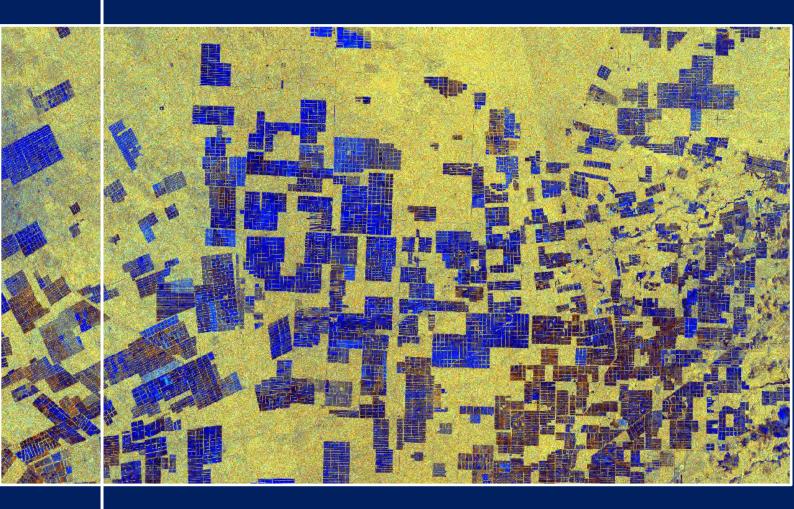


COPER RUS Opermicus



TRAINING KIT – LAND07

DEFORESTATION MONITORING WITH SENTINEL-1 Case Study: Paraguay, 2018









Research and User Support for Sentinel Core Products

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Authors would be glad to receive your feedback or suggestions and to know how this material was used. Please, contact us on training@rus-copernicus.eu

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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 Preprocessed data stored locally

@/shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/

3.2 Software in RUS environment

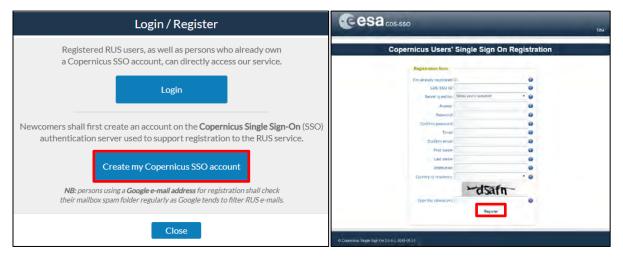
Internet browser, SNAP + S1 Toolbox

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 (<u>www.rus-copernicus.eu</u>) and click on *Login/Register* in the upper right corner.

CORRUS Research and User Support	
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Senth
	News from RUS
	One year on!
	Copernicus Info Session - Reykjavik - 19 September 2018
To a series of the series of t	SPIE Remote Sensing 2018 – Berlin (Germany) – 11-12 September 2018
	SIWI World Water Week 2018 – Stockholm – 26-31 August 2018
	MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018
	RUS Webinar – Special edition "AskRUS – Sentinel-1" – 12 July 2018
Welcome to Research and User Support	RUS Training Session – Valencia – 22 July 2018
	IGARSS 2018 - Valencia - 22-27 July 2018
Welcome to the Copernicus Research and User Support (RUS) Service portal!	The RUS agenda
The RUS Service is the "New Expert Service for Sentinel Users" funded by the European Commission,	Conferences & Workshops

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 email to activate your account.

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

Credentials			
CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close Login Reset	Y Y	0000
	CDS-SSO ID Password Max Idle Time	CDS-SSO ID Password Max Idle Time half a day Max Session Time Until browser close	CDS-SSO ID Password Max Idle Time half a day Max Session Time Until browser close

