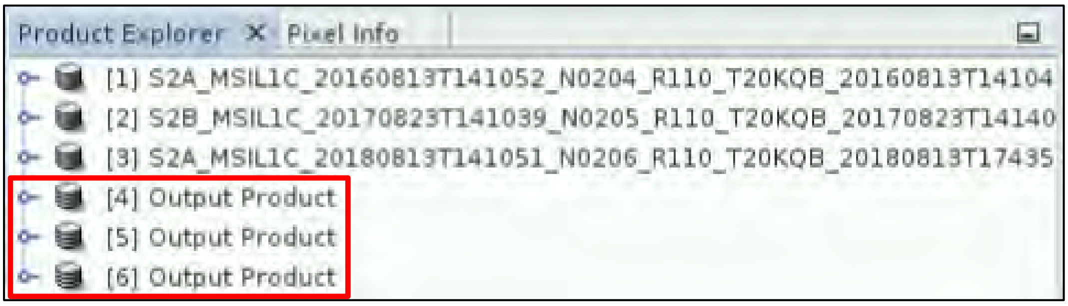
Go to **Optical → Thematic Land Processing → Sen2Cor.**

In the **I/O Parameters** tab, click on "**…**" next to the product name and navigate to the ***Original*** folder. Open the "***.SAFE***" folder of the 2016 product. Then open the ***MTD_MSIL1C.xml*** file. In the **Processing Parameters** tab change the resolution to ***"ALL"*** and select ***"Display execution output".*** Click **Run**.



This is rather a time demanding process and requires approximately 30 minutes per image (with 8GB RAM). Repeat for products [2] and [3]. Close **Sen2Cor** window when all processing is completed.

You will see three new products created at the **Product Explorer** window, named "**Output Product**". Select them all, right click on them and select "**Close 3 Products**". Click "**No**" to the following windows that will appear.



This process creates three new Level 2-A products in the ***.SAFE*** format in the ***Original*** folder. Move them to: ***/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Original/Level-2A***

Now let's load the results to SNAP.

Click **Open Product**, navigate to:

/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Original/Level-2A and open the Level-2A product folder for 2016:

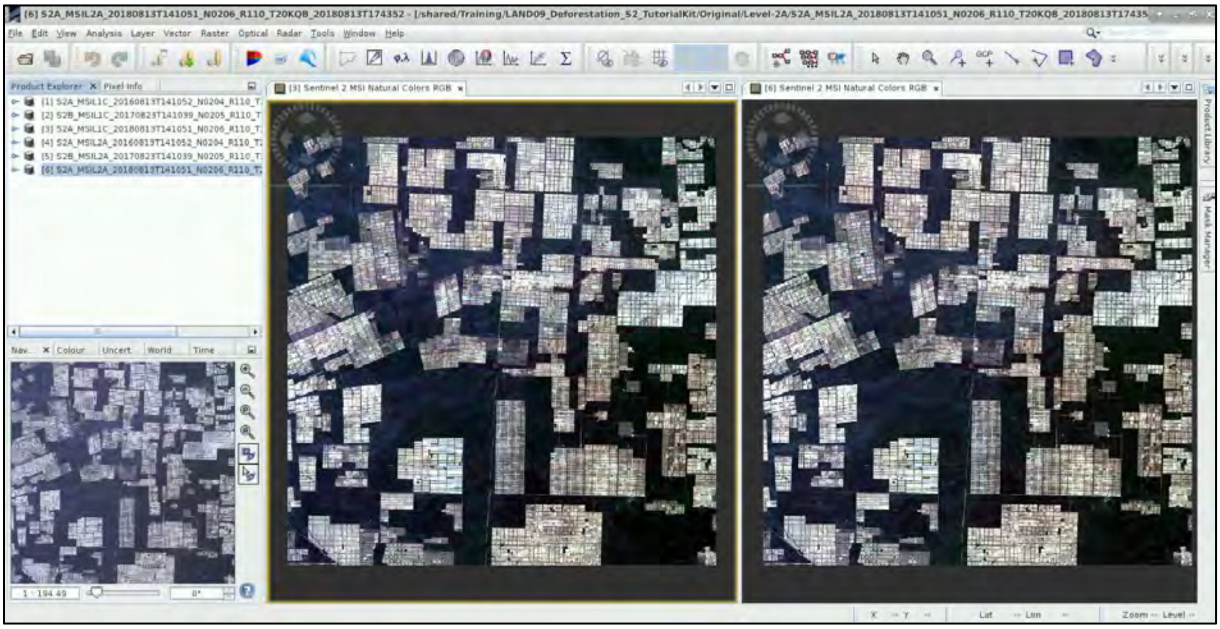
S2A_MSIL2A_20160813T141052_N0204_R110_T20KQB_20160813T141049.SAFE

Open the ***MTD_MSIL2A.xml***. Repeat the same for the Level-2A products from 2017 and 2018.

In the **Product Explorer** window, right-click the Level-2A product from 2018 and click **Open RGB image window,** a new window will open. From the drop-down menu select:

Profile: Sentinel 2 MSI Natural Colors

Then go to **Window → Tile Horizontally** to compare the L1C and L2A products side by side.



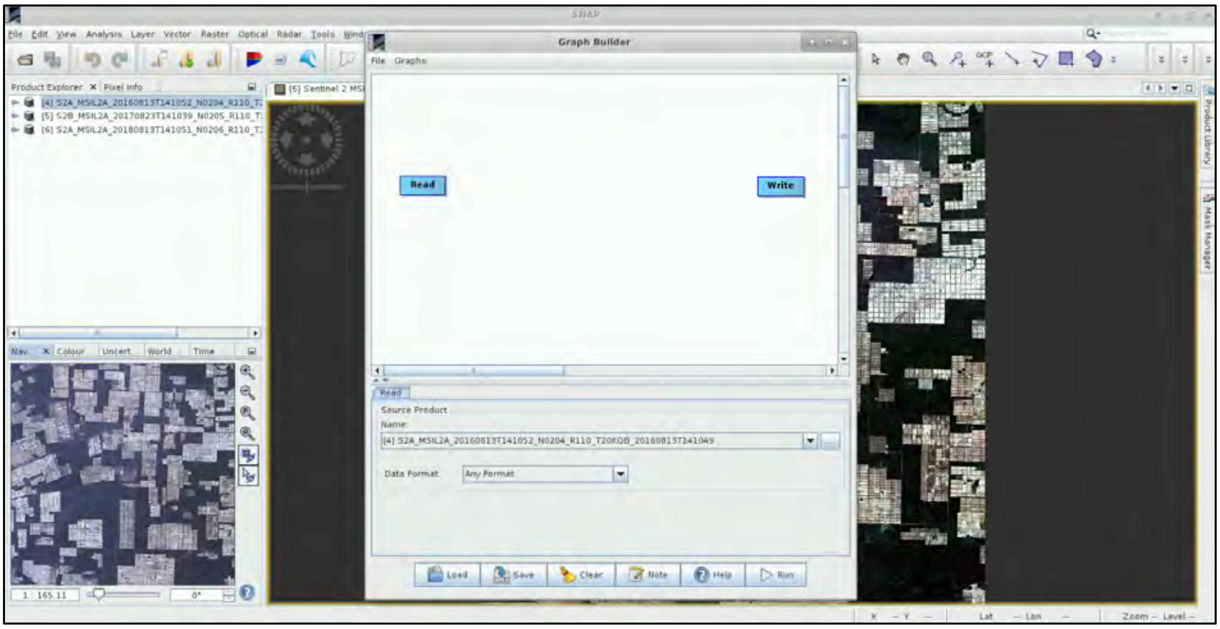
In this case there is not much visible difference, but we can now be reasonably sure that the values in our three images are comparable and correspond to the reflectance of the objects on the ground.

Now in the **Product Explorer** window, select the L1C products ([1] – [3]), right-click and go to "**Close 3 products**", as we will not need them anymore. Click "**No**" to discard changes to the products.

