

TRAINING KIT – LAND07

DEFORESTATION MONITORING WITH SENTINEL-1

Case Study: Paraguay, 2018



Research and User Support for Sentinel Core Products

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1 Introduction to RUS

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.

In this tutorial, we will employ RUS to monitor on-going deforestation in the Chaco region, located in the north of Paraguay, using Sentinel-1 GRD data as input data to run a supervised classification (Random Forest).

2 Deforestation – background



Forests cover almost a third of world's land surface, representing one of the most important ecosystems in our planet and a fundamental element to fight climate change. They provide fundamental ecosystem services such as absorbing, storing and converting carbon dioxide (CO₂) into oxygen or reducing the effect of erosion caused by wind and rain amongst other. Moreover, forests create natural habitat to a large variegate of flora and fauna species hence preserving global

biodiversity.

Rapid shrinking of forest creates a major threat and increases the effects of climate change. Every year, large forested areas are cleared out all over the world due to different driving forces and precise monitoring of these activities is required to reduce their negative impact.

The Copernicus program, which includes a new family of earth observation satellites known as the Sentinels, provides a unique opportunity to quickly map the ever-changing forests and provide regular updates on their condition at a range of spatial and temporal resolutions.

3 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is **LAND07. 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.**

3.1 Data used

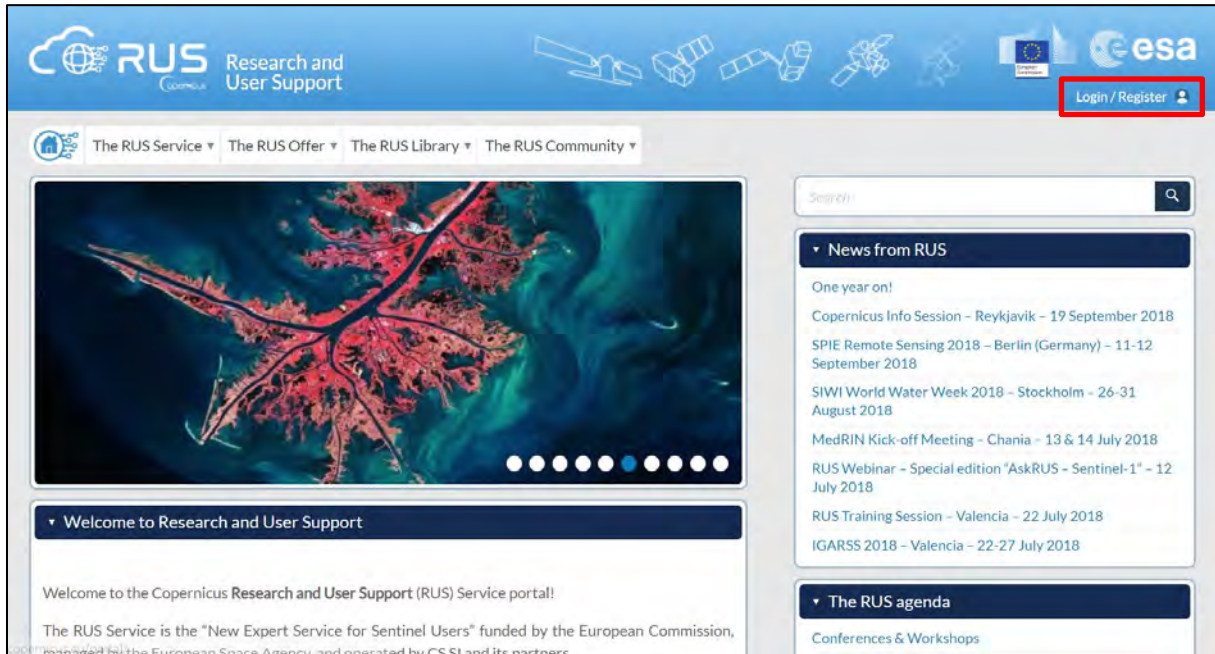
- 5 Sentinel-1B images acquired from June 2017 until November 2018 [downloadable at <https://scihub.copernicus.eu/> using the .meta4 file provided in the *Original* folder Pre-processed data stored locally
`@/shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/`

3.2 Software in RUS environment

Internet browser, SNAP + S1 Toolbox

4 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*.

The image shows two side-by-side screenshots of the registration process. The left screenshot is a 'Login / Register' dialog box. It contains a 'Login' button and a 'Create my Copernicus SSO account' button, which is highlighted with a red box. Below the buttons, there is a note about checking the spam folder for Google email addresses. The right screenshot is the 'Copernicus Users' Single Sign On Registration' form. It contains a 'Registration form' section with fields for 'I'm already registered', 'GDH SSO ID', 'Secret question', 'Answer', 'Password', 'Confirm password', 'Email', 'Confirm email', 'First name', 'Last name', 'Institution', and 'Country of residence'. A 'Register' button is highlighted with a red box at the bottom right of the form.

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.

Login / Register

The registration system to access the RUS service platform has moved toward the COPERNICUS Single Sign On authentication server.

- New Users who have not yet registered to the RUS portal shall first create a COPERNICUS SSO account.

Note that your Copernicus SSO account will be activated only after the reception of the third email sent by the Copernicus service. We advise you to consult [this document](#) and [this page](#) to facilitate your registration procedure.

REGISTER COPERNICUS SSO account

Users who already have a COPERNICUS SSO account can login here:

Login

Close

Credentials

CDS-SSO ID

Password

Max Idle Time

Max Session Time

Login **Reset**

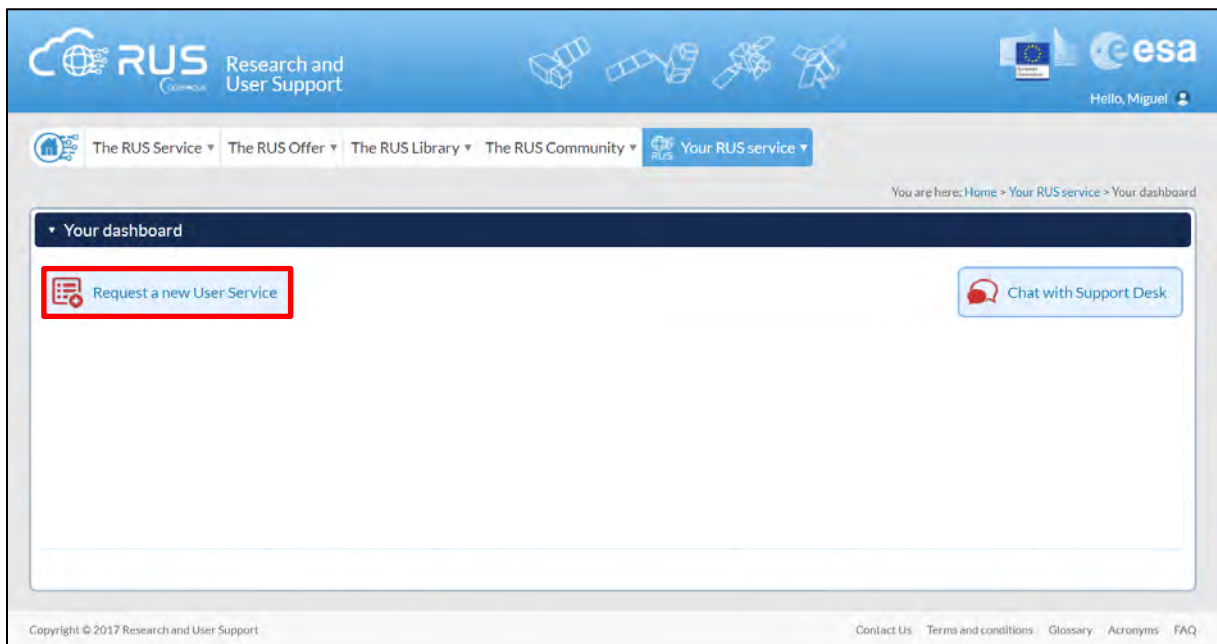
[Forgot your password?](#)

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

5 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.

The image shows the 'User Support Request' form, Step 1/3: Your experience. The form asks for experience in Remote Sensing and whether the user has downloaded or handled Copernicus data. A red rectangle highlights the section for selecting tutorial exercises. The exercises listed are: HAZA01 - Flood Mapping in Malawi, HAZA02 - Burned Area Mapping in Portugal, HYDR01 - Water Bodies Mapping over Northern Poland, LAND01 - Crop Mapping in Seville, LAND04 - Land Monitoring in Cyprus, and OCEA01 - Ship Detection in Gulf of Trieste. Below the list, there is a text input field for requesting other exercises not in the list. The form has 'Cancel' and 'Next' buttons at the bottom.

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

User Support Request

Summary information on your request:

This is a collection of information selected across the USR forms.

You can go back and edit this information if necessary.

General information on your request:

Years of experience in Remote Sensing

5-10 years

Downloaded Copernicus data?

✓

Handled/processed Copernicus data?

✓

Webinar codes

HAZA02, LAND04

About your RUS project:

Thematic area

Cryosphere (ice and snow)

Operations to perform on RUS

Algorithm development

Preference for downloading process

Self-downloading

Foreseen activities and support needs

Develop a land cover classification

Project name

RUS_Project1

Earth Observation Data Information:

Type of Earth Observation Data:

Sentinel-1

✓

S1 - Product type

S1 - Product 1

S1 - Sensor mode

GRD

S1 - Polarisation

-

S1 - Orbit direction

-

Sentinel-2

X

Sentinel-3

X

Other

X

I don't know

X

Region of interest:

Min Latitude

39.3303

Max Latitude

40.5877

Min Longitude

-4.6736

Max Longitude

-2.7205

Reference polygons

Data acquisition date(s):

None

Additional data specifications

☒

I have read and agree to the Terms and conditions of RUS Service.

Back and edit

Submit the request

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*.

Research and User Support

Hello, Miguel

The RUS Service

The RUS Offer

The RUS Library

The RUS Community

Your RUS service

You are here: Home > Your RUS service > Your dashboard

Your dashboard

Request a new User Service

Chat with Support Desk

Project Name	ID	Date of submission	Status	Actions			Virtual Environment	
RUS_training1	231	2017-08-31	Open	Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
				Cancel my request	Get a webinar kit	Rate my service ★★★★★	Freeze my Virtual Machine(s)	Report a technical incident

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[Acronyms](#)
[FAQ](#)

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.