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

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The RUS Service . The RUS C	Do you want t	o subscribe for a new RUS account?	Í		
	Your ESA-SSO subscription	data:		We write the same is the interview	
+ Your RUS service	Login		- 1	9.	
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 Your dashboard: allows you to ac- 	Organization	1000		est - 23 a (22 Nov. 2018	
· Your training silows you to rops	Country			g Pressurcharry Workshop - Washe	
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	Please complete the followi			ation Shivesk - Francish - 17-18 Way	
	Where did you hear about the RUS service?	outreach event colleagues	~		
	Select one or more items	newsletter	- 1	imm - Paland - 6. 9 10 & 17 Nov 2010	
		conference social media		tran - Toujouse - 26% 27 Oct. 2018	
		other		1	
	Institution type Phone number	Select one item	~	nda.	
	Italy (IT):	+39		skskere ·	
	Title	Select one item	~		
				w 16 13	
		Subscribe Cancel			
Inspection in 2 17 Summer in and down Support			Christin	Trentandesistence (Distance Frequet # 1/2	

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* \rightarrow *Your Dashboard*.

CORRUS Research and User Support	~9 # %	Hello, Miguel
The RUS Service The RUS Offer The RUS Library The RUS C	Community Vigit Your RUS serv Vour profile Vour dashboard Vour training	You are here: Home > Your RUS service
 This section gathers pages related to your RUS services: Your profile: displays your personal information linked to your ESA SSO a Your dashboard: Illows you to access your private dashboard, Your training: allows you to register to a training session you have been in 	and RUS accounts,	 News from RUS One year on! Copernicus Info Session - Reykjavik - 19 September 2018 SPIE Remote Sensing 2018 - Berlin (Germany) - 11-12 September 2018 SIWI World Water Week 2018 - Stockholm - 26-31 August 2018 MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018 RUS Webinar - Special edition "AskRUS - Sentinel-1" - 12 July 2018
		RUS Training Session - Valencia - 22 July 2018 IGARSS 2018 - Valencia - 22-27 July 2018

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.

CORRUS 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
Copyright © 2017 Research and User Support	Contact Us Terms and conditions Glossary Acronyms FAQ

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

Step 1/3 Your experience	
Please help us learn more abo information will be stored in you	out your background by answering a few questions. I Ir User Profile.
How many years of experience in R	temote Sensing do you have?
Choose one Item	
Have you already downloaded Cop	ernicus data via the Copernicus Open access hubs?
Yes	
© No	
Have you already handled/processe	ed Copernicus data?
III Yes	
© No	
Do you wish to practice a tutorial e (hold down CTRL key for multiple s	xercise shown in a RUS webinar? If yes, please select your choice selections).
HAZA01 - Flood Mapping in Malav	
HAZA02 - Burned Area Mapping in HYDR01 - Water Bodies Mapping	
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyp	
OCEA01 - Ship Detection in Gulf o	of Trieste
If you wish to request another tuto	rial exercise that doesn't appear in the above list, please type he
	n request multiple tutorial exercises.

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

This is a collection of information selected					
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?	1				
Handled/processed Copernicus data?	4				
Webinar codes	HAZA02, LAND04				
About your RUS project:					
Thematicarea	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	1				
	S1-Product 1				
S1 - Product type	GRD				
S1 - Sensor mode	-				
S1 - Polarisation S1 - Orbit direction	1				
Sentinel-2	x				
Sentinel-3	x				
Other	x				
I don't know	x				
Region of Interest:	8				
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					

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* \rightarrow *Your Dashboard* and click on *Access my Virtual Machine*.

							You are here: Home >	Your RUS service > Your dash
Your dashboard								
Request a new L	Jser Servi	ce						Chat with Support Desk
Project Name	ID	Date of submission	Status		Actions		Virtual	Environment
	1.50	-		Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
RUS_training1	231	2017-08-31	Open		Get a webinar kit	Rate my service	Freeze my Virtual Machine(s)	Report a technical incident

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.