5.4 Resample, subset & calculate

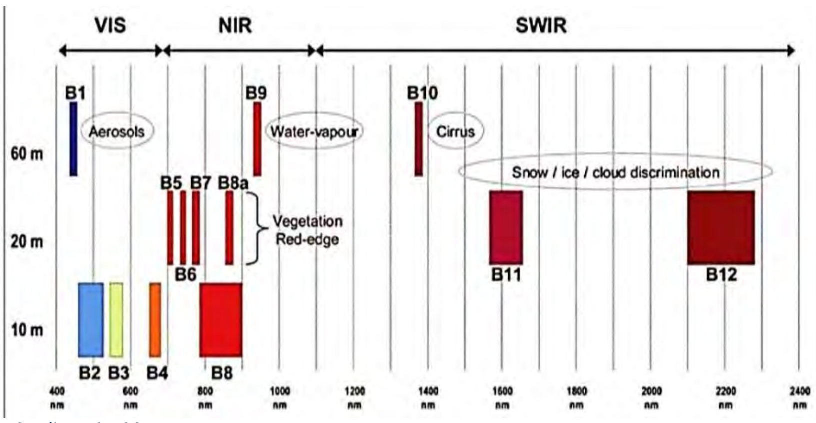
To avoid processing the data step-by-step we will use the **Graph Builder**.

Go to **Tools → GraphBuilder**. So far, the graph only has two operators: **Read** (to read the input) and **Write** (to write the output).



The 13 bands in Sentinel-2 products do not all have the same resolution (therefore size) as mentioned in NOTE 2. Many operators do not support products with bands of different sizes, so we need to resample the bands to equal resolution first. To add the operator right-click the white space between the existing operators and go to **Add → Raster → Geometric → Resample.**

NOTE 2: The input product contains 13 spectral bands in three different spatial resolutions (The surface area measured on the ground and represented by an individual pixel). When we open the RGB view all our input bands have 20 m resolution, however, the view is displayed in the full 10 m resolution.



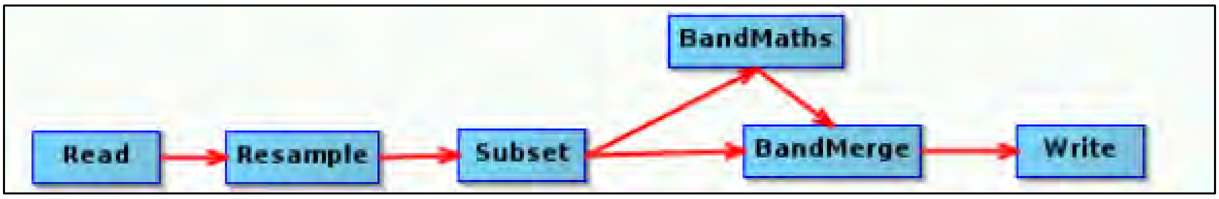
Credits: ESA 2015

A new operator rectangle appears in our graph and a new tab appears below. Now connect the new **Resample** operator with the **Read** operator by clicking to the right side of the **Read** operator and dragging the red arrow towards the **Resample** operator.

Next step will be to subset the images to the area of interest. We do this by right-clicking the white space somewhere right of the resample operator and going to **Add → Raster → Geometric → Subset.** Connect the **Subset** operator with the **Resample** operator.

Now, we will add the **BandMerge** operator from **Add → Raster → BandMerge** and connect it to the **Subset** operator.

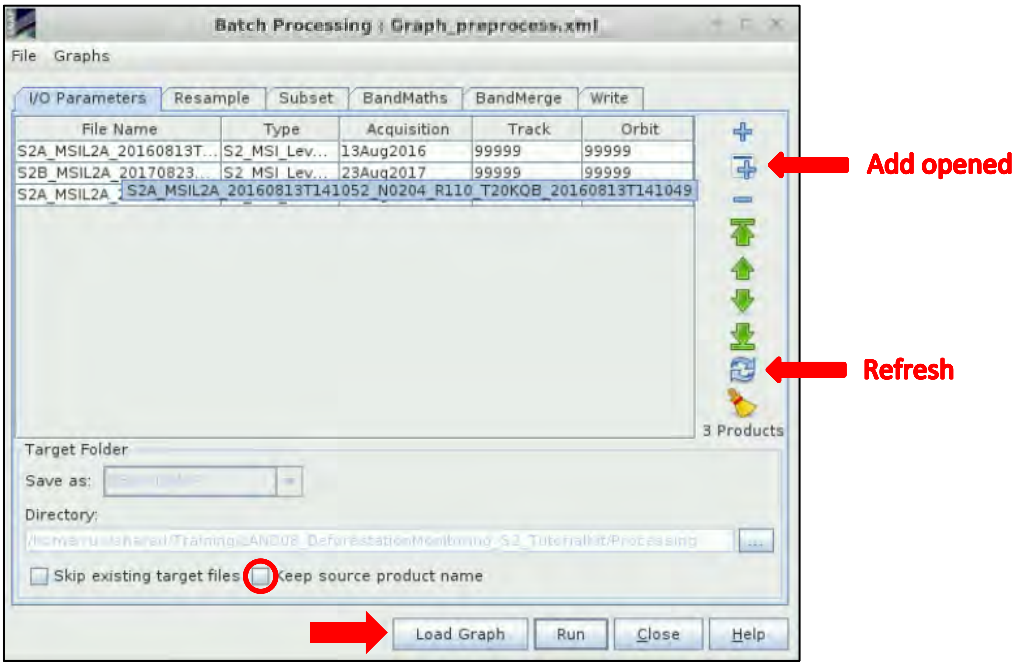
Then, we add the **BandMaths** operator from **Add → Raster → BandMaths**. Now connect the **BandMaths** operator with the **Subset** operator and then connect it to the **BandMerge** operator as well. Then connect the **BandMerge** operator with the **Write** operator.



For each of our operators a tab has appended in the bottom of the graph. Do not change any parameters in the tabs at the moment. Click **Save** at the bottom of the window and save the graph as ***Graph_preprocess.xml*** in:
/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing

Now, we can close the **Graph Builder** window and open the **Batch Processing** tool (**Tools → Batch Processing**). Now we will set our processing parameters for each operator.

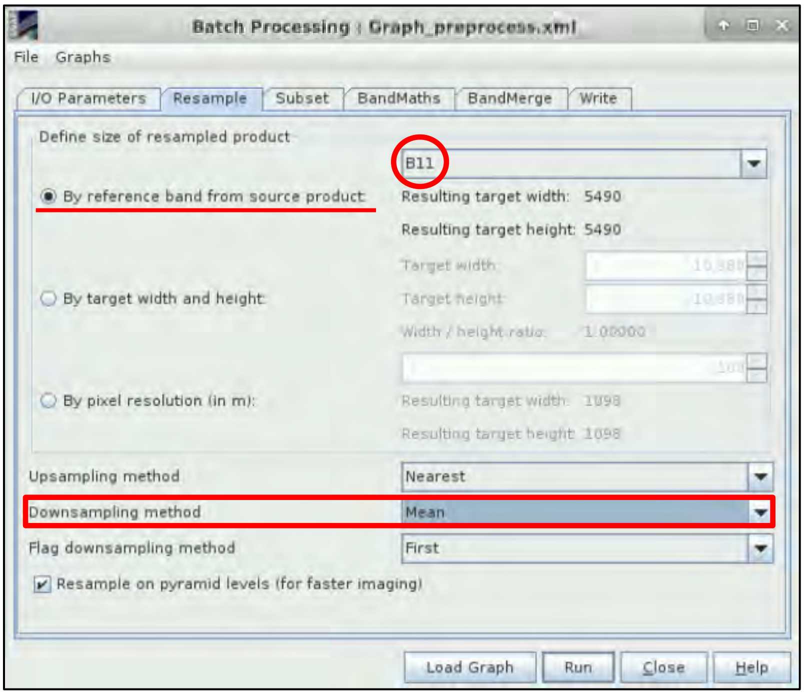
In the **I/O Parameters** tab, we will add all three opened products by clicking **Add Opened** on the upper right (second from top). Click **Refresh** . Unselect the **Keep source product name**. Then, click **Load Graph** at the bottom of the window, navigate to our saved graph and open it. We see that new tabs have appeared at the top of window corresponding to our operators.



Finally, we can set the parameters.

In **Resample** tab we set:

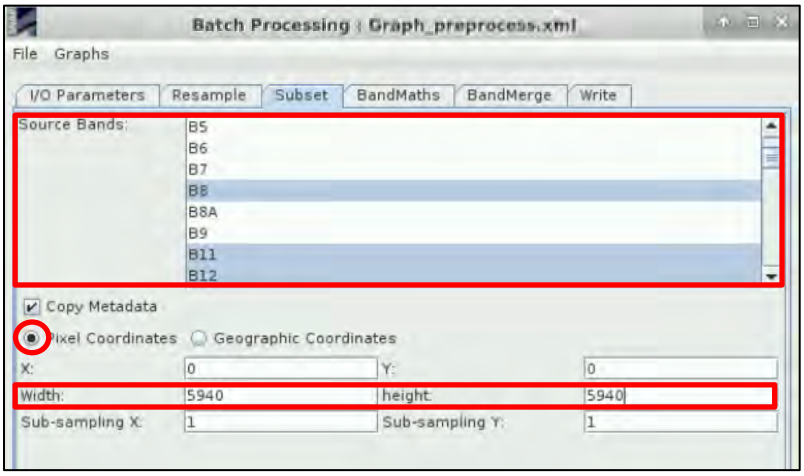
Define size of resampled product: By reference band from source product: **B11** (we will resample all the bands to 20 m resolution).
Downsampling method: Mean



In the **Subset** tab, we select bands: **B4, B8, B11** and **B12** (to select multiple hold Ctrl).