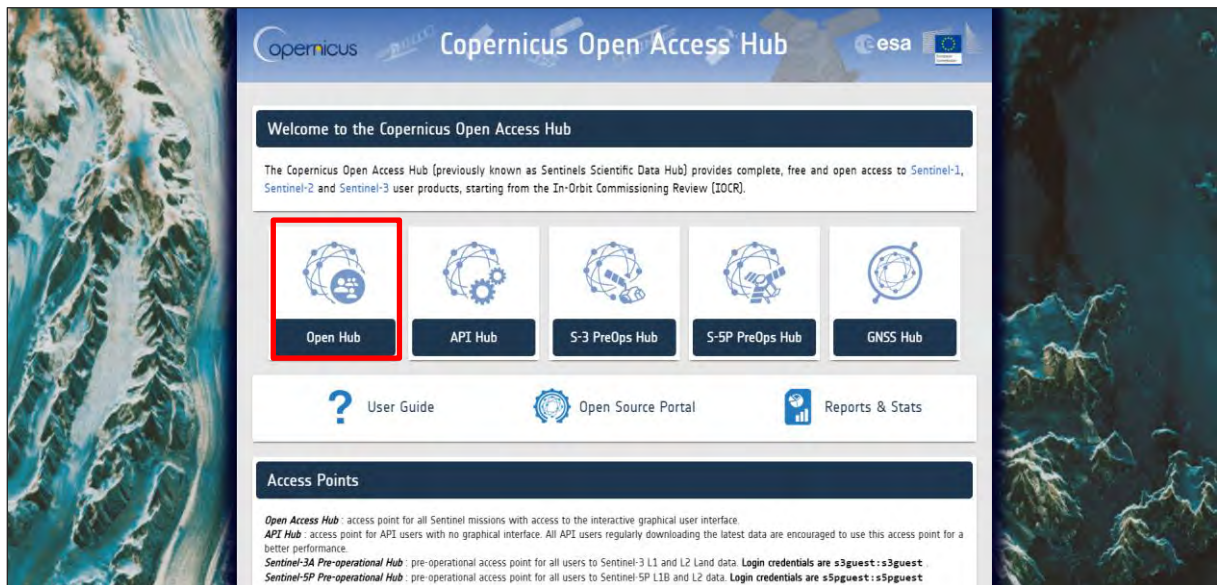


6 Step by step

6.1 Data download – ESA SciHUB

Before starting the exercise, make sure you are registered in the Copernicus Open Access Hub so that you can access the free data provided by the Sentinel satellites.

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



Go to *Open Hub*. If you do not have an account, sign up in the upper right corner, fill in the details and click register.

The image shows the 'Register new account' form on the Copernicus Open Access Hub. The form is titled 'Register new account' and includes a sub-header 'Sentinel data access is free and open to all.' Below this, there's a paragraph explaining the registration process. The form fields are: Firstname, Lastname, Username, Password, Confirm Password, E-mail, Confirm E-mail, Select Domain (dropdown), Select Usage (dropdown), and Select Country (dropdown). At the bottom right, there's a 'REGISTER' button, which is pointed to by a red arrow. A red arrow also points to the 'SIGN UP' button in the top right corner of the page.


You will receive a confirmation email on the e-mail address you have specified: open the email and click on the link to finalize the registration.


Once your account is activated – or if you already have an account – log in.


6.2 Download data

In this exercise, we will analyse 5 Sentinel-1B images acquired during 2017 and 2018. The following table shows the date and reference of the images that will be used:

SATELLITE	DATE	IMAGE ID
Sentinel-1B	2017-06-11	S1B_IW_GRDH_1SDV_20170611T223258_20170611T223327_006008_00A8BA_DC5E
	2017-12-08	S1B_IW_GRDH_1SDV_20171208T223303_20171208T223332_008633_00F558_1DC7
	2018-01-13	S1B_IW_GRDH_1SDV_20180113T223301_20180113T223330_009158_01064E_8B75
	2018-06-06	S1B_IW_GRDH_1SDV_20180606T223304_20180606T223333_011258_014AA1_3FAC
	2018-11-21	S1B_IW_GRDH_1SDV_20181121T223310_20181121T223339_013708_019648_0322

To improve the data acquisition process, we will use a download manager (See  NOTE 1) that will take care of downloading all products that will be used in this exercise. The metadata of the Sentinel products are contained in a *products.meta4* file created using the 'Cart' option of the Copernicus Open Access Hub.


 NOTE 1: A download manager is a computer program dedicated to the task of downloading possibly unrelated stand-alone files from (and sometimes to) the Internet for storage. For this exercise, we will use aria2. Aria2 is a lightweight multi-protocol & multi-source command-line download utility. More info at: <https://aria2.github.io/>

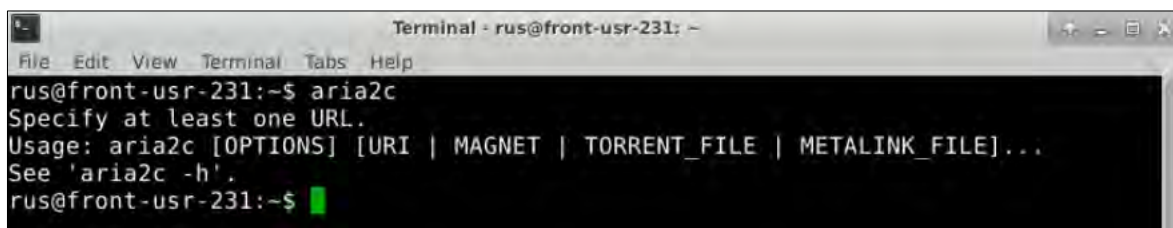
The *products.meta4* file containing the links to the Sentinel-1 products to be downloaded can be created following the methodology explained in  NOTE 2. Follow the instructions and create your cart file, download it and save it in the following path:

Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/Original/*

Before using the downloading manager and the .meta4 file, let's test if *aria2* is properly installed in the Virtual Machine. To do this, open the Command Line (in the bottom of your desktop window) type the following command and press *Enter*.

```
aria2c
```



If *aria2* is properly installed, the response should be as follows. If the response is '*-bash aria2c: command not found*' it means *aria2* is not installed (See  NOTE 3).

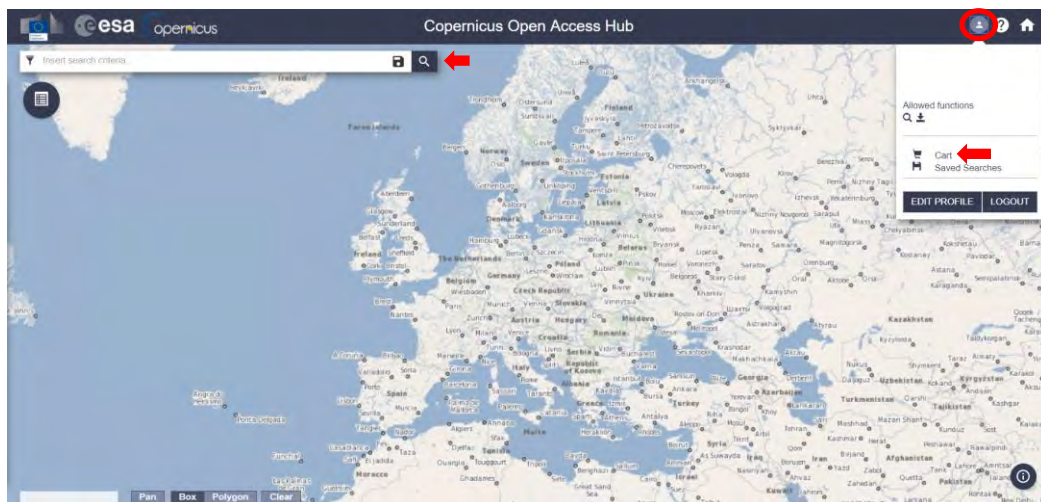
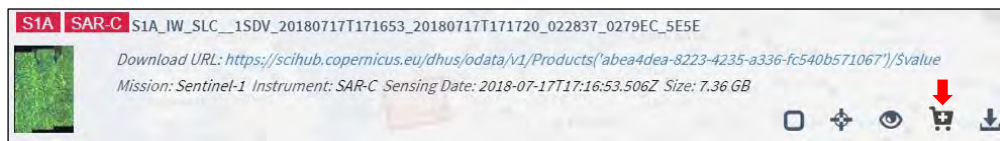


```


Terminal - rus@front-usr-231: ~
File Edit View Terminal Tabs Help
rus@front-usr-231:~$ aria2c
Specify at least one URL.
Usage: aria2c [OPTIONS] [URI | MAGNET | TORRENT_FILE | METALINK_FILE]...
See 'aria2c -h'.
rus@front-usr-231:~$

```

 NOTE 2: The Copernicus Open Access Hub allows you to add products to a 'Cart'. For that, perform a query; select the desired products from the result list and click on the 'Add Product to Cart' icon - . To find the appropriate images, copy-paste the image ID specified in the table (pg. 11) in the search box of the Copernicus Open Access Hub.

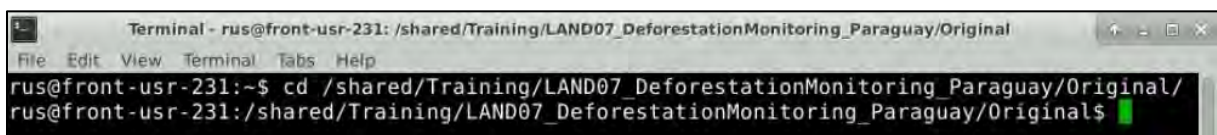


To view the products present in the cart just click anytime on the User Profile icon on top right corner of the screen and then on "Cart". To download the cart click on "Download Cart" on the bottom right of the page. A download window will pop up, asking the user confirmation to save a .meta4 file named '*products.meta4*'. This file contains all the metalinks of the products.

 NOTE 3: If (**and only if**) the response is '*-bash aria2c: command not found*', you need to install aria2. In the command line, type: `sudo apt-get install aria2`
When requested, type: `Y`
Once finished, test the installation as explained before.

Once *aria2* is ready to use, we can start the download process. For that, we need to navigate to the folder where the *products.meta4* is stored. Type the following command in the terminal and run it.

```
cd /shared/Training/LAND07_DeforestationMonitoring_Paraguay/Original/
```



Next, type the following command (in a single line) to run the download tool. Replace *username* and *password* (leave the quotation marks) with your login credentials for Copernicus Open Access Hub (COAH). Do not clear your cart in the COAH until the download process is finished.

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

The Sentinel products will be stored in the same path where the *products.meta4* is located. Move the image from 2018-11-21 to the following path (it will be used later to test the monitoring capabilities of SNAP).