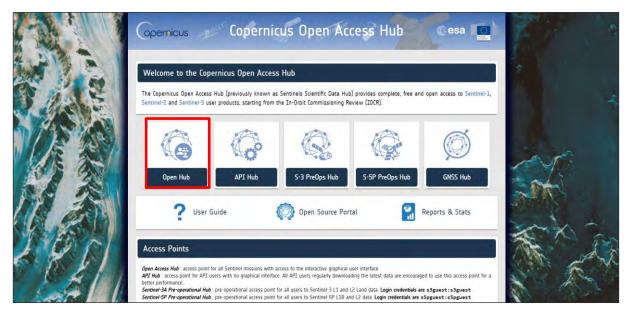
S Applications				
Alu System Redex	Schweiding.	00 389	R	SNAP
Home Decementation		BIAT GU	Lusylar-	Alonsevend
duree Tradi				
CORUS				
opernicus				

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.

esa opernicus	Copernicus Op	en Access Hub	
	Register ne	ew account	
	Sentinel data access is free and open to all.		
	On completion of the registration form below you will receive an e-mail with a link to valida Usemame field accepts only alphanumeric characters plus " " " " " " and "."	te your e-mail address. Following this you can start to download the data.	_
	Firstisame.	Lasiname	
	Usemame		
	Parasword	Confirm Password	
	£-ma)	Comme E-trail	
	Select Domain		
	Select Usage		
	Select Country .		
	2		
	By registering in this website you are deemed	to have accepted the T&C for Sentinei data use.	
			REGISTER

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
	2017-06-11	S1B_IW_GRDH_1SDV_20170611T223258_20170611T223327_006008_00A8BA_DC5E
	2017-12-08	S1B_IW_GRDH_1SDV_20171208T223303_20171208T223332_008633_00F558_1DC7
Sentinel-1B	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 \square 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: <u>https://aria2.github.io/</u>

The *products.meta4* file containing the links to the Sentinel-1 products to be downloaded can be created following the methodology explained in \square 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/

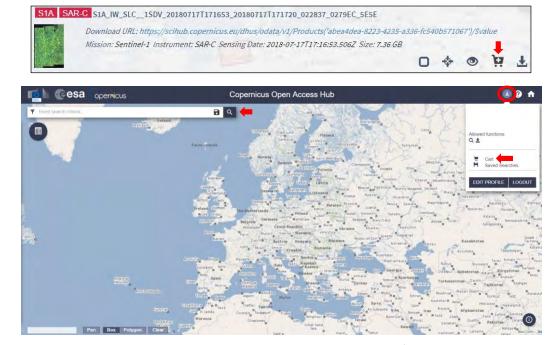
Before using the downloading manager and the .meta4 file, let's test if *aria2* is properly installed in the Virtual Machine. To do this, open the Command Line (in the bottom of your desktop window) type the following command and press *Enter*.

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).



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 - **W**. 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 explanied 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).

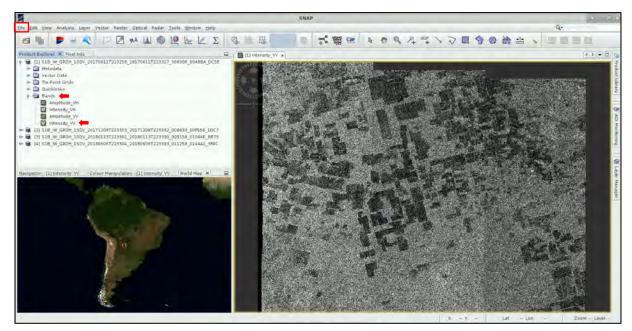
Path: /shared/Training/LAND07_DeforestationMonitoring_Paraguay/New_S1_images/

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 preprocessing 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

Be Ede Yew Analysis Layer Vector Raster Gotical Radar Todio Window Help S S P S T P P S T P P P S S T P P S S S S	Graph Builder	Q.
	File Graphy	NEED .
Product Explane: Next Info P [1] 1150.w. GOPL_350V_201705117223526_201706117223327_006006_00488A_DC5E Image: State St	Read Bight click have to add an operator	Andre Lawy
heyspton-(1) messay W Solver Hersolden -(1) intensity W World Hap X C	Feed Write Source Product: Hane [11] S1B_M_CR6H_ISDV_2017/65117223258_001706117723327_06600B_00A88A_DC5E Data Format Data Format Any Format	

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*)

Read		ile
------	--	-----

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.