Make sure the **Pixel Coordinates** option is selected and then set:

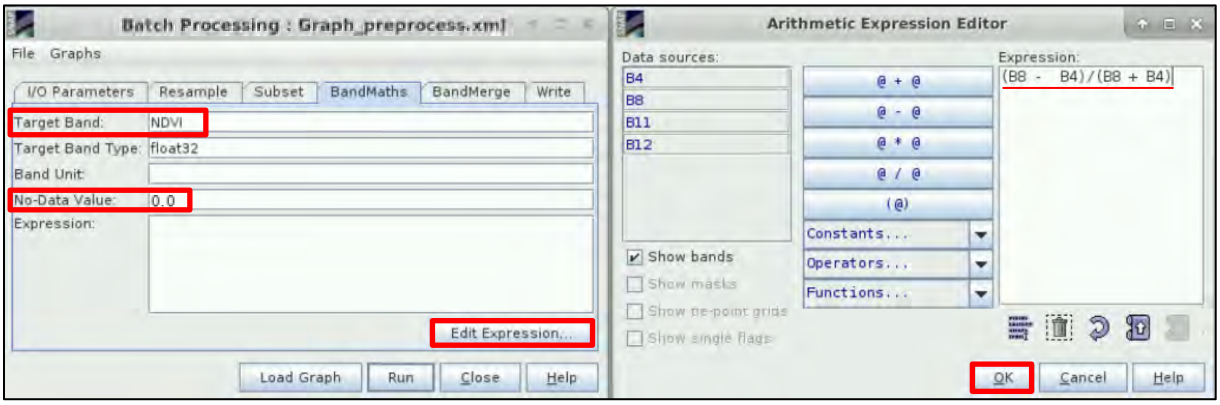
Width: 5940 **Height:** 5940



To create additional information for our classification we will calculate the <u>N</u>ormalized <u>D</u>ifference <u>V</u>egetation <u>I</u>ndex (NDVI) – developed by Rouse[2], the NDVI algorithm exploits the strength and the vitality of the vegetation on the earth's surface. It indicates amount of vegetation, distinguishes vegetation from soil and minimizes topographic effects. NDVI is calculated as :

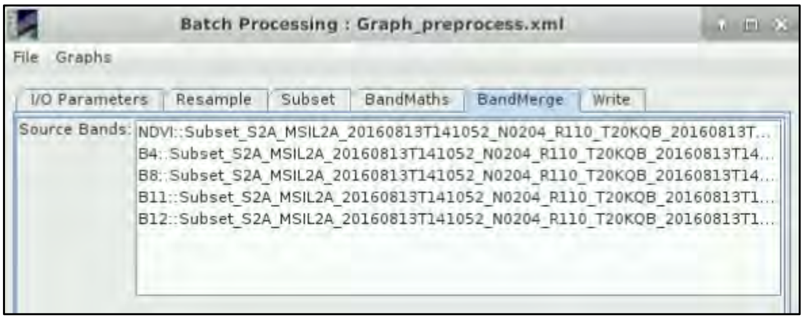
$$NDVI = \frac{NIR - Red}{NIR + Red} = \frac{B8 - B4}{B8 + B4}$$

We define the expression for the calculation of NDVI in the **BandMaths** tab:
Target band: NDVI
No-Data Value: 0.0
Click on **Edit Expression** and set: `(B8 - B4)/(B8 + B4)`



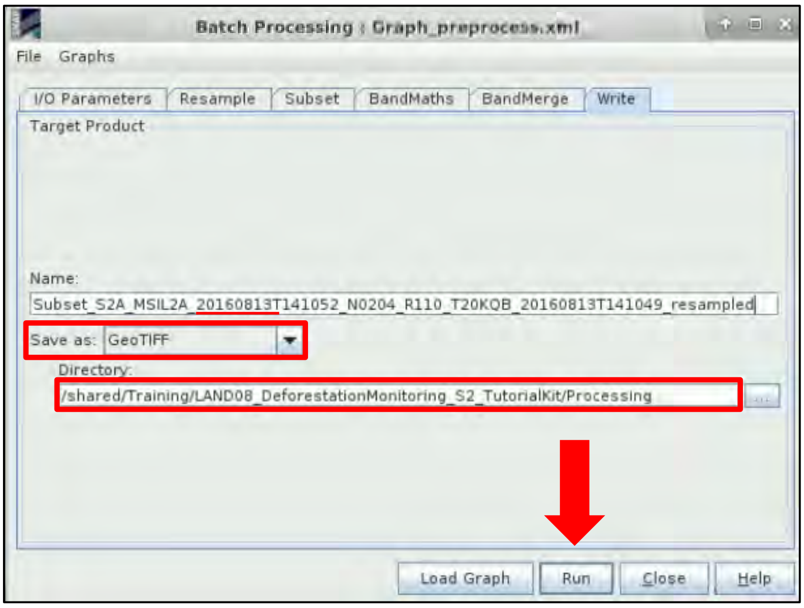
Then click **OK**.

Now we need to add the NDVI band to our original subset using the **BandMerge**. We will not change anything in the **BandMerge** tab, use the default settings.



In the **Write** tab check that the name contains *"**20160813**"* (or the date of the first loaded image) but do not change anything. Then set **Save as**: ***GeoTIFF***

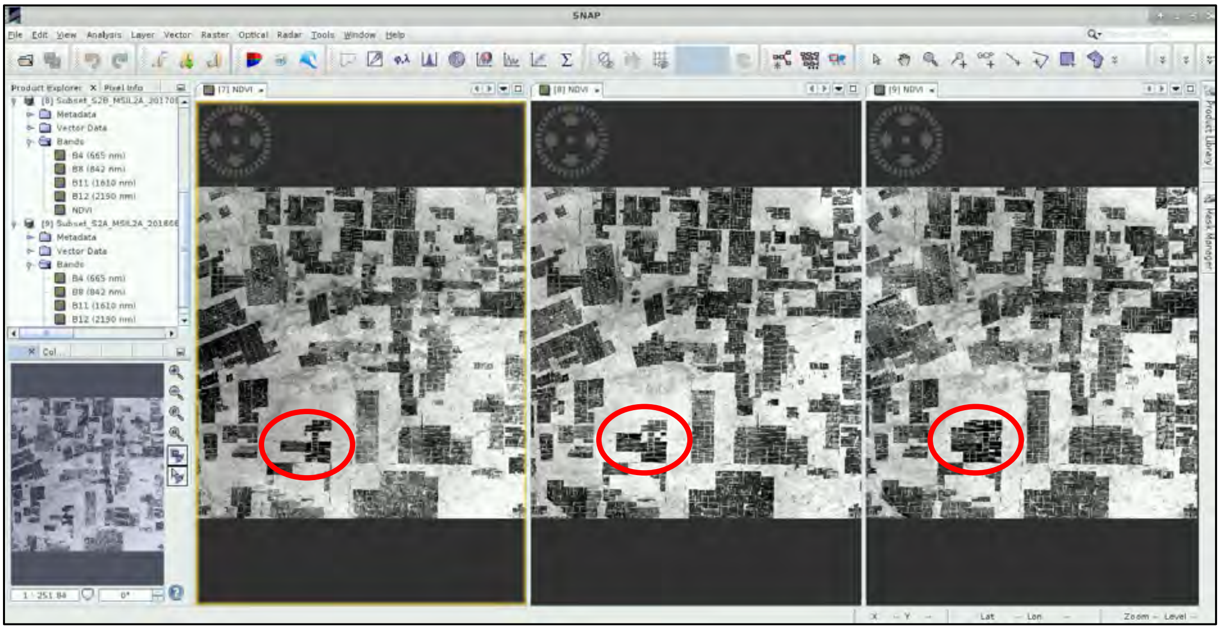
Set the output directory:
/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing



Finally, let's click **Run.** This might take a few minutes depending on your machine.