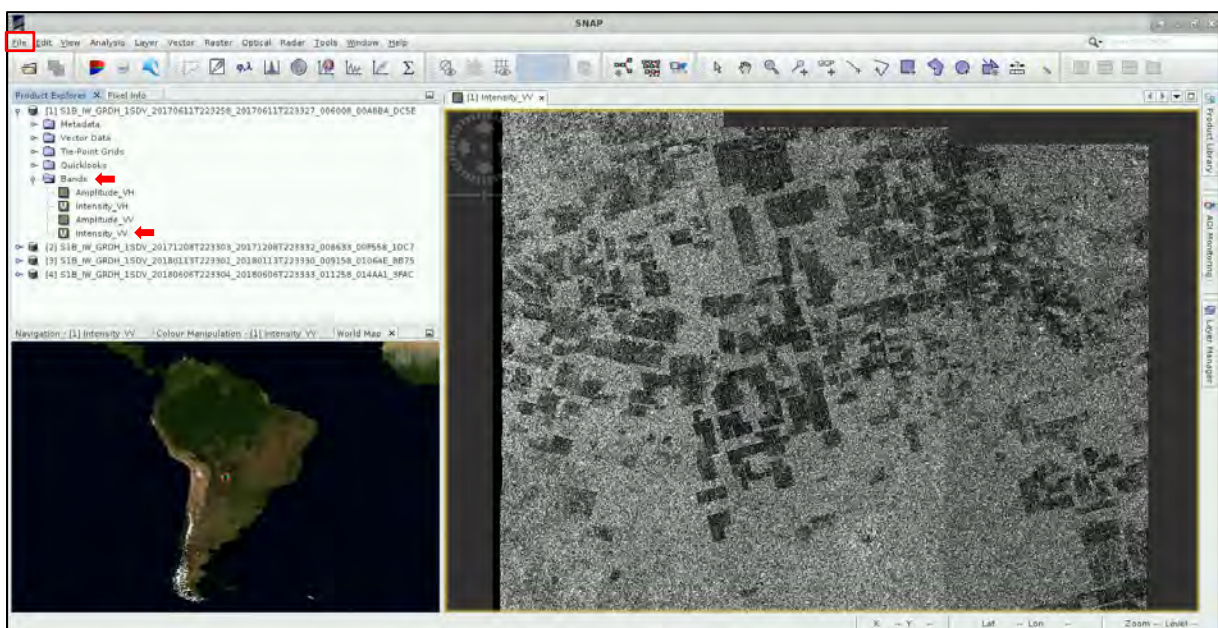
Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/New_S1_images/*

6.3 Sentinel-1 SNAP Pre-processing

Open SNAP (*Applications -> Processing* or click on the desktop icon). Click on *File -> Open Product*, navigate to the following path and open all the 4 Sentinel-1 products

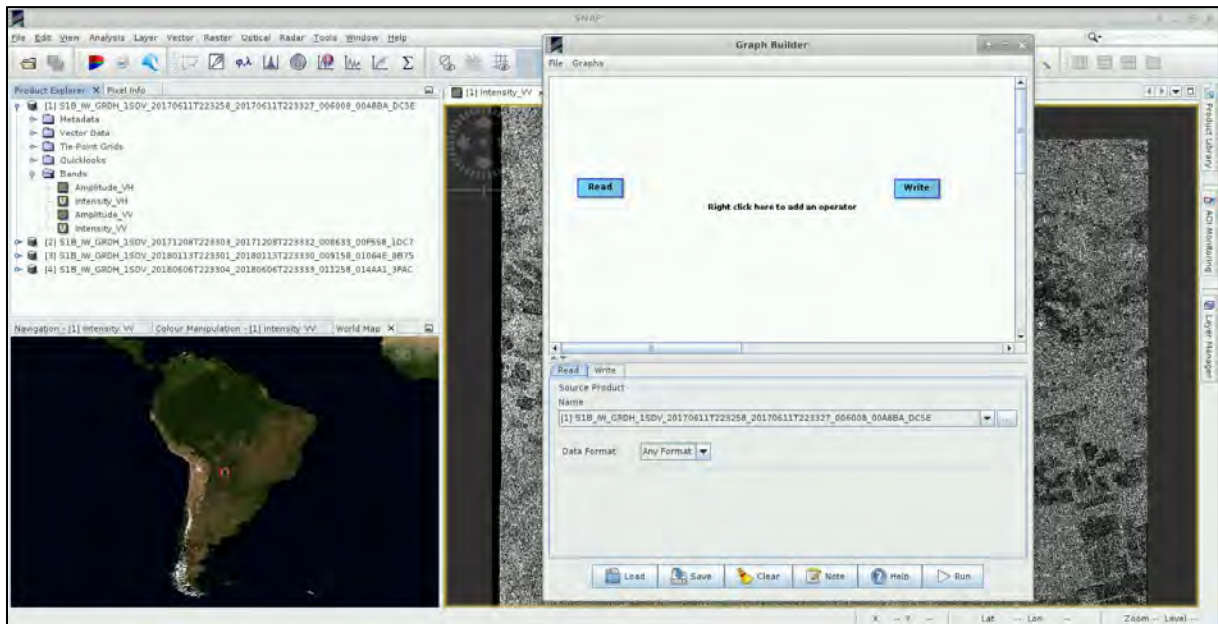
Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/Original/*

The opened products will appear in the *Product Explorer*. Click + to expand the contents of the file from June 2017, then expand *Bands* and double click *Intensity_VV* to visualize the band.




Before being able to use the Sentinel-1 products for our application, we need to apply identical pre-processing steps to all our scenes. However, processing the data step by step and product by product would be time consuming and inconvenient. Luckily, we can use the *Graph Builder* tool available in SNAP to create a chain containing all the pre-processing steps we need to apply. This creates a first level of automatization when dealing with large datasets. In addition, using graphs saves disk space as only the final product is physically created and saved.


To start the process, open a new graph file by going to *Tools -> GraphBuilder*



Now, the graph only has two operators: *Read* (to read the input) and *Write* (to write the output). Right-clicking on the top panel, you can add an operator while a corresponding tab is created and added on the bottom panel. To avoid confusion, delete the *Write* operator (*right click* on it-> *Delete*)

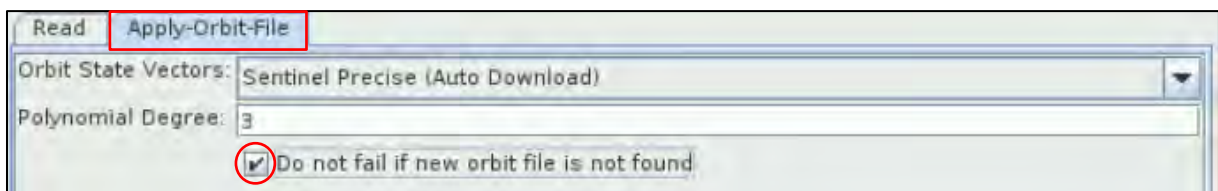
6.3.1 Apply Orbit File

First, we will update the orbit metadata of the Sentinel-1 products (See  NOTE 4). To add the operator, right-click the white space between existing operators and go to *Add -> Radar -> Apply-Orbit-File*. Connect the new *Apply-Orbit-File* operator with the *Read* operator.


 NOTE 4: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product. The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated. (*SNAP Help*)

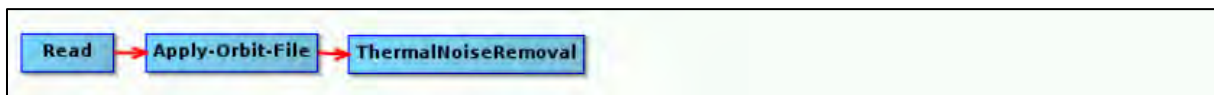


In the corresponding tab, select the option *Do not fail if new orbit is not found*. In case precise orbits are not found, restituted orbit files will be used.



6.3.2 Thermal Noise Removal

The next step will remove the thermal noise (See  NOTE 5). Add the operator by right-clicking on the white area and go to *Add -> Radar -> Radiometric -> ThermalNoiseRemoval*. Connect the *ThermalNoiseRemoval* operator with the *Apply-Orbit-File* operator. In the corresponding tab, leave the default parameters.

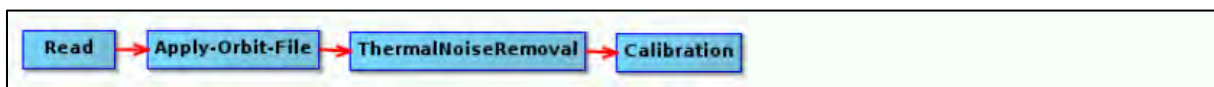


NOTE 5: Thermal noise in SAR imagery is the background energy that is generated by the receiver itself. (SNAP Help) It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates. Level-1 products provide a noise LUT for each measurement dataset, provided in linear power, which can be used to remove the noise from the product.

6.3.3 Calibration

Now, we can add the *Calibration* operator. The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the RADAR backscatter. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data (See NOTE 6). To add the operator go to *Add -> Radar -> Radiometric -> Calibration*. Connect the *ThermalNoiseRemoval* operator to the *Calibration* operator. In the corresponding tab, leave the default parameters.

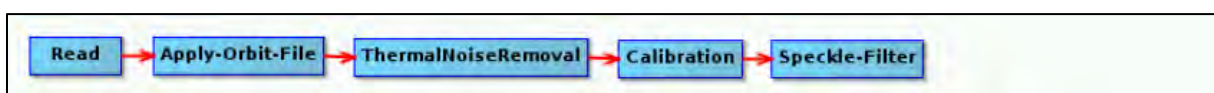
NOTE 6: Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison of SAR images acquired with different sensors, or acquired from the same sensor but at different times, in different modes, or processed by different processors. (SNAP Help)



6.3.4 Speckle Filtering

SAR images have inherent salt and pepper like texturing called speckles which degrade the quality of effect and smooth the image we apply speckle filter (See NOTE 7). To add the operator, go to *Radar -> Speckle Filtering -> Speckle-Filter* then connect the *Calibration* operator to it. In the corresponding tab, leave the default parameters.

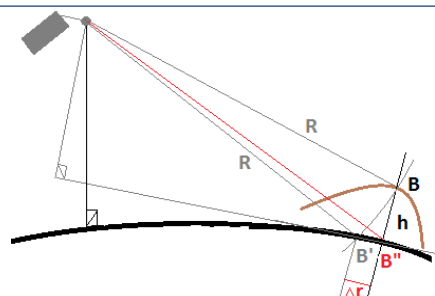
NOTE 7: Speckle is caused by random constructive and destructive interference of the de-phased but coherent return waves scattered by the elementary scatters within each resolution cell. Speckle noise reduction can be applied either by spatial filtering or multilook processing. (SNAP Help)



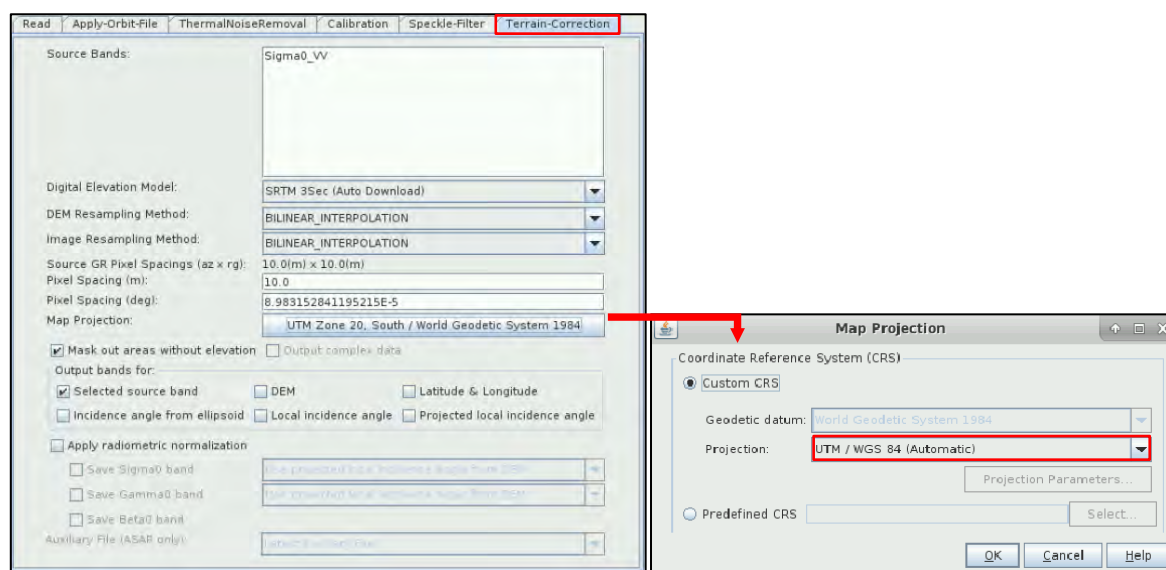
6.3.5 Terrain Correction

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. Therefore, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See NOTE 8). To add the operator, go to *Radar -> Geometric -> Terrain Correction -> Terrain-Correction* then connect the *Speckle-Filter* operator to it.