Read Apply-Or	bit-File	
Orbit State Vectors	Sentinel Precise (Auto Download)	*
Polynomial Degree	3	
	Do not fail if new orbit file is not found	

6.3.2 Thermal Noise Removal

The next step will remove the thermal noise (See NOTE 5). Add the operator by right-cliking 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.

Read Apply-Orbit-File - ThermalNoiseRemoval

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 \frown 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.

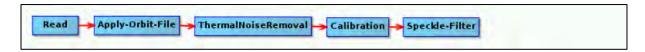
NOTE 6: Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison 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 \square 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.

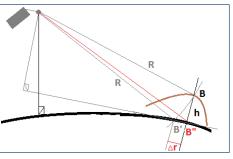
NOTE 7: Speckle is caused by random constructive and destructive interference of the de-phased but coherent return waves scattered by the elementary scatters within each resolution cell. Speckle noise reduction can be applied either by spatial filtering or multilook processing. (*SNAP Help*)



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 INOTE 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).

Source Bands:	Sigma0_VV		
Digital Elevation Model:	SRTM 3Sec (Auto Download)	-	
EM Resampling Method:	BILINEAR_INTERPOLATION	-	
mage Resampling Method:	BILINEAR INTERPOLATION	-	
ource GR Pixel Spacings (az × rg):	10.0(m) × 10.0(m)		
ixel Spacing (m):	10.0		
ixel Spacing (deg):	8.983152841195215E-5		
lap Projection:	UTM Zone 20, South / World Geodetic System 19	984	👙 🚽 Map Projection 🔶
Mask out areas without elevation Output bands for:	n 🗌 Output complex data		Coordinate Reference System (CRS)
Selected source band	DEM Latitude & Longitude		Custom CRS
Incidence angle from ellipsoid	Local incidence angle 🔲 Projected local incidence	angle	Geodetic datum: World Geodetic System 1984
Apply radiometric normalization			Projection: UTM / WGS 84 (Automatic)
Save Sigma0 band	the process of the inclusion in the Province	-	
Save Gamma0 band	The second of the second second second second second	-	Projection Parameters
Save Betat bann			Predefined CRS Select.
Auxiliary File (ASAR only)	and the first first		

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.

Read Apply-Orbit-File ThermalNoiseRemoval 🛶 Calibration 🛶 Speckle-Filter 🛶 Terrain-Correction Subset

```
POLYGON ((-60.6203727722168 -20.61688995361328, -60.19137191772461 -20.6168
8995361328, -60.19137191772461 -21.03205108642578, -60.6203727722168 -21.03
205108642578, -60.6203727722168 -20.61688995361328, -60.6203727722168 -20.6
1688995361328))
```

ThermalNoiseRemov	al Calibration	Speckle-Filter	Terrain-Correction	Subset	4 -	
Source Bands:	Sigma0_VH Sigma0_VV					
Copy Metadata	●Geographic C	oordinates			0.01	Zoom in
	and the			2		200111
3642578, -60.6203727	722168 -20.61688	3995361328, -60.	6203727722168 -20.6	1688995361328)) Update	

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*

Calibration Spec	kle-Filter Ten	rain-Correction	Subset	Convert-Datatype	4
	Sigma0_VH Sigma0_VV				
	Sigina v				
Source Bands:					
Target Data Type:	int8				-
Target Data Type: Scaling:	10000	en 95% clipped	histogram)		+

6.3.8 GLCM

To increase the amount of information, we will derive the Grey Level Co-occurrence Matrix (GLCM) (See \square 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*)

Calibration Spec	kle-Filter Terrain-Correction Subset Convert-Datatype GLCM	
Source Bands:	Sigma0 VH, Sigma0 W	
Window Size:	11×11	-
Angle:	ALL	-
Quantizer:	Probabilistic Quantizer	-
Quantization Levels	32	-
Displacement:		4
Contrast		
Dissimilarity		
Homogeneity		
Angular Second	Moment	
Energy		
🔲 Maximum Proba	bility	
Entropy		
🗹 GLCM Mean 🗲		
GLCM Variance	🛏	
GLCM Correlatio	n	

6.3.9 Band Merge

In the last step, we will combine the GLCM features derived in the previous step with the *SigmaO* 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.