Now, you should have three new products in the **Product Explorer** window. Close the **Batch Processing** window and all the **View** windows and expand the first new product [7]. In **Bands** folder, double-click the **NDVI** band. Now do the same for the other two products ([8] and [9]) as well. Go to **Window → Tile Horizontally** and then in **Navigation** tab, click **Zoom All** .

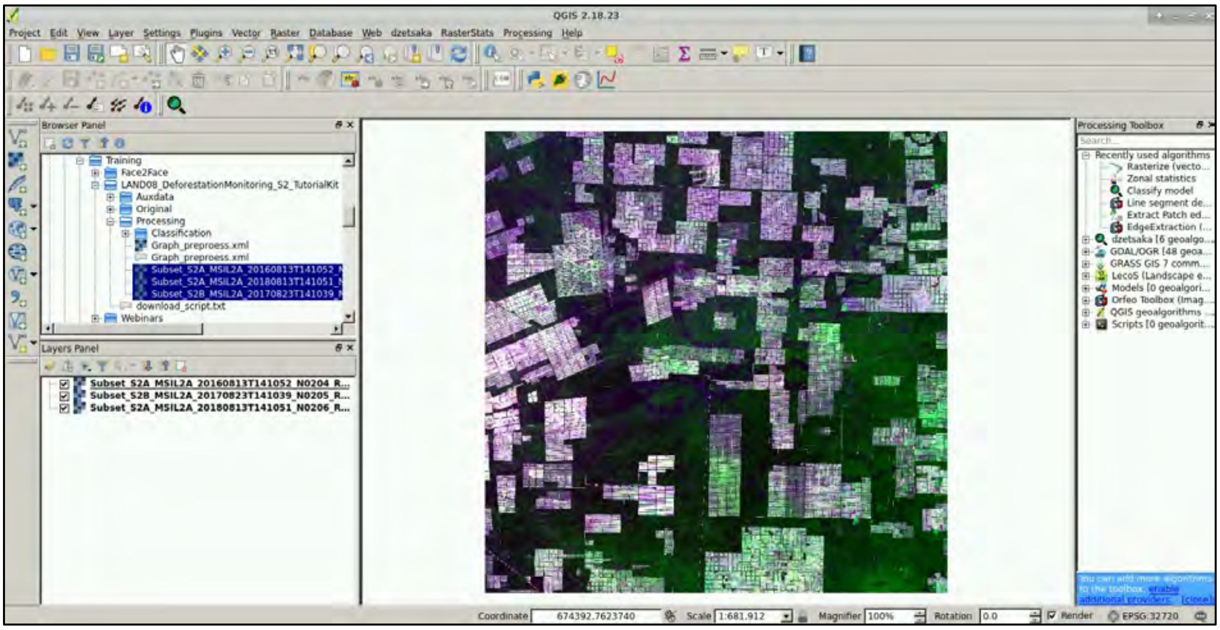
To be able to compare the images better, we can apply the same stretch to all Views. We can do this by applying the same histogram stretch. Select the first View [7] and go to **Colour Manipulation** tab, here we can see the histogram. Click **Apply to other bands**, in the menu of the window that appears, select only **[8] NDVI** and **[9] NDVI,** then click **OK**. Click "**No**" in the next dialogs.



Now we can move to QGIS to start the classification. Close **SNAP** and click "**No**" to the pop-up window.

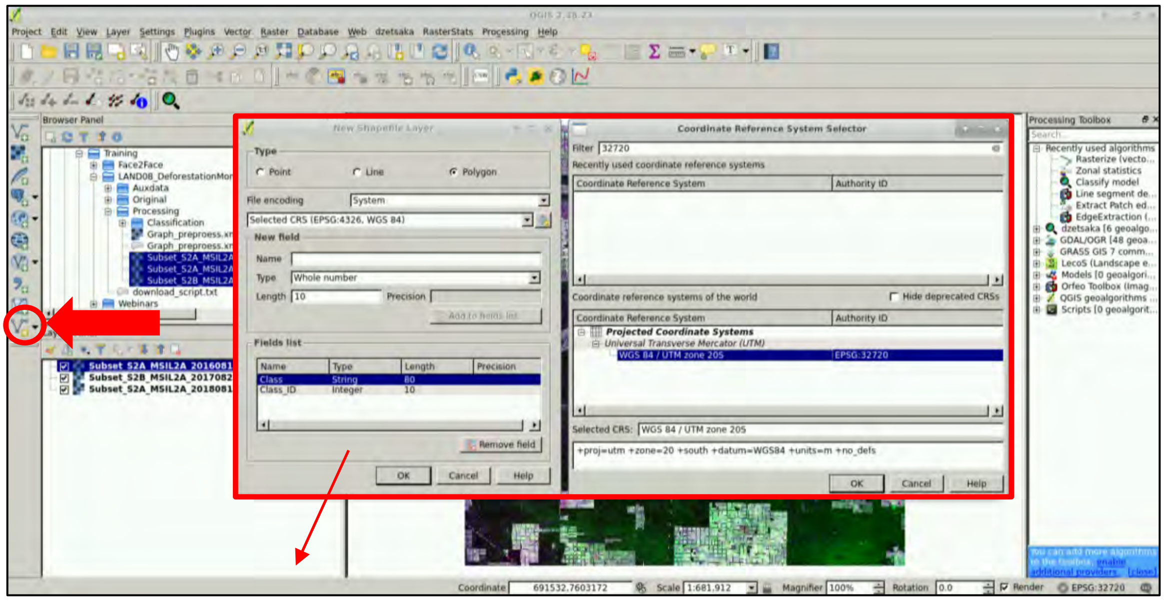
5.5 Classification in QGIS

Let's open QGIS . Go to **Application → Processing → QGIS Desktop**. In the **Browser Panel** we navigate to ***/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing*** and load the three GeoTIFF products we have created in SNAP (hold CTRL, select all 3 layers and drag them to the **Layers Panel**).



A good training dataset is very important for the accuracy of any classification. Here it has already been created for you, using the image from 2016 to create training polygons for deforested areas and the image from 2018 to create training polygons for forest. If you wish to create your own see NOTE 3.

NOTE 3: If you would like to create your own training dataset you can do this by inspecting the images closely and then using drawing polygons over the areas you identify as forested or deforested. In the attribute table you need to fill the Class of each polygon "**forest**"/"**non-forest**" and the Class ID "**1**"/ "**2**".



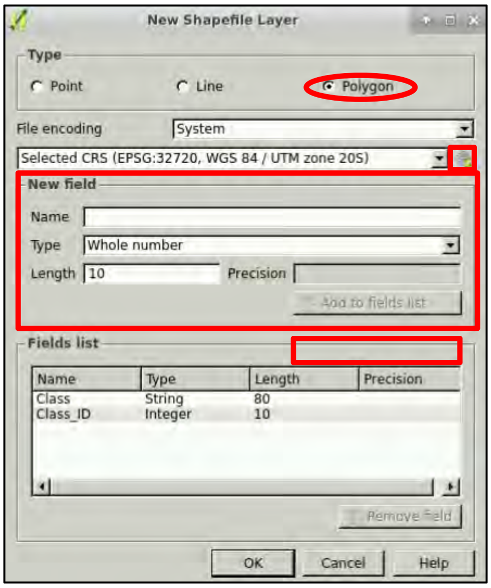
Set the parameters of a new layer: **Type:** Polygon

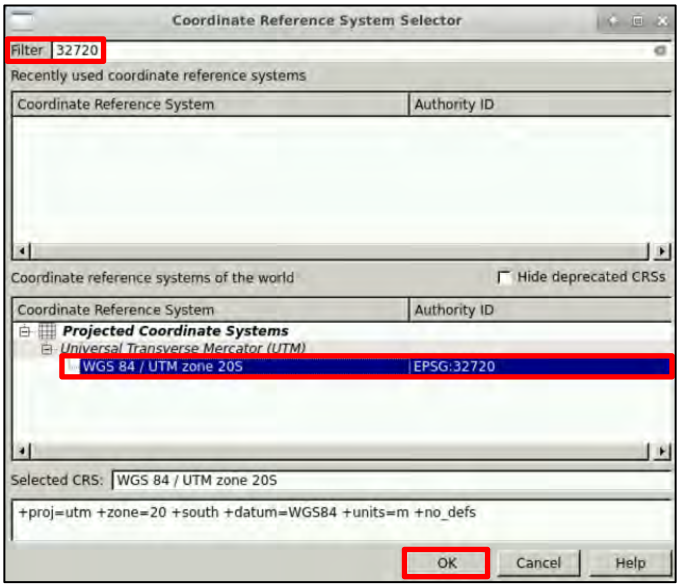
Coordinate system: "32720" (Select it and click **OK**)