NOTE 8: The geometry of topographical distortions in SAR imagery is shown on the right. Here we can see that point **B** with elevation **h** above the ellipsoid is imaged at position **B'** in SAR image, though its real position is **B''**. The offset Δr between **B'** and **B''** exhibits the effect of topographic distortions. (*SNAP Help*)

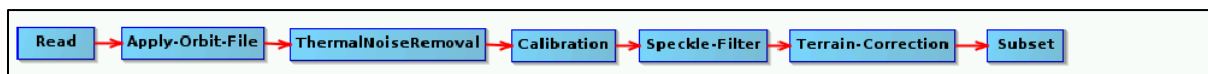


In the corresponding tab, change the map projection to *UTM / WGS 84 (Automatic)*.

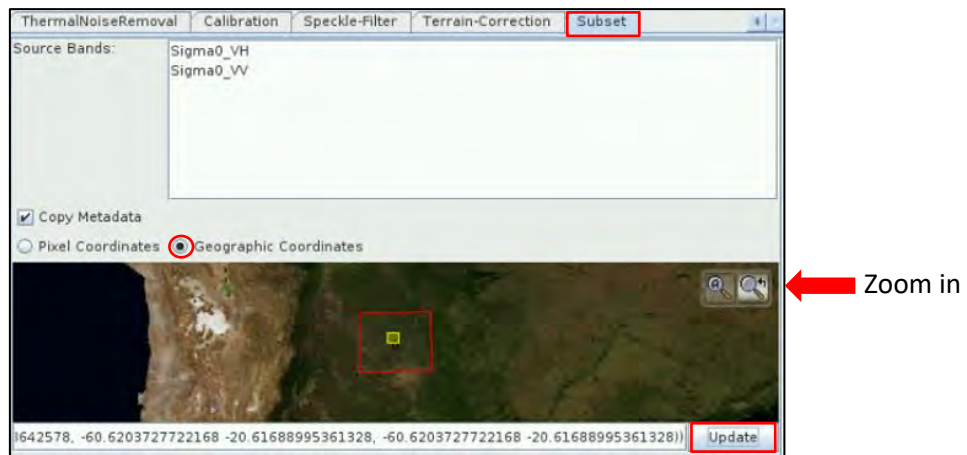


6.3.6 Subset

Since we want to focus the analysis on our study area, we add the *Subset* operator to reduce the extent of the final product. To add the operator go to *Add -> Raster -> Geometric -> Subset*. Connect it to the *Terrain-Correction* operator. Select the option *Geographic Coordinates* and paste the following coordinates in Well-Known-Text format. Click *Update* to load the coordinates and Zoom in to the area.

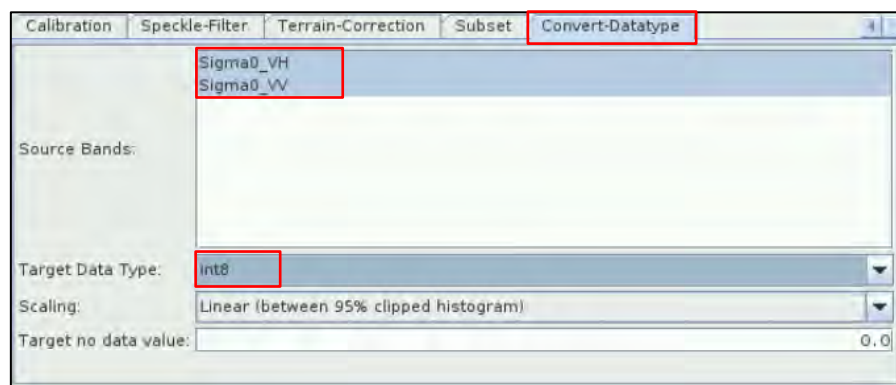


```
POLYGON ((-60.6203727722168 -20.61688995361328, -60.19137191772461 -20.61688995361328, -60.19137191772461 -21.03205108642578, -60.6203727722168 -21.03205108642578, -60.6203727722168 -20.61688995361328, -60.6203727722168 -20.61688995361328))
```



6.3.7 Convert Data Type

Due to software requirements, we need to convert our products to bytes inputs since the GLCM operator that we will use in the next step works with this data type. This step will allow us to have both bands (*Sigma0_VV* and *Sigma0_VH*) in a common scale. To add the operator, go to *Raster -> Data Conversion -> Convert-Datatype*. Connect the *Subset* operator to the *Convert-Datatype* operator. In the corresponding tab, make sure to select *int8* as *Target Data Type*

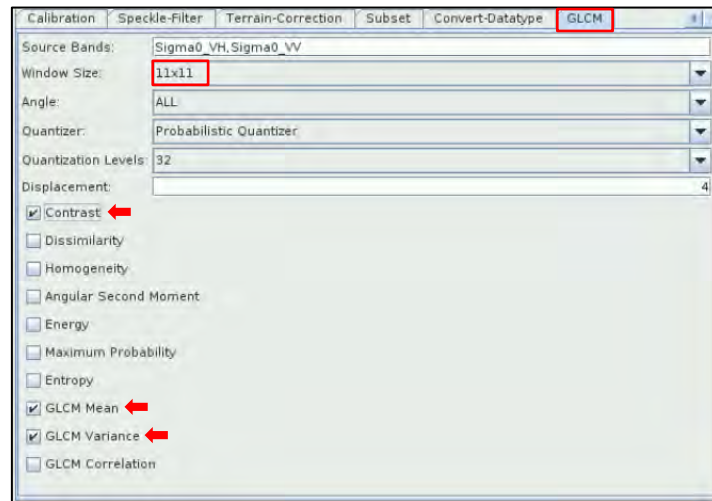
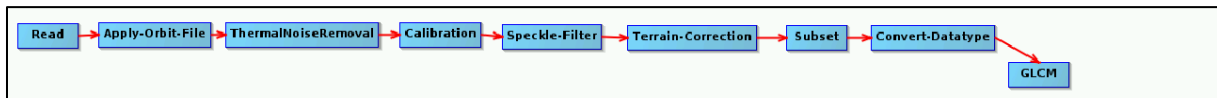


6.3.8 GLCM

To increase the amount of information, we will derive the Grey Level Co-occurrence Matrix (GLCM) (See NOTE 9). To add the operator, go to *Raster -> Image Analysis -> Texture Analysis -> GLCM*. Connect the *GLCM* operator to the *Subset* operator. In the corresponding tab, make sure to select *11x11* as *Window Size* and the following features: *Contrast*, *GLCM Mean*, *GLCM Variance*.

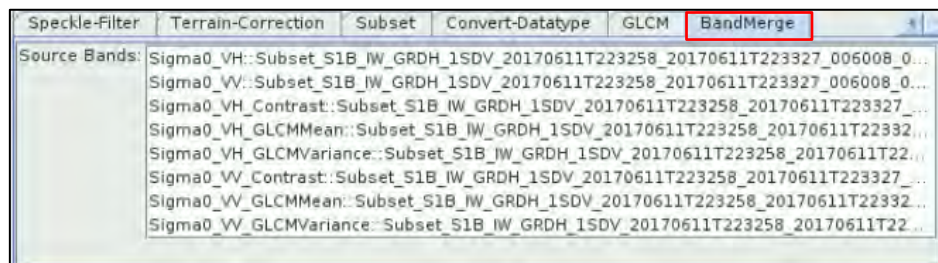
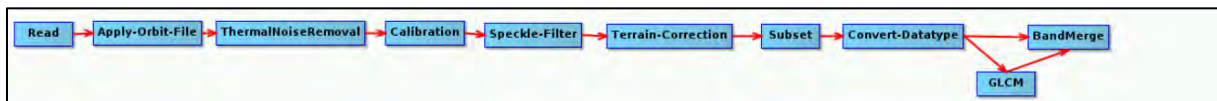
NOTE 9: Spatial information in the form of texture features can be useful for image classification. Texture measures can produce new images by making use of spatial information inherent in the image. It involves the information from neighboring pixels which is important to characterize the identified objects or regions of interest in an image.

The Gray Level Co-occurrence Matrix (GLCM) proposed by Haralik is one of the most widely used methods to compute second order texture measures. Each feature models different properties of the statistical relation of pixels co-occurrence estimated within a given moving window and along predefined directions and inter-pixel distances. The GLCM is a measure of the probability of occurrence of two grey levels separated by a given distance in a given direction (Source: *SNAP Help*)



6.3.9 Band Merge

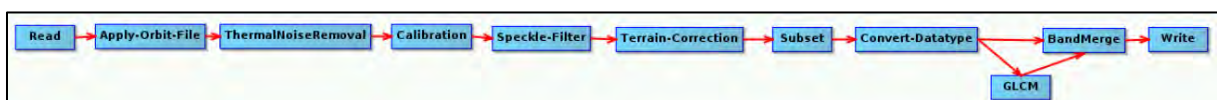
In the last step, we will combine the GLCM features derived in the previous step with the *Sigma0* bands of the Sentinel-1 product. Merging all the bands in the same product will allow us to use them as input in our classification. To add the operator, go to *Raster -> Band Merge*. Connect the *GLCM* and *Convert-Datatype* operators to *Band Merge*. In the corresponding tab, leave the default parameters.



6.3.10 Write

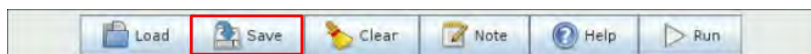
Finally, we need to properly save the output. For that, we first need to add the *Write* operator to our graph. Right click and navigate to *Add -> Input-Output -> Write*. Connect the *Write* operator to the *BandMerge* operator. In the *Write* tab, leave the default output name and make sure you set the following path as output directory.

Path: `/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/`





Save the graph (Save icon at the bottom of the window) as *S1_Processing.xml* in the following path and close the *Graph Builder* window. DO NOT RUN THE GRAPH YET.




Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/*

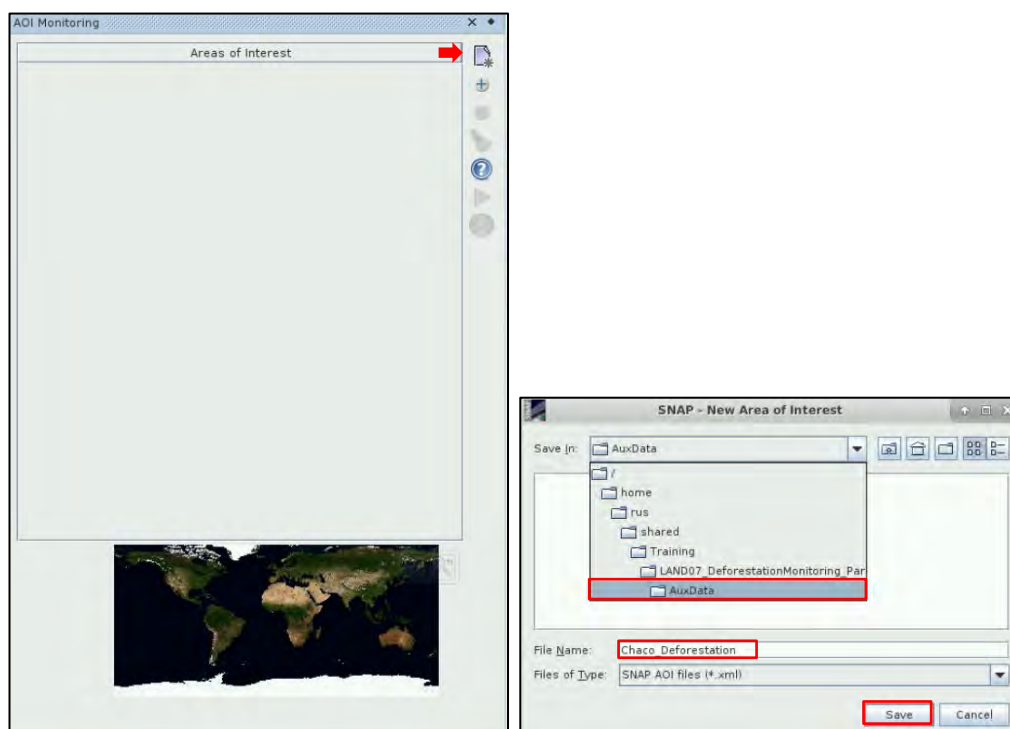
6.4 AOI Monitoring

Deforestation is an evolving process that changes at different time rates and requires continuous monitoring activities. For this reason, in this exercise we will use the *Area Of Interest Monitoring (AOI Monitoring)* functionality of SNAP, which allows to specify, save, and load AOIs to be automatically batch processed using a chain of processing steps defined with the Graph Builder.

Although regular batch processing could be used to pre-process our Sentinel-1 products, this functionally adds a second level of automatization. By using this tool, each time a new image is downloaded and stored in a pre-defined folder of the RUS Virtual Machine, SNAP will automatically detect the product, process it and save the output in a pre-defined output directory ready to be used for post-processing analysis. To start using *AOI Monitoring*, go to *Tools -> AOI Monitoring*.

First, we will create a new AOI. For that, click on the *Create New AOI* icon . In the folder manager, navigate to the following path and name the AOI as *Chaco_Deforestation.xml*.

Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/*





In the *AOI Menu* window that appears, set the input folder parameter to the directory where the original Sentinel-1 products are stored (see Path1). Set the output directory to the folder where the results will be saved (See Path2). Specify the path to the graph that will be used to analyse the input images (See Path3).

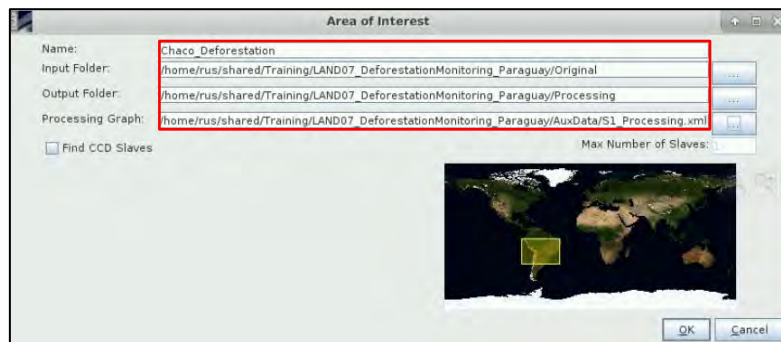
Path1 → `/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Original/`


Path2 → `/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/`

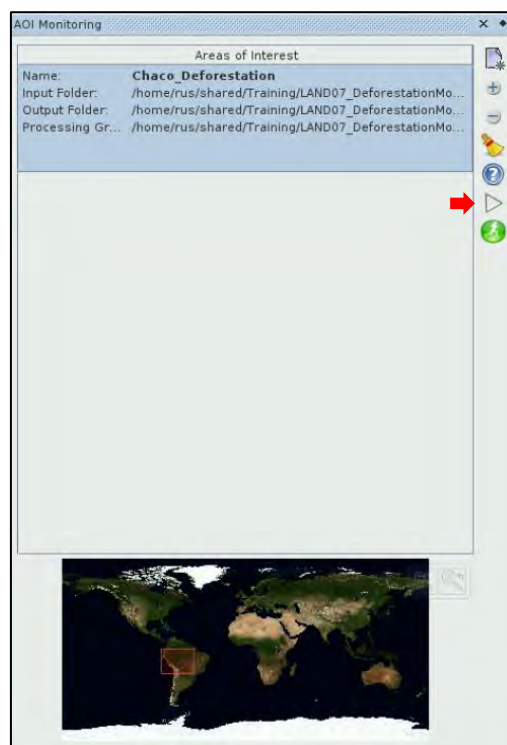
Path3 → `/shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/S1_Processing.xml`

In the bottom part of the *AOI Menu*, a world map is shown to geographically locate our AOI by drawing a polygon. Specify the AOI by drawing a rectangle over South America in the world map. (See  NOTE 10). Click *Ok*.

 NOTE 10: It is not necessary to locate our study area precisely in the world map. This step will only identify the Sentinel products that overlap with the area and are candidate to be analyzed by the pre-defined processing chain. If no rectangle is drawn, then the entire globe is the AOI.

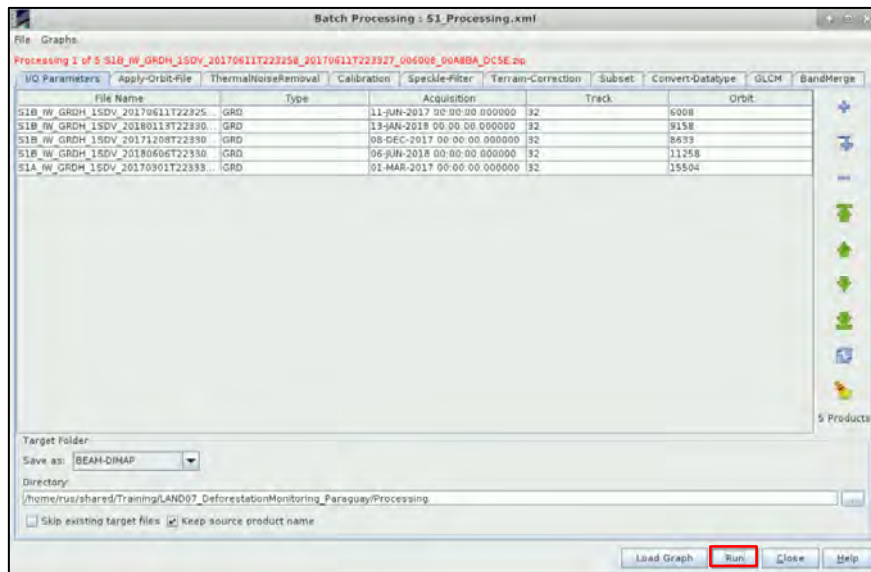



Once the AOI is defined, it will appear in the list. To start processing our Sentinel-1 products, select the AOI and click on the *Process selected AOI* button .



The *AOI Monitoring* tool will start the search for products in the AOI in the input folder. The "Batch Processing" window will open in few seconds populated with the search results. Products that have already been processed will be excluded from the search results. If there are no products inside the AOI or they have all been processed, a warning message will pop up.

Since the products that will be detected will be loaded randomly, use the *Move up* and *Move down* arrows to put them in the desired order, from the oldest to the most recent and click *Run* to start batch processing. Wait until the process is completed, close the *Batch Processing* window and close (right click on the product -> *Close Product*) the 4 original Sentinel-1 products from the *Product Explorer*.




To start monitoring our AOI, click the *Begin Monitoring all AOI folders* button  (it will turn red and become the *Stop monitoring AOIs* button). When a new product in any of the AOI folders is found to be covered in whole or partially by the AOI, that AOI will be queued for batch processing. To test this capability, move the Sentinel-1 product located in Path1 (see below) to Path2 (see below).

Path1 → /shared/Training/LAND07_DeforestationMonitoring_Paraguay/New_S1_images/

Path2 → /shared/Training/LAND07_DeforestationMonitoring_Paraguay/Original/

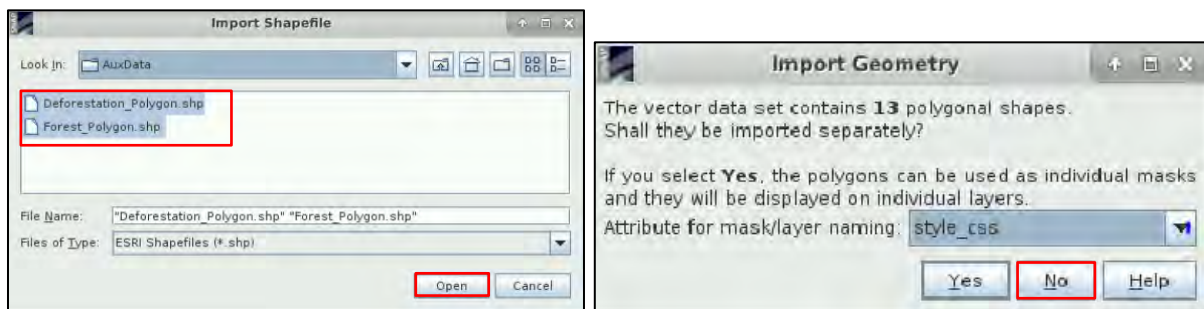
Since *AOI Monitoring* is active, SNAP will automatically detect this product and start to process it with the pre-defined graph (a new batch processing window will appear and start running). Wait until the process is finished and then click the red *Stop monitoring AOIs* button to stop the monitoring (it will turn back to green).

6.5 Random Forest Classification

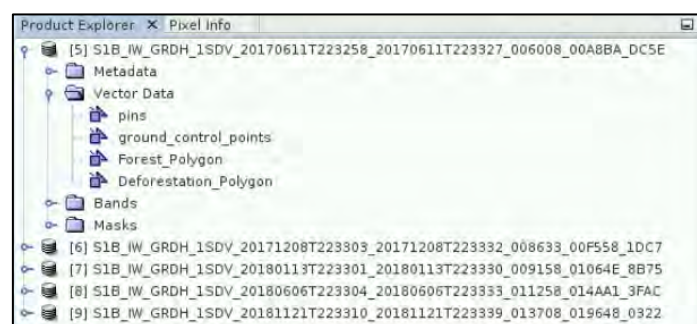
In this exercise, we will use the Random Forest classification algorithm (See  NOTE 11) to distinguish forest and non-forest areas in each Sentinel-1 product individually. Since we will run a supervised classification, we need to import our training data which have been created in advance.

To import them, select the first Sentinel-1 pre-processed product in the *Product Explorer* window (2017-06-11), go to *Vector -> Import -> ESRI Shapefile*, navigate to the following path, select the *Forest_Polygon.shp* and *Deforestation_Polygon.shp* shapefiles and click *Open*. In the pop-up window, select *No*.