Speckle-Filter	Terrain-Correction	Subset	Convert-Datatype	GLCM	BandMerge	
	Sigma0_VV:Subset_S: Sigma0_VH_Contrast: Sigma0_VH_GLCMMear Sigma0_VH_GLCMVaria Sigma0_VV_Contrast: Sigma0_VV_GLCMMear Sigma0_VV_GLCMMear	Subset_S1 n::Subset_S ance::Subs Subset_S1 n::Subset_S1	B W GRDH 15DV 20 S1B W GRDH 15DV et S1B W GRDH 15D B W GRDH 15DV 20	0170611T2 20170611 DV_20170 170611T2 20170611	223258_20170611T2 T223258_20170611 611T223258_2017061 23258_20170611T2 T223258_20170611T2	23327 T22332 611T22 23327 T22332

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/

Read Apply-Orbit-File ThermalNoiseRemoval Calibration Speckle-Filter Terrain-Correction Subset Convert-Datatype BandMerge Write
GLCM

Speckle-Filter	Terrain-Correction	Subset	Convert-Datatype	GLCM	BandMerge	Write	- 4
Target Product						_	
Name:							
Subset_S1B_N	GRDH_1SDV_20170	511T223258	3_20170611T223327_	006008_0	DASBA_DCSE_	Orb_NR_Ca	al_Spk
Save as: BEAM	1-DIMAP						
Directory:							
-	abarad (Training (LAN)	07 Defores	stationMonitoring Par	anuav/Pro	careina		1

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.

						_
Load	Save	Clear	Note	🕐 Help	D Run	

Path: /shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/

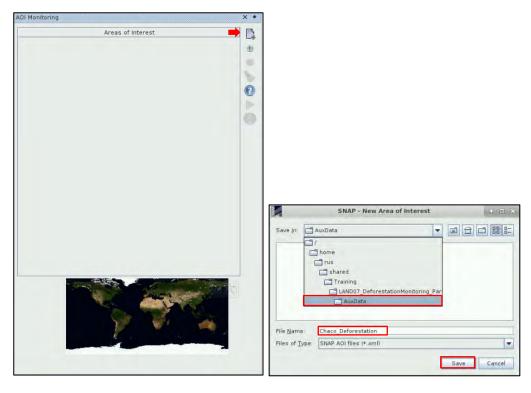
6.4 AOI Monitoring

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).

 $Path1 \rightarrow / shared / Training / LAND07 _ Defore station Monitoring _ Paraguay / Original /$

Path2 \rightarrow /shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/

 $Path3 \rightarrow / shared / Training / LAND07 _ Defore station Monitoring _ Paraguay / AuxData / S1 _ Processing.xml$

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 predefined processing chain. If no rectangle is drawn, then the entire globe is the AOI.

	Area of Interest	• = ×
Name:	Chaco_Deforestation	
Input Folder:	/home/rus/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Original	1222
Output Folder:	/home/rus/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing	1.042
Processing Graph:	/home/rus/shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/S1_Processing.xml	
Find CCD Slaves		Gancel

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 $\boxed{\square}$.



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*.

8	5.	atch Process	ing : 51 Process	ing.xi	ml .				
ile Graphs									
rockssing 1 of 5 S18_IW_GRDH_1SDV	201706117223258 2011	06117223927		CSE DO					
	ThermalNoiseRemoval					Subset	Convert-Dataty	e GLCM	BandMerge
File Name	Type		Acquisition			Track		Orbit	
518 W_GRDH_15DV_20170611T22325			N-2017 DC-00-00 00		32		6008		+
518_NV_GRDH_15DV_20180113T22330			N-2018 00.00.00.00		92		9158		_
518 W GRDH_15DV_20171208722330			C-2017 00 00 00 0				8633		
518_W_GRDH_15DV_20180606T22330			N-2018 00:00:00.00				11258		
51A_W_GRDH_15DV_20170301T22333	GRD	01-MA	AR-2017 00:00:00.0	00000	32		15504		
									Ŧ
									-
									-
									63
									5 Produc
Target Folder									
Save as: BEAN-DIMAP									
Directory									
/home/rus/shared/Training/LAND07_D	eforestationMonitoring_	Paraguay/Proc	essing.						
🛄 Skip existing target files 😿 Keep	source product name								
				-		1.1	and Graph	Run C	ose Help

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).