Add two new fileds → **New field:** **Name:** **Class** (Type: Text data)

Class_ID (Type: Whole number)

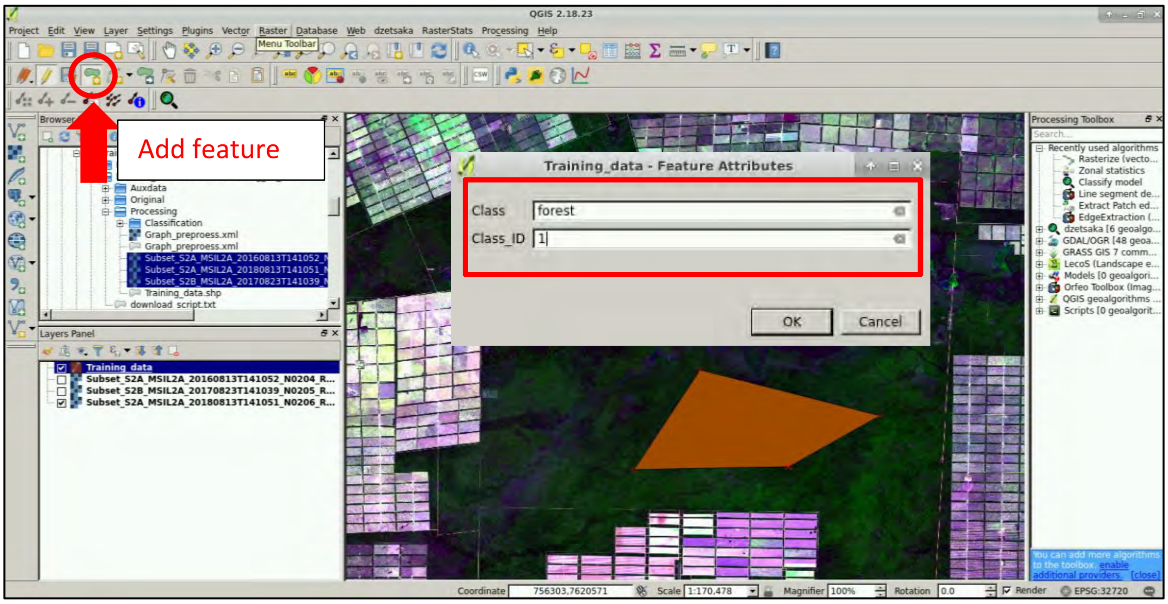
Once you create each field, click on "**Add to fields list**".





Click **OK**. Finally, you will be asked to set the location and name of the layer. Save it as "**Training data**" in the ***/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing*** folder.

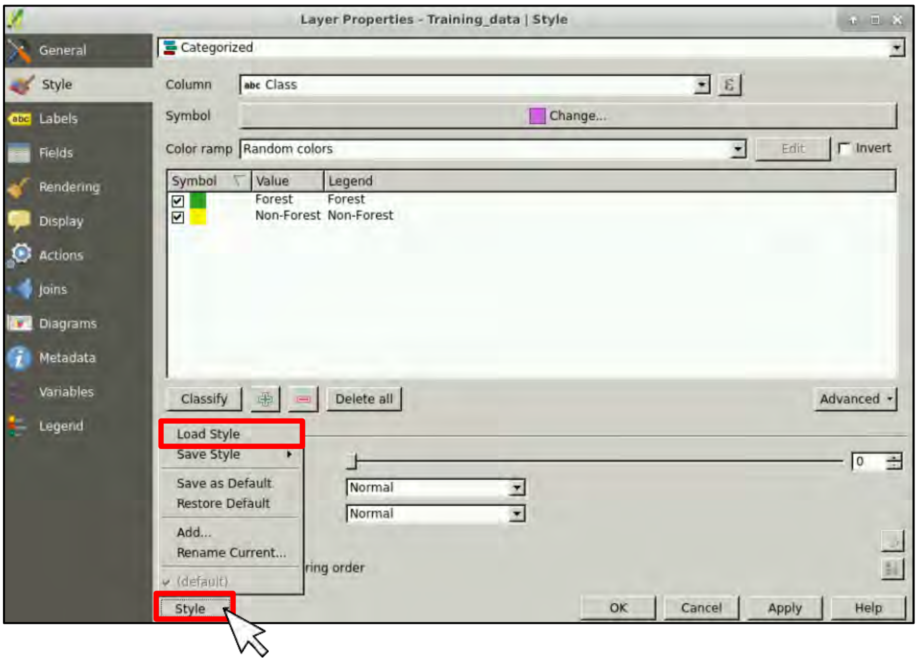
When the new empty layer is created you can right-click the layer and select "**Toggle editing**", then select "**Add feature".** You can then start drawing by clicking on the image and you can close polygon by right-click, then you must set the field values. When you are done with all polygons for both classes, click the **"Toggle editing"** again to save edits. (**Remember**: Class: forest – Class_ID: 1, Class: non-forest – Class_ID: 2).



In this way we have single training dataset for all three images as we can assume that that if an area was forest in 2018 it must have been forest also in 2016. Of course, training data created over high resolution imagery or even in situ training data would be invaluable and may improve the accuracy of our classification.

Now we load the training dataset that is already provided. In the **Browser panel** navigate to: ***/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/AuxData***
Load: ***Training_data.shp***

Then, right-click the layer and go to **Properties → Style** to change the appearance. Click **Style → Load Style**, then navigate to the ***AuxData*** folder and select ***Training_data.qml***. Then click **OK**.



Now we can start with the classification. We will be using the **dzetsaka** tool to train our classifier (build a model) and classify our images. You can find it in the **Processing Toolbox** window on the right (See NOTE 4).

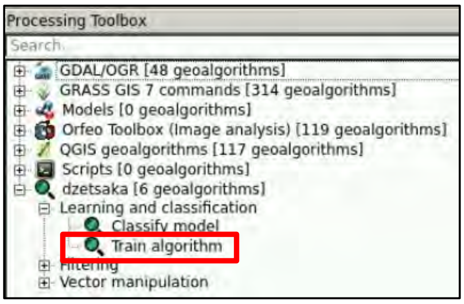
This plugin has by developed by Nicolas Karasiak, for work in the Amazon, it simplifies classification algorithms and automatically determined the best parameters to be used.

> NOTE 4: In case the **dzetsaka** plugin is not installed, click on **Plugins → Manage and Install Plugins**. Select the ***"All"*** tab on the left side panel and write ***"dzetsaka"*** on the search box. Select the plugin on the list and click "**Install Plugin**". You may need to restart QGIS to finalize the installation.
> To find out more about the plug-in go to https://github.com/lennepkade/dzetsaka
> A **Scikit-learn library** is also required to run the plug-in. It can be installed from command line by running following line: `python2.7 -m pip install scikit-learn --user`

5.5.1 Build Model

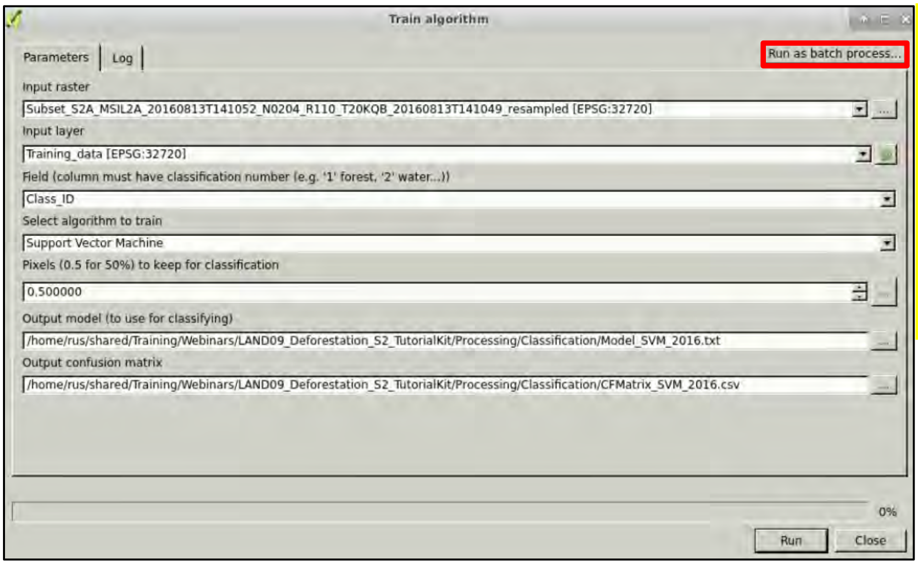
First, we need to train our classifier using the vector training dataset. In our training data, we have defined 2 classes: Forest (Class_ID: 1)

Non-forest (Class_ID: 2)



Go to the **Processing Toolbox** and expand the **dzetsaka** group. Double click on the **Train algorithm** tool. The tool menu will open, allowing us to process a single image. However, we have 3 images to process so we can select the Batch processing mode (**Run as batch process**…) at the top right side. Below you can see the menu pre-set for processing one of our images.