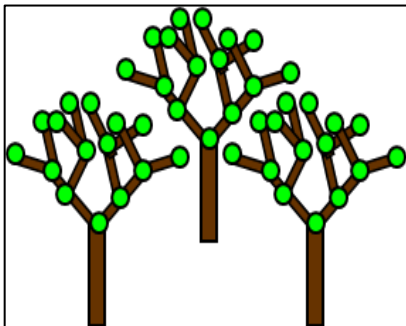
Path → /shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/



Save the product (*Right click on the product -> Save product*). The *Vector Data* folder of the product contains now the shapefiles that have been imported and should look like this. Repeat the same procedure for the 4 remaining products and remember to save them afterwards.



To start the classification procedure, click on *Raster -> Classification -> Supervised Classification -> Random Forest Classifier*.




NOTE 11: The Random Forest algorithm is a machine learning technique that can be used for classification or regression. In opposition to parametric classifiers (e.g. Maximum Likelihood), a machine learning approach does not start with a data model but instead learns the relationship between the training and the response dataset. The Random Forest classifier is an aggregated model, which means it uses the output from different models (trees) to calculate the response variable.

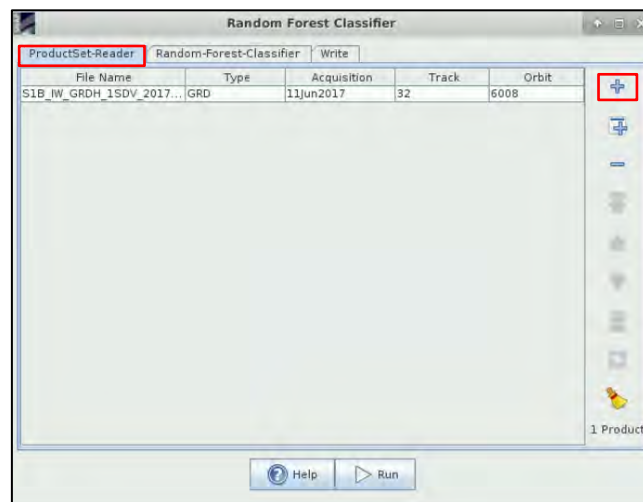
Decision trees are predictive models that recursively split a dataset into regions by using a set of binary rules to calculate a target value for classification or regression purposes. Given a training set with n number of samples and m number of variables, a random subset of samples n is selected with replacement (bagging approach) and used to construct a tree. At each node of the tree, a random selection of variables m is used and, out of these variables, only the one providing the best split is used to create two sub-nodes.

By combining trees, the forest is created. Each pixel of a satellite image is classified by all the trees of the forest, producing as many classifications as number of trees. Each tree votes for a class membership and then, the class with the maximum number of votes is selected as the final class.

More information about Random Forest can be found in Breiman, 2001.

In the *ProductSet-Reader* tab, click on the  symbol. Navigate to the following path and select the pre-processed image from 20170611.

Path: /shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/

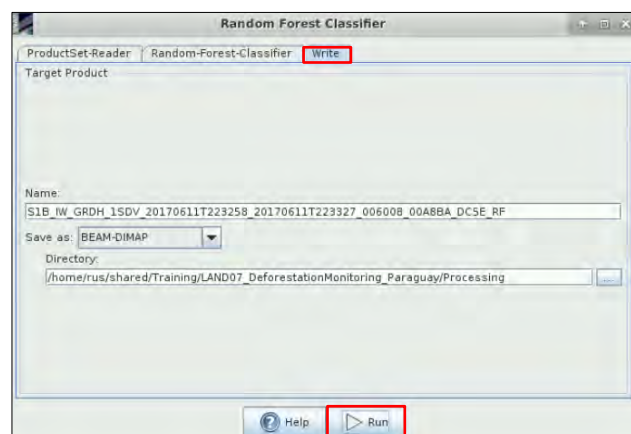
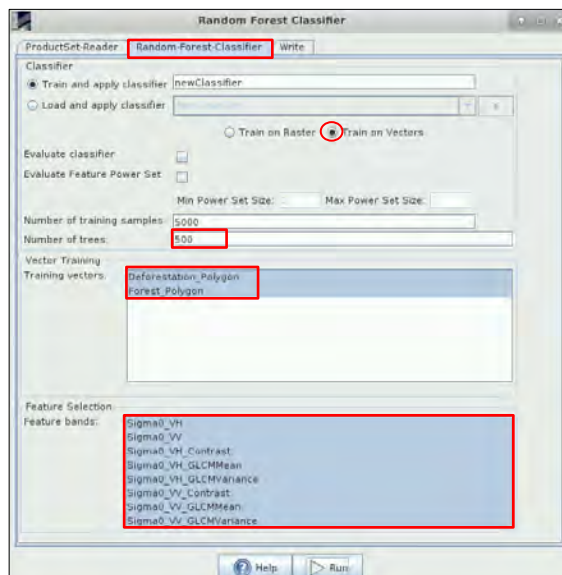


Move to the *Random-Forest-Classifer* tab and set the following parameters:

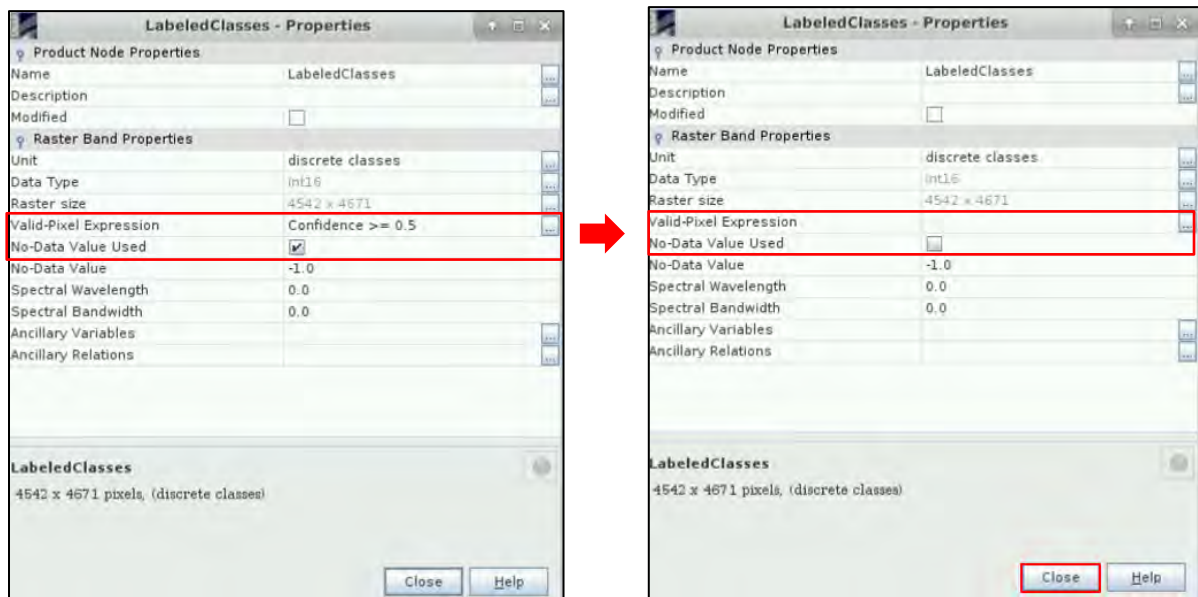
- Check the option *Train and apply classifier*
- Uncheck the Evaluate classifier option
- Set the number of trees to 500
- Select all the shapefiles as training vectors
- Select all the bands as feature bands

Click now on the *Write* tab, set the Output folder to the following path and leave the default name. The, click *Run*.

Path: /shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/

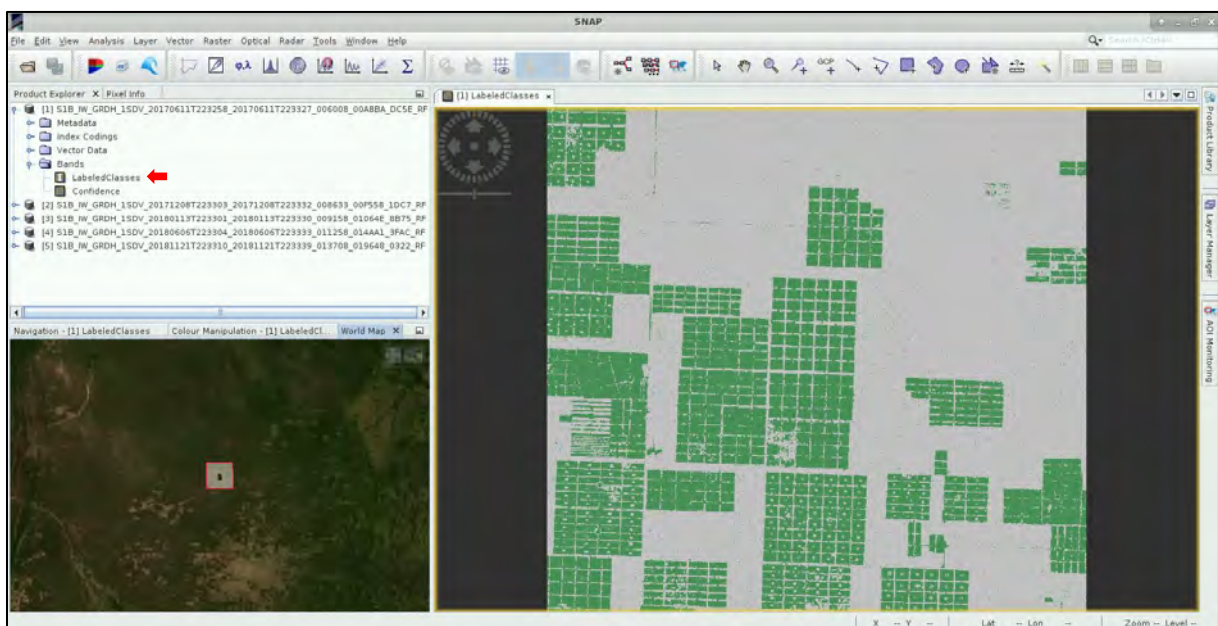


Once the product is created, expand the *Bands* folder, right click on the band *LabelledClasses*, uncheck the option *No-Data Value Used* and delete the *Valid pixel expression*. Then, click *Close* and save the product (*Right click on the product -> Save Product*).



To visualize the result, double click on *LabelledClasses* band. You can change the colours by clicking on the *Colour Manipulation* tab located in the lower left corner or by clicking on *View -> Tool Windows -> Colour manipulation*. Repeat the classification procedure with the remaining images (20171208, 20180113, 20180606, 20181121).