 $\texttt{Path1} \rightarrow / \textit{shared/Training/LAND07} _ Defore station \textit{Monitoring} _ \textit{Paraguay/New} _ \texttt{S1}_ \textit{images/}$

$\texttt{Path1} \rightarrow / \textit{shared/Training/LAND07} _ Defore station Monitoring_Paraguay/Original/$

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

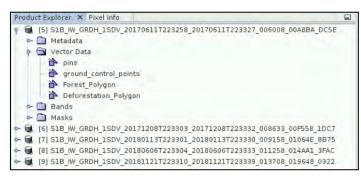
In this exercise, we will use the Random Forest classification algorithm (See NOTE 11) to distinguish forest and non-forest areas in each Sentinel-1 product individually. Since we will run a supervised classification, we need to import our training data which have been created in advance.

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*.

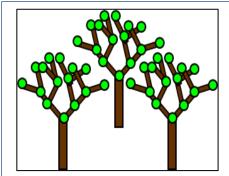
Path \rightarrow /shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/



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.

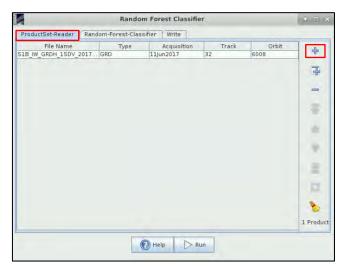
Decision trees are predictive models that recursively split a dataset into regions by using a set of binary rules to calculate a target value for classification or regression purposes. Given a training set with n number of samples and m number of variables, a random subset of samples n is selected with 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-Classifier 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/

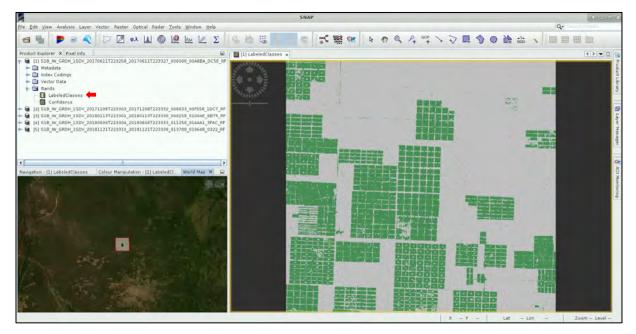
	Random Forest Classifier	1 H H		
ProductSet-Reader	Random-Forest-Classifier Write			
Classifier				
Train and apply i	Jassifier newClassifier			
C Load and apply s	lassifier	(Ŧ) 8		
	C Train on Raster Train on Vectors			
Evaluate classifier			Reading Provide Classifier	
Evaluate Feature Pos	wer Set		Random Forest Classifier	+ B X
	Min Power Set Size: Max Power Set Size.		ProductSet-Reader Random-Forest-Classifier Write	
Number of training s			Target Product	
Number of trees.	500		Provide and the second s	
Vector Training				
	Deforestation_Polygon			
2000	Forest_Polygon			
			Name:	
			S1B_IW_GRDH_1SDV_20170611T223258_20170611T223327_006008_00A8BA_DC5E_RF	
			Save as: BEAM-DIMAP	
Feature Selection			Directory.	
	Sigma0_VH		/home/rus/shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing	
	5lgma0_W			
	Sigma0_VH_Contrast Sigma0_VH_GLCMMean			
	SigmaD_VH_GLCMVariance			
	Sigma0_VV_Contrast Sigma0_VV_GLCMMean			
	Sigma0_VV_GLCMVariance			
-				
-	Help Run		💽 Help D Run	

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*).