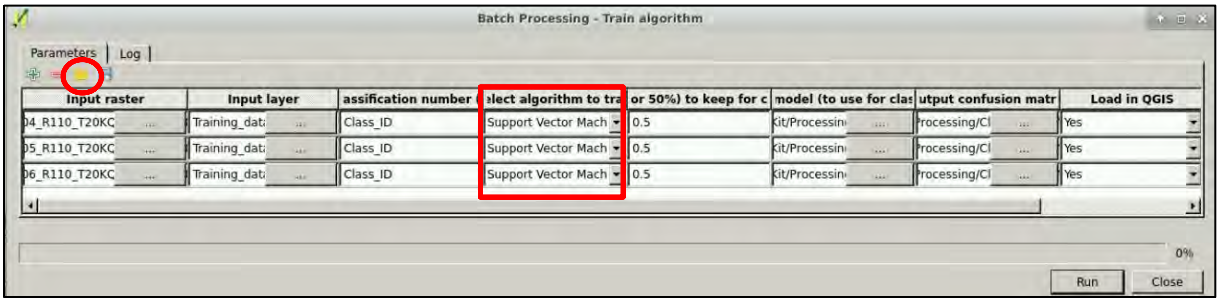
We can choose from 4 classifiers, in this example we will be using the **Support Vector Machine (SVM)** classifier (See NOTE 5). Generally, many settings are required to run SVM but **dzetsaka** is a simplified tool that estimates the best parameters for us and allows us to get good results without needing to have much knowledge of the algorithm. Note that we are keeping only 50% of the training samples (pixels within our training polygons) to train the model. The other 50% is used to generate a confusion matrix (See NOTE 6). Click on "**Run as batch process**…".



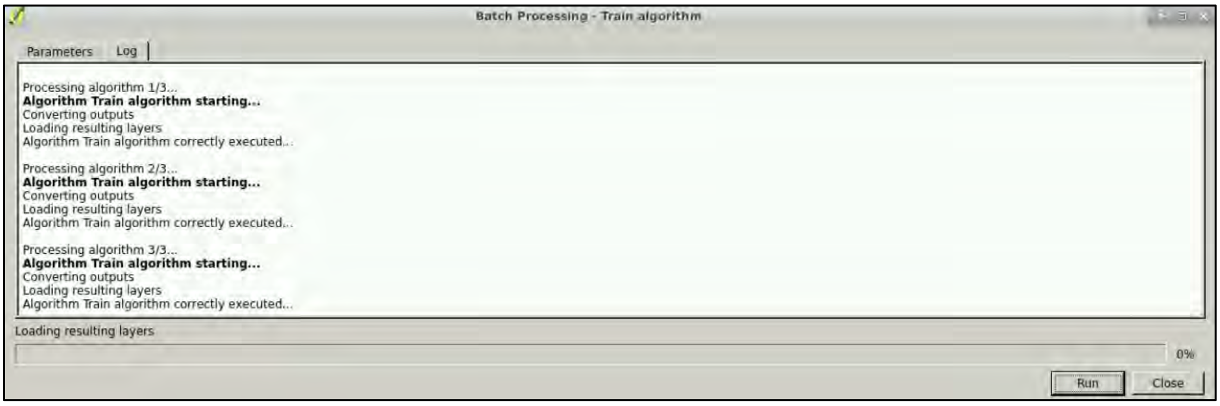
We do not need to set any parameter in this window since we will use ***"Run as batch process…"*** where will set the parameters/load file containing pre-set parameters.

Then click on and load the prepared settings from ***QGIS_Batch_TrainModel.json*** in:
/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/AuxData

Find the column called **Select algorithm to train** and set *"**Support Vector Machine**"* for all three instances. After the processing is completed, check that three new text files have been created in the ***/Processing/Classification/*** folder (See NOTE 7).



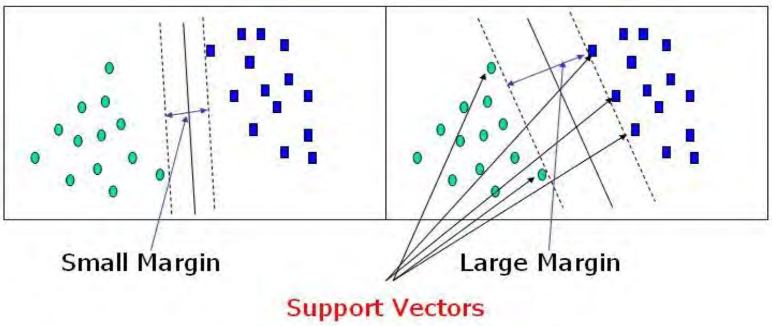
Click **Run**. *This may take up to 45 minutes.*



Close the Batch Processing and Train Algorithm windows.

NOTE 5: The Support Vector Machine (SVM) algorithm translates (plots) the data points to n-dimensional space with the values of different input features/raster bands acting as coordinates. The objective of the support vector machine algorithm is to find a hyperplane in this N-dimensional space (N — the number of input features) that distinctly classifies the data points into two classes.

To separate the classes of data points, there are many possible hyperplanes that could be chosen. Our objective is to find a plane that has the maximum margin, i.e the maximum distance between data points of both classes. The Support vectors are the data points close to the hyperplane that influence its position. (Rohith Gandhi, https://towardsdatascience.com/)

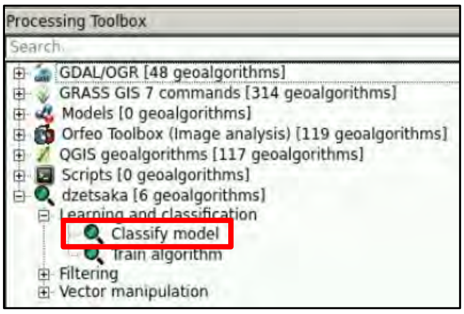


NOTE 6: A confusion matrix is a table that is used to describe the performance of a classification model (or "classifier") on a set of test data for which the true values are known.

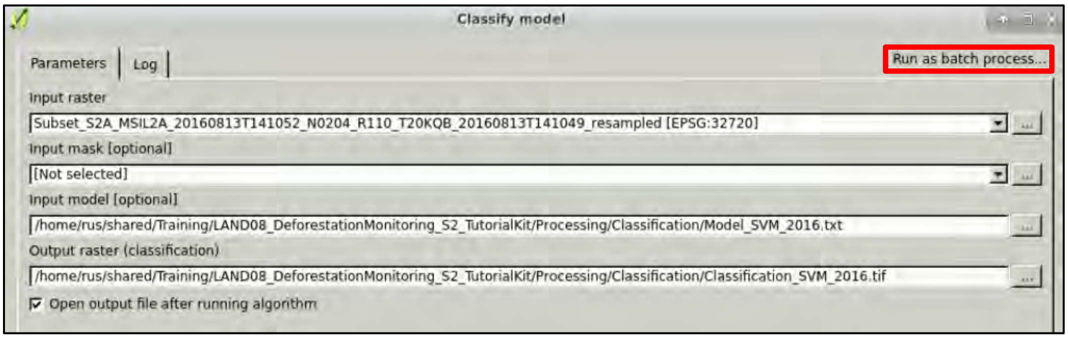
NOTE 7: Make sure that there is already created the ***/Classification*** folder in the ***/Processing*** folder. If no, create it by yourself and then continue with the following steps.