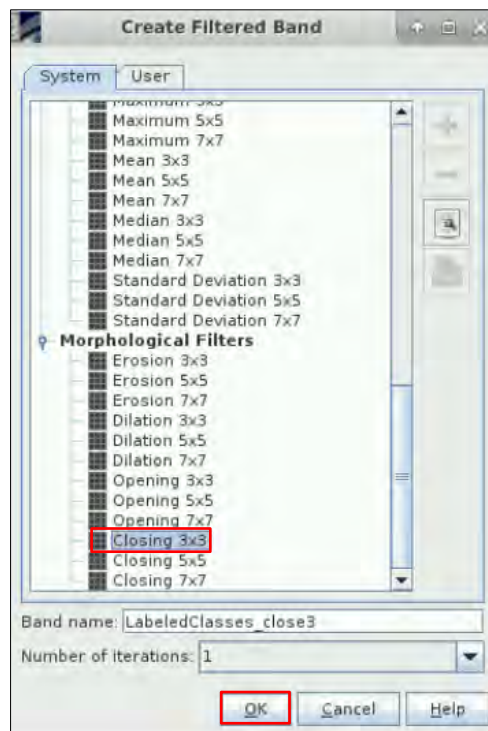
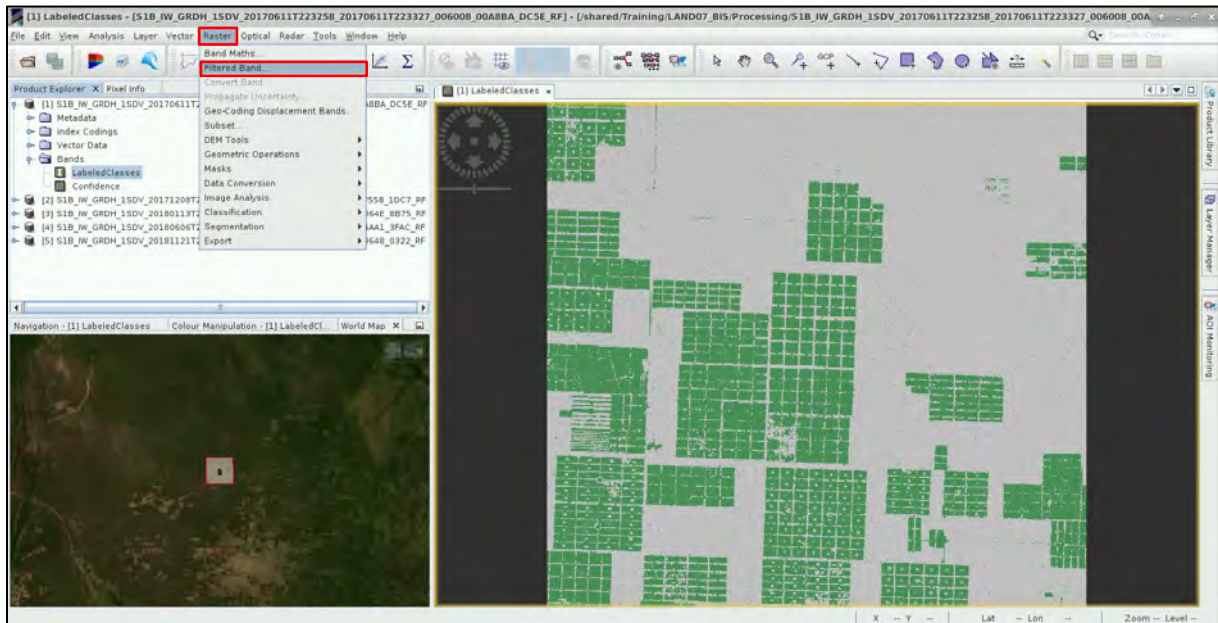
Once finished, close the 5 pre-processed Sentinel-1 images (indexes [5] – [9]) and leave only the classified products (indexes [10] – [14]).



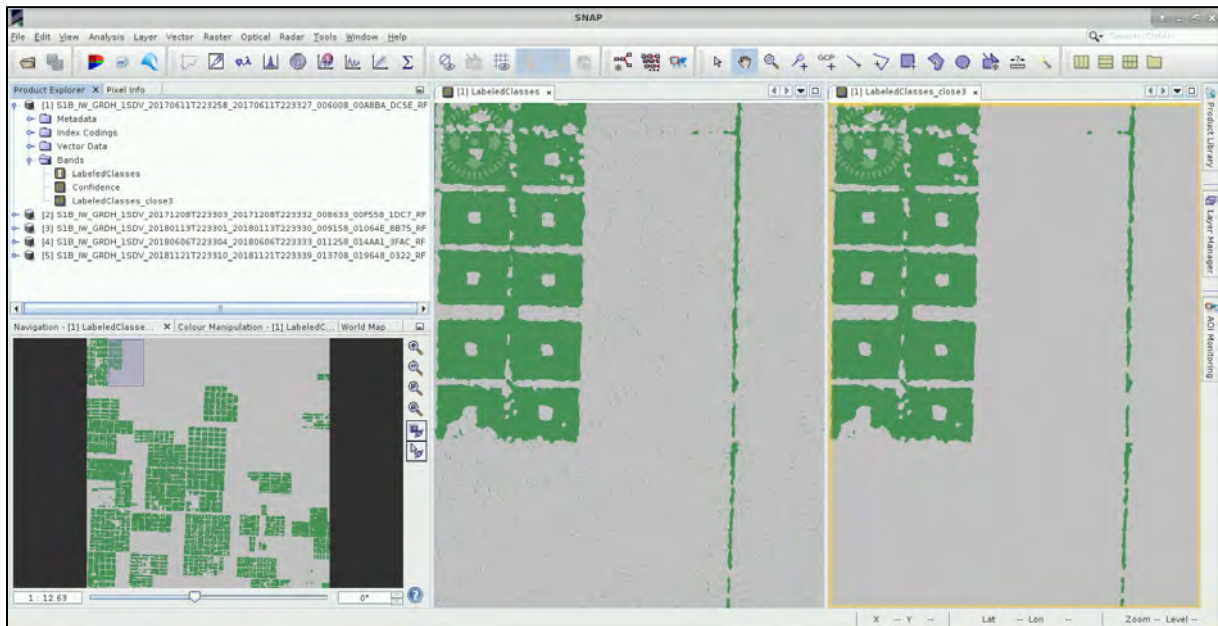
7 Post-processing

Since we are using a SAR sensor as input for our classification, the inherent speckle noise of the original data is still present in our results. In this occasion, we will use a morphological filter known as closing (Dilation + Erosion) to clean our dataset. Expand the first classified product (20170611), open the *Bands* folder and select the *LabelledClasses* band. Then, go to *Raster -> Filtered Band*. In the

System tab go down to the *Morphological filters*. Select *Closing 3x3*, keep the *Band name* as default and click *Ok*.

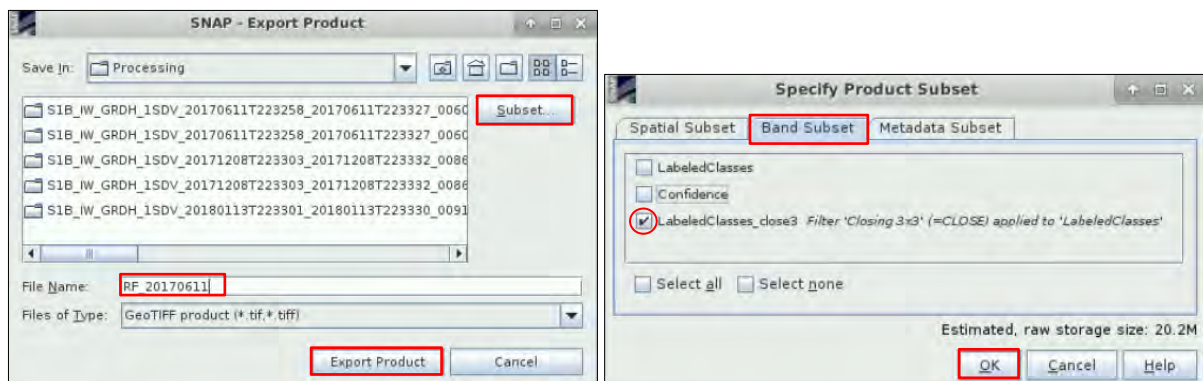


Expand the first classified product and go to the *Bands* folder. Open the *LabelledClasses* and *LabelledClasses_close3* and go to *Windows -> Tile Horizontally* to visualize them at the same time.



Select the first product (20170611) and click on *File -> Export -> GeoTIFF*. Navigate to the following path and set the name to RF_ + dates (e.g. *RF_20170611*). In the *Export Product* window, click on *Subset -> Band Subset*. Select only the band *LabeledClasses_close3*. Then, click *Ok* and *Export Product*.

Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/*



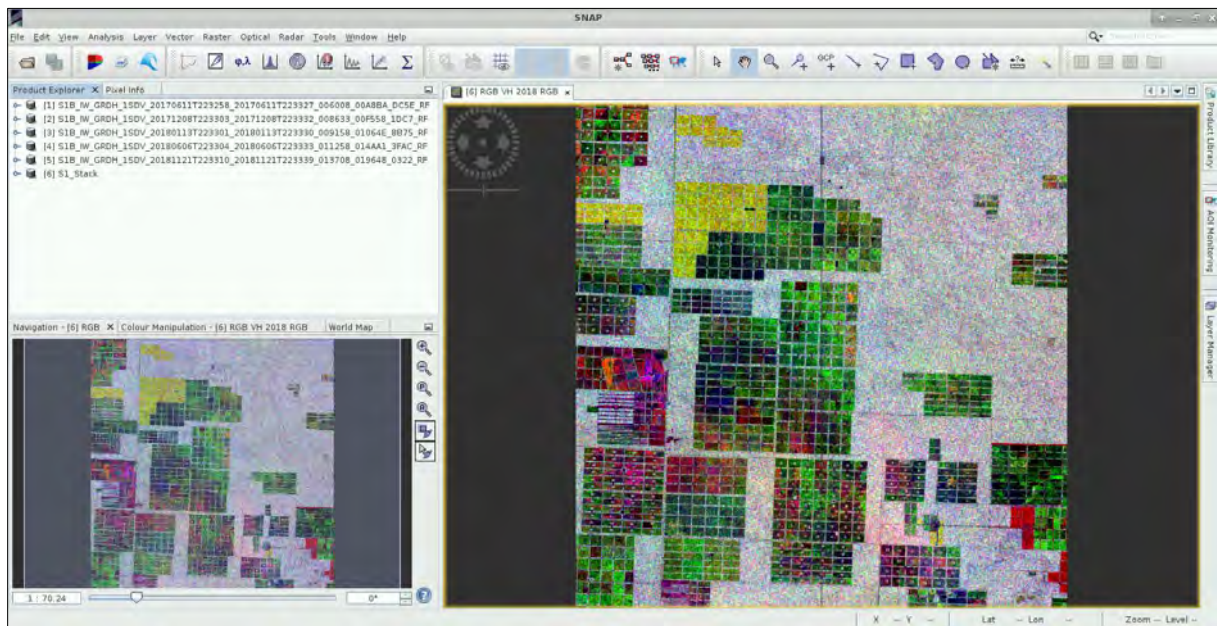
Repeat the complete procedure for the remaining products (20171208, 20180113, 20180606, 20181121) and named them *RF_20171208*, *RF_20180113*, *RF_20180606* and *RF_20181121*.