LabeledClas	ises - Properties	* = *		LabeledClasses	- Properties	* • *
Product Node Properties			9 Product Node	Properties		
Name	LabeledClasses		Name		LabeledClasses	
Description		100	Description			144
Modified			Modified			
9 Raster Band Properties			Raster Band F	Properties		
Unit	discrete classes		Unit		discrete classes	100
Data Type	Ini16	and a	Data Type		(nt16	
Raster size	4542 × 4671		Raster size		4542 × 4671	H-
Valid-Pixel Expression	Confidence >= 0.5		Valid-Pixel Expres	ssion		
No-Data Value Used	V		No-Data Value Us	sed		
No-Data Value	-1.0		No-Data Value		-1.0	
Spectral Wavelength	0.0		Spectral Wavelen	igth	0.0	
Spectral Bandwidth	0.0		Spectral Bandwid		0.0	
Ancillary Variables			Ancillary Variable	S		
Ancillary Relations		100	Ancillary Relation	5		
LabeledClasses		0	LabeledClasse	5		
4542 x 4671 pixels, (discrete clas	seg)		4542 x 4671 pix	els, (discrete classes)		
	Close	Help			Clos	ie <u>H</u> elp

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).

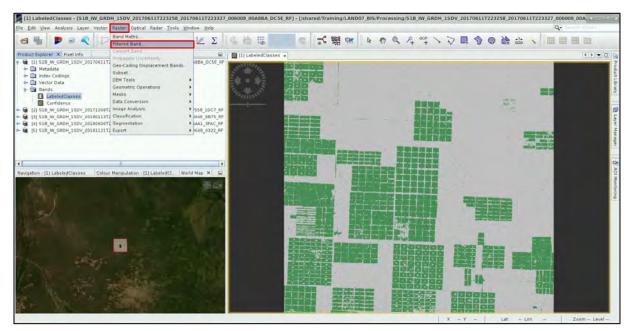
Once finished, close the 5 pre-processed Sentinel-1 images (indexes [5] - [9]) and leave only the classified products (indexes [10] - [14]).



7 Post-processing

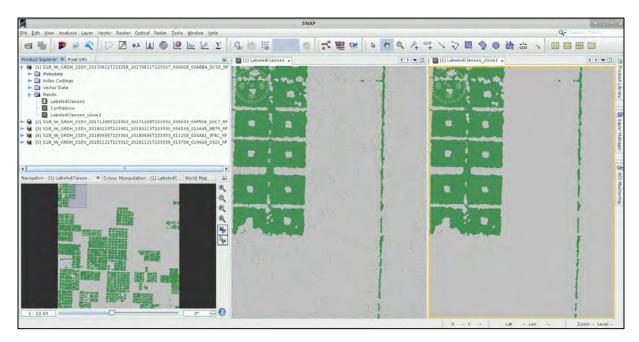
Since we are using a SAR sensor as input for our classification, the inherent speckle noise of the original data is still present in our results. In this occasion, we will use a morphological filter known as closing (Dilation + Erosion) to clean our dataset. Expand the first classified product (20170611), 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*.



Create Filtered Band	(🕈 🖻
User	
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	1.000
	100
	-
Erosion 7x7	
Dilation 3x3	
Dilation 5x5	
Dilation 7×7	
Opening 3x3	=
Opening 5x5	
Opening 7x7	
Closing 3x3	
Closing 7×7	
	User Maximum 5x5 Maximum 7x7 Mean 3x3 Mean 5x5 Mean 7x7 Median 3x3 Median 3x3 Median 5x5 Median 7x7 Standard Deviation 3x3 Standard Deviation 5x5 Standard Deviation 7x7 phological Filters Erosion 5x5 Erosion 5x5 Erosion 5x5 Erosion 7x7 Dilation 5x5 Dilation 5x5 Dilation 7x7 Opening 5x5 Opening 5x5 Opening 7x7

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 *LabelledClasses_close3*. Then, click *Ok* and *Export Product*.