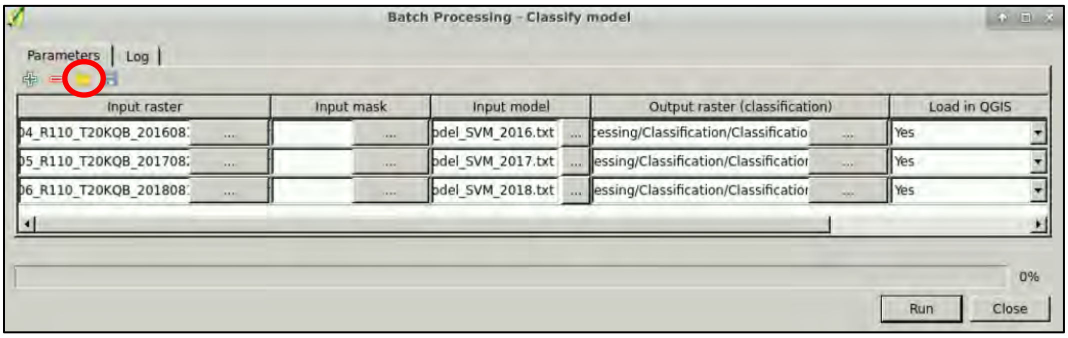
5.5.2 Classify image

Next, we will apply the model to classify the images. Go to the **Processing Toolbox** and expand the **dzetsaka** group. Double-click on the **Classify model** tool.



Go to **Run as batch process…** again and click on and load the prepared settings from: ***/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/AuxData/QGIS_Batch_Classification.json***





Then click **Run**. *This may take up to 10 minutes.*

NOTE! If QGIS fail to run the process, set in the Batch Processing all the parameters manually.

Go to **Run as batch process…** and set:

In the "**Input raster**" select the three **.tif** images from: ***shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing*** path:

- **Subset_S2A_MSIL2A_20160813T141052_N0204_R110_T20KQB_20160813T141049_resampled.tif**
- **Subset_S2B_MSIL2A_20170823T141039_N0205_R110_T20KQB_20170823T141404_resampled.tif**
- **Subset_S2A_MSIL2A_20180813T141051_N0206_R110_T20KQB_20180813T174352_resampled.tif**

In the “**Input model**” select the three **.txt** files from: ***shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing/Classification*** path:

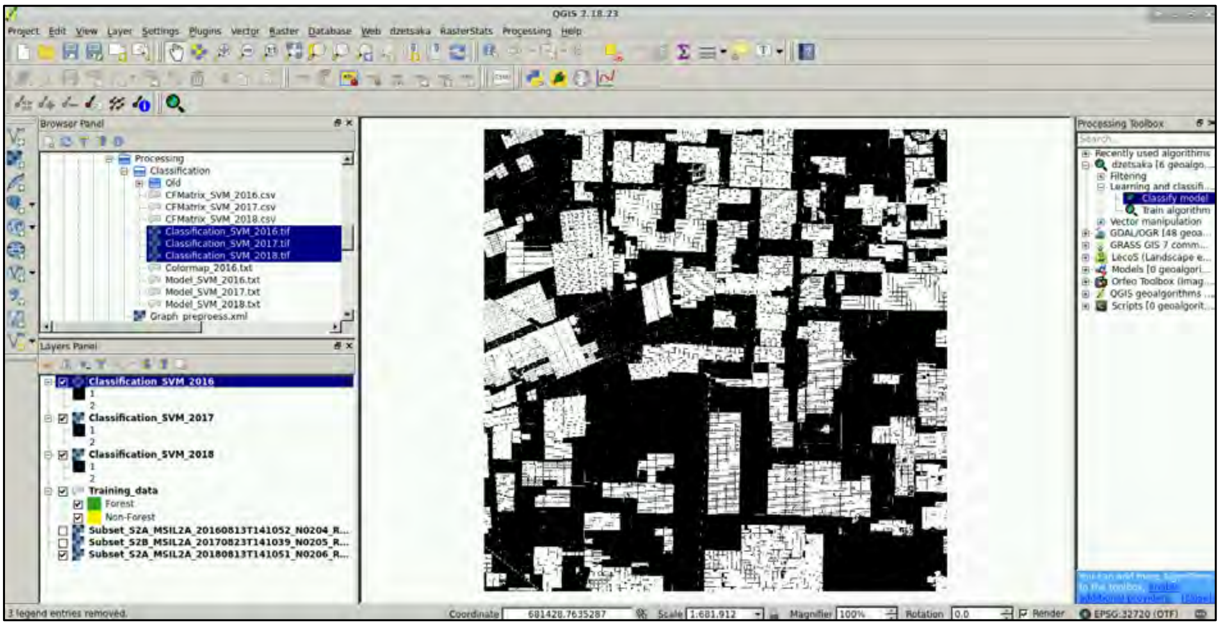
- **Model_SVM_2016.txt**
- **Model_SVM_2017.txt**
- **Model_SVM_2018.txt**

In the “**Output raster (classification)**” save each image in: ***shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing/Classification*** with the following names:

- **Classification_SVM_2016.tif**
- **Classification_SVM_2017.tif**
- **Classification_SVM_2018.tif**

Then click **Run**.

Three new raster files have appeared in our **Layers Panel** tab. They are however all named ***Output …*** so we will close them and reload them again with the correct names. In the **Browser Panel** tab, navigate to the ***/Classification*** folder and open the three raster-layers.