8 Multi-temporal RGB

A different way of analysing the evolution of deforestation is to create multi-temporal RGB compositions. For this, a raster stack containing all relevant bands (*Sigma0_VV* and *Sigma0_VH*) has to be created. However, our Sentinel-1 pre-processed data contain also the texture bands we used in the classification. To solve this issue, a graph that selects the appropriate bands from each product and then stack them together was used. For convenience, the product is already created. Go to *File -> Open Product* navigate to the following path and open the product *S1_Stack.dim*

Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/*

Right click on the product and select *Open RGB Image Window*. Choose the temporal profile you prefer to visualize the deforestation evolution. The image below shows the following composition:
Red: Sigma0_VH_20180113 | **Blue:** Sigma0_VH_20180606 | **Green:** Sigma0_VH_20181121

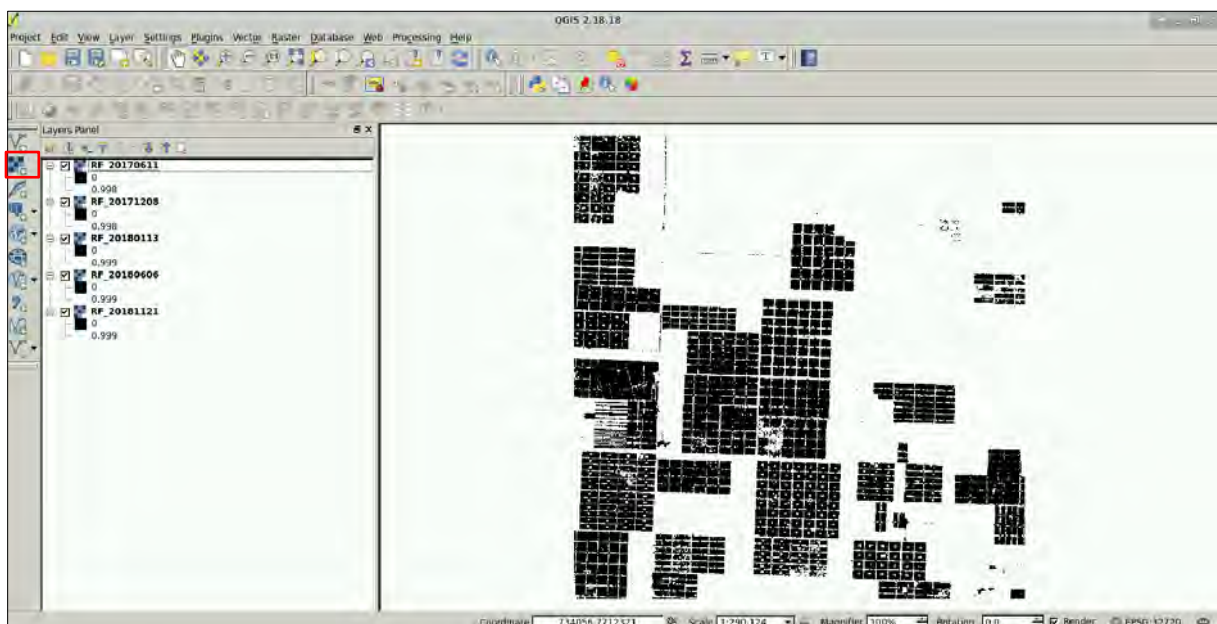


9 QGIS Visualization

Finally, we will visualize the evolution of the deforested area in QGIS. Minimize SNAP and open QGIS (*Applications -> Processing -> QGIS Desktop*). Click on the *Add Raster Layer* button located in the left panel (🗎), navigate to the following path, open the five GeoTIFF files we just created in the previous step and click *Open*. Make sure they are displayed in chronological order (most recent down).

Path: `/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/`


The classification product is open as a *singleband gray* raster file. To change the visualization, right click on the first layer (2017-06-11) file and select *Properties*.



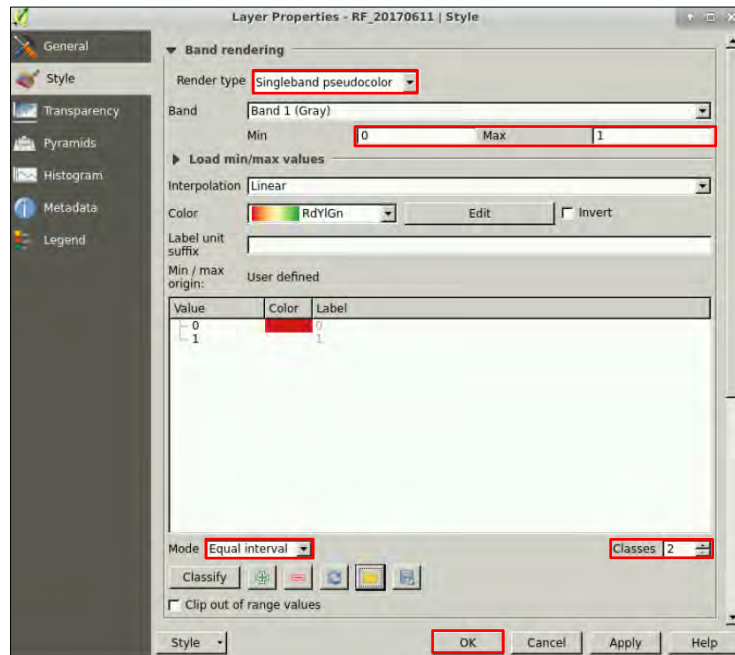
Select the *Style* tab on the left panel and choose the following parameters:

Render type: Singleband pseudocolor **Mode:** Equal Interval

Classes: 2 **Min / Max:** 0 / 1

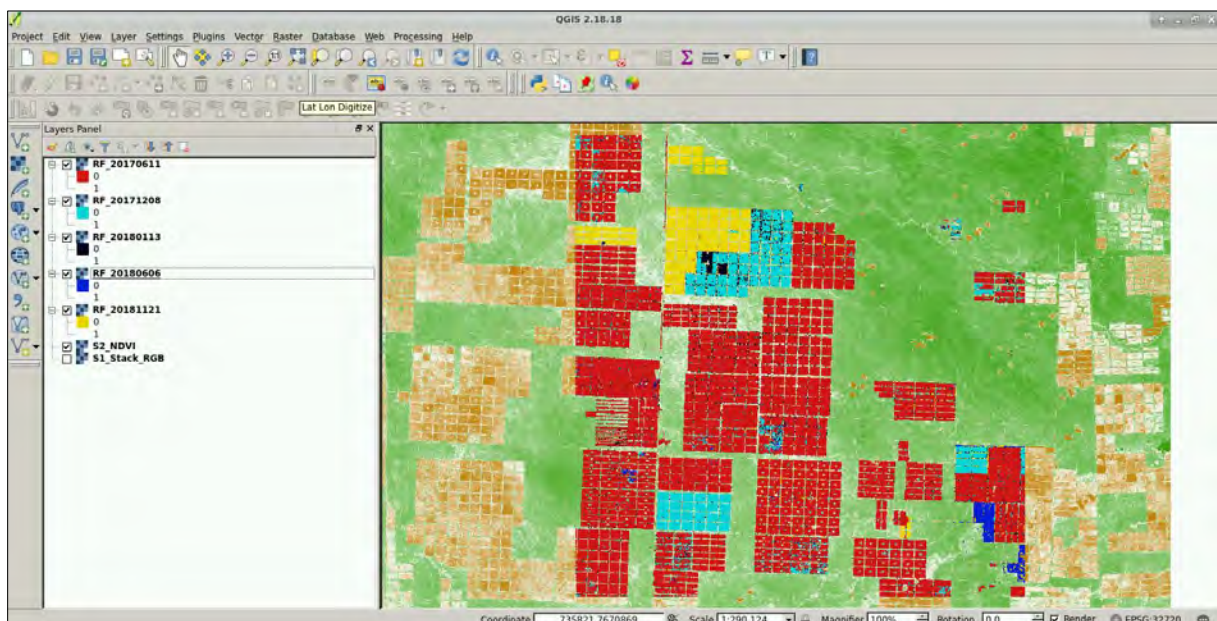
Press *Classify*. You can choose your own colors or use a predefined color palette. Press the *Load Color Map* icon (), navigate to the following path, select *Color_QGIS_1.txt* and click OK.


Path: */shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/*

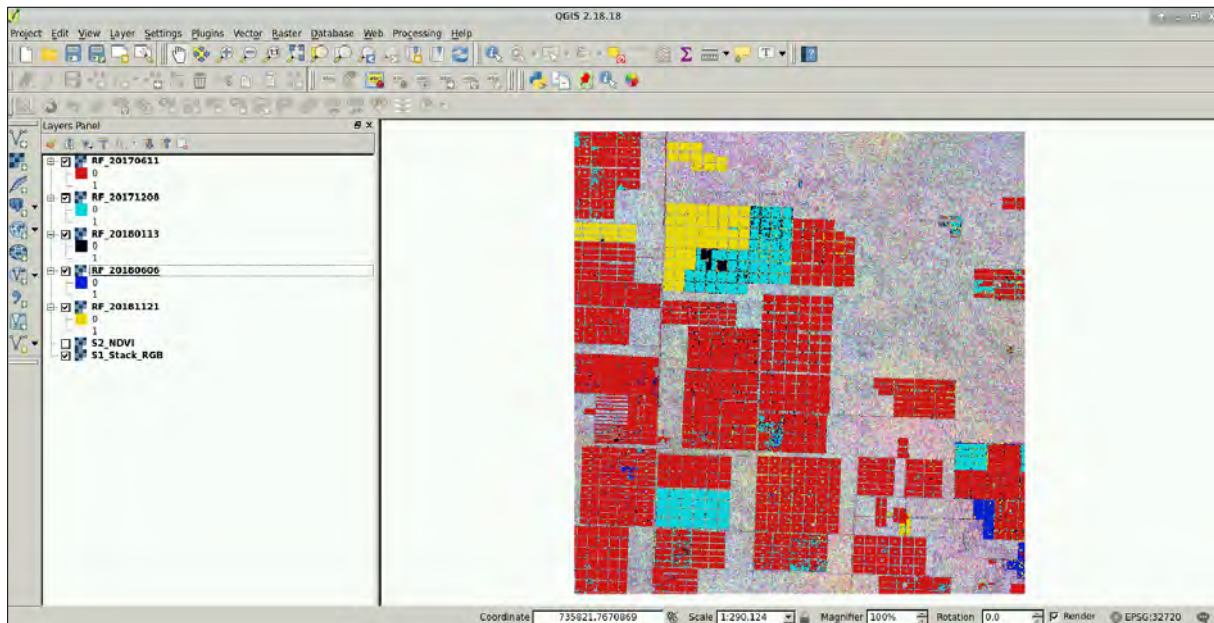


For the remaining images, repeat the same procedure and open the following color palettes respectively. *Color_QGIS_2.txt*, *Color_QGIS_3.txt*, *Color_QGIS_4.txt*, *Color_QGIS_5.txt*

Finally, load the raster *S2_NDVI.tiff* and *S1_Stack_RGB.tiff* to add a basemap layer. (See  NOTE 12).



 **NOTE 12:** In this example, value 0 refers to the forest area and value 1 to the deforested area. Check to which category the values correspond in the Color Manipulation tab in SNAP. In case they are inverted during your classification, the colors will appear inverted here as well. (e.g. the forest area in the first image will be white instead of red).



THANK YOU FOR FOLLOWING THE EXERCISE!

10 Further reading and resources

[Sentinel-1 User Guide](#)

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar>

[Sentinel-1 Technical Guide](#)

<https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar>

Breiman, L. (2001). Random Forests. Machine Learning, 45, 5–32, 45(1), 5–32.

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