Path: /shared/Training/LAND07_DeforestationMonitoring_Paraguay/Processing/

2	SNAP - Export Produ	ct	• • ×				
Save In:	Processing	• 66			Specify Pr	oduct Subset	+ @ X
	GRDH_1SDV_20170611T223258_20170 GRDH_1SDV_20170611T223258_20170		<u>S</u> ubset	Spatial Subset	Band Subset	Metadata Subset	
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File <u>N</u> ame:	RF_20170611			Select all	Select none		
Files of Type	GeoTIFF product (* tif,* tiff)		-			Estimated, raw s	torage size: 20.2M
	Exp	ort Product	Cancel			<u>O</u> K <u>C</u> e	ancel <u>H</u> elp

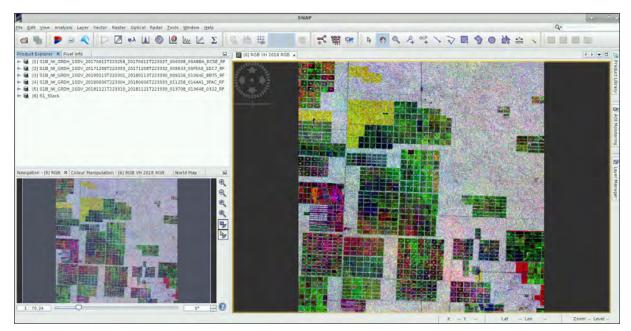
Repeat the complete procedure for the remaining products (20171208, 20180113, 20180606, 20181121) and named them RF_20171208, RF_20180113, RF_20180606 and RF_20181121.

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 (*SigmaO_VV* and *SigmaO_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*

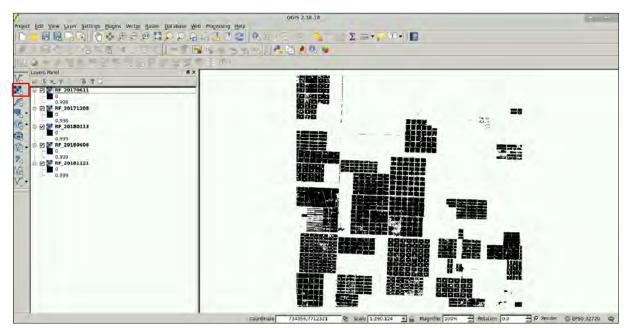


9 QGIS Visualization

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 pseudocolorMode: Equal IntervalClasses: 2Min / Max: 0 / 1

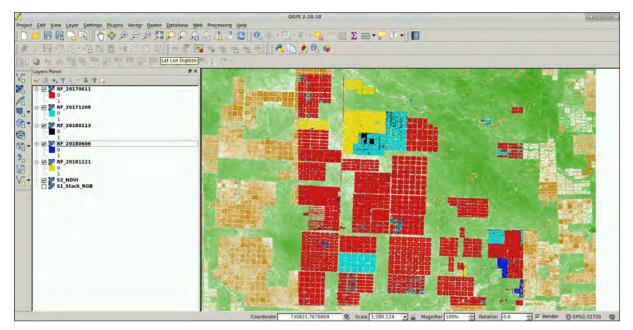
Press *Classify*. You can choose your own colors or use a predefined color palette. Press the *Load Color Map* icon (E), navigate to the following path, select *Color_QGIS_1.txt* and click *OK*.

Path: /shared/Training/LAND07_DeforestationMonitoring_Paraguay/AuxData/

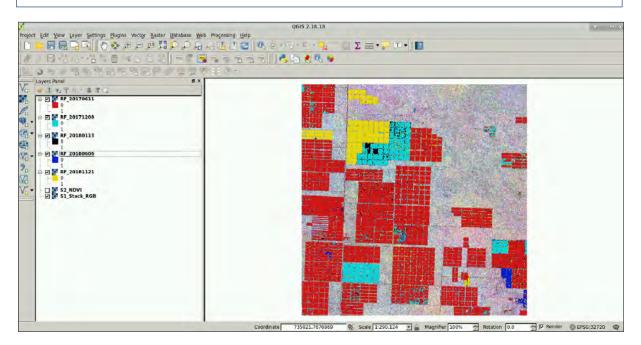
► Load min/ Interpolation [Color [Label unit Suffix [Min / max origin: U	Singleband Band 1 (Gra Min max value Linear	y) 0 YlGn T	Max