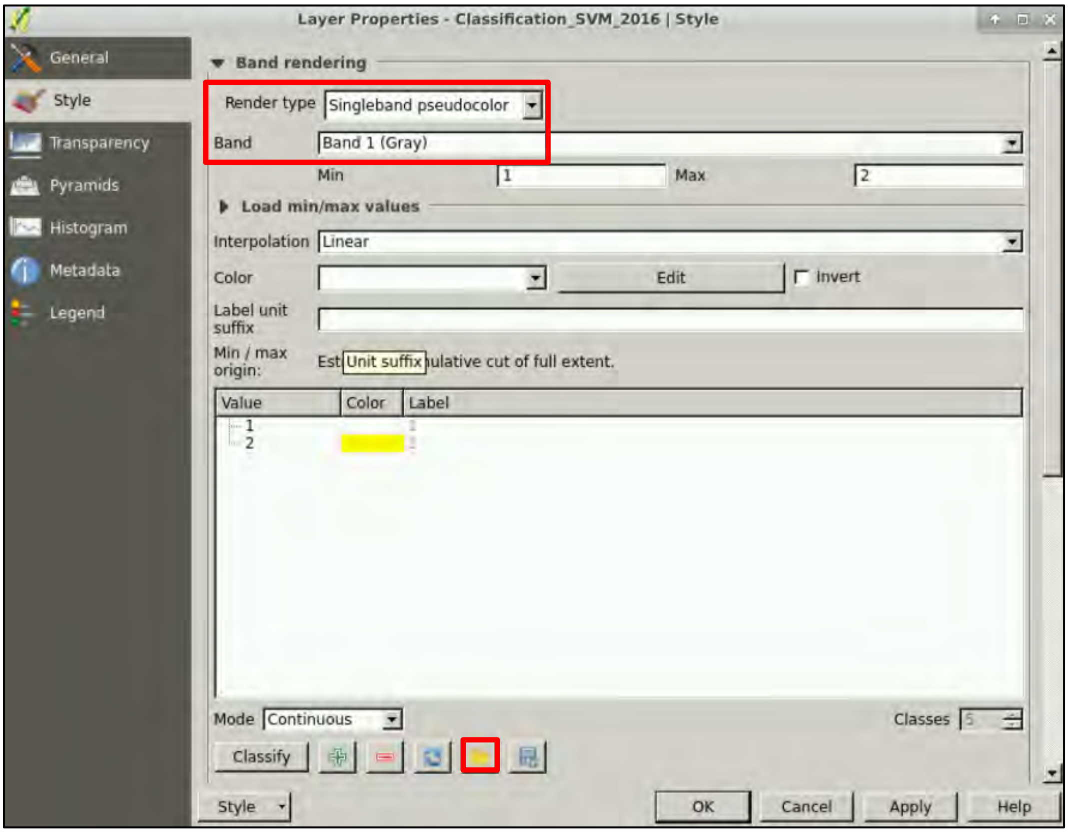


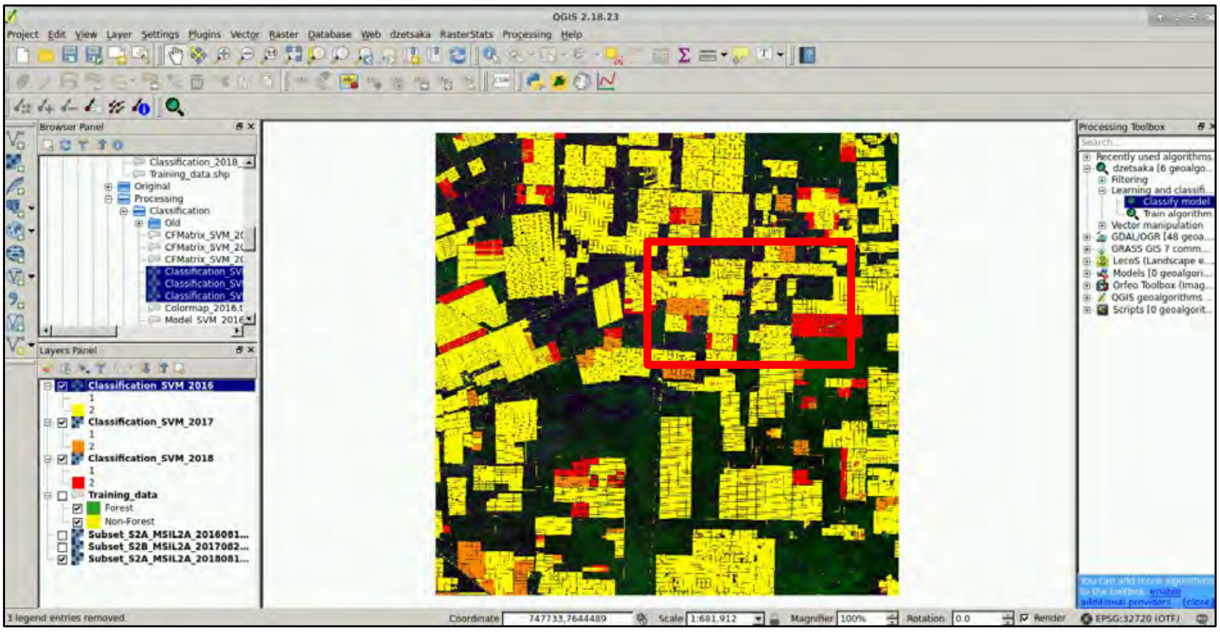
Then let’s visualize them better. Right-click on the first layer (classification from 2016) and go to **Properties**.

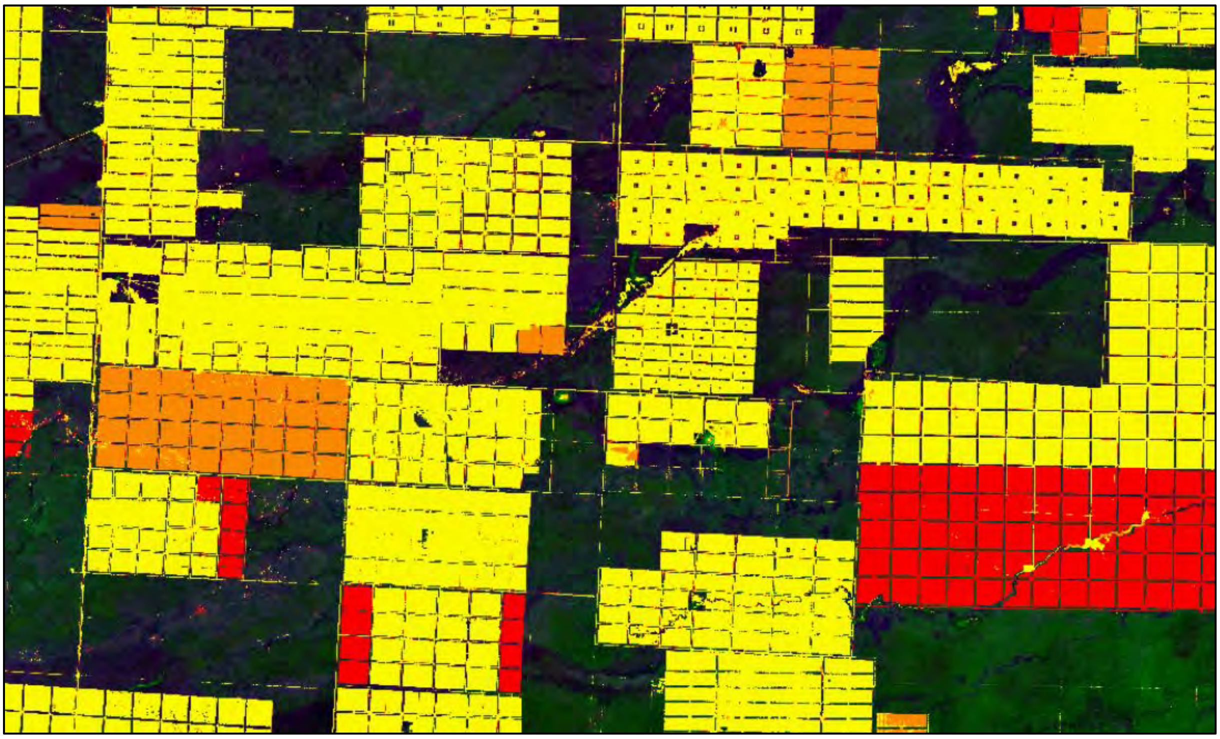
In the **Style** tab select: **Render type:** Singleband pseudocolor

Band: Band 1 (Gray)

Then in the bottom go to **Load colour map from file**, navigate to the ***Auxdata*** folder and select ***Classification_2016_colour_palette.txt***. Click **OK** and do the same for the other two classified layers using the respective colour palettes.


Layer Properties - Classification_SVM_2016 | Style
General
Style
Transparency
Pyramids
Histogram
Metadata
Legend
Band rendering
Render type
Singleband pseudocolor
Band
Band 1 (Gray)
Min
1
Max
2
Load min/max values
Interpolation
Linear
Color
Edit
Invert
Label unit suffix
Min / max origin:
Est Unit suffix ulative cut of full extent.
Value
Color
Label
1
2
Mode
Continuous
Classes
5
Classify
Style
OK
Cancel
Apply
Help


QGIS 2.18.23
Project Edit View Layer Settings Plugins Vector Raster Database Web dzetsaka RasterStats Processing Help
Browser Panel
Layers Panel
Classification_SVM_2016
Classification_SVM_2017
Classification_SVM_2018
Training_data
Forest
Non-Forest
Processing Toolbox



Investigate the classifications visually compared to the natural composite images. You can turn the layers on and off in the **Layers Panel**.

The **dzetsaka** tool has also produced a simple confidence matrix for each classification. We can open it from the file explorer when we go to:

/shared/Training/LAND08_DeforestationMonitoring_S2_TutorialKit/Processing/Classification

There you can find 3 files named ***CFMatrix_2016_SVM.csv, CFMatrix_2017_SVM.csv*** and ***CFMatrix_2018_SVM.csv***

Note that these confusion matrices are generated using the second half of our training data and therefore cannot be considered independent. If we truly want to assess the performance, we would have to create new independent validation dataset and compute additional statistics.

Classification 2016			**Classification 2017**			**Classification 2018**		
True value	Classified as forest	Classified as non-forest	True value	Classified as forest	Classified as non-forest	True value	Classified as forest	Classified as non-forest
forest	201404	9	forest	201402	3	forest	201395	12
non-forest	0	30237	non-forest	2	30237	non-forest	9	30234

THANK YOU FOR FOLLOWING THE EXERCISE!

6 Extra steps

6.1 *Downloading the outputs from VM*

On your keyboard, press **Ctrl+Alt+Shift.** A pop-up window will appear on the left side of the screen. Click on the bar below **Devices**, the folder structure of your VM will appear. Navigate to your Processing folder and **double click any file you want to download.**

7 References and resources

1. Mousivand, A., Verhoef, W., Menenti, M. & Gorte, B. Modeling Top of Atmosphere Radiance over Heterogeneous Non-Lambertian Rugged Terrain. *Remote Sens.* 7, 8019–8044 (2015).
2. Rouse, J. W. Monitoring vegetation systems in the Great Plains with ERTS. in (1974).
3. MacDonald, C. & MacDonald, C. The Tragic Deforestation of the Chaco. *Rolling Stone* (2014). Available at: https://www.rollingstone.com/culture/culture-news/green-going-gone-the-tragic-deforestation-of-the-chaco-116951/. (Accessed: 30th January 2019)
4. Gandhi, R. Support Vector Machine — Introduction to Machine Learning Algorithms. *Towards Data Science* (2018). Available at: https://towardsdatascience.com/support-vector-machine-introduction-to-machine-learning-algorithms-934a444fca47. (Accessed: 30th January 2019)
5. Patel, S. Chapter 2: SVM (Support Vector Machine) — Theory. *Machine Learning 101* (2017). Available at: https://medium.com/machine-learning-101/chapter-2-svm-support-vector-machine-theory-f0812effc72. (Accessed: 30th January 2019)

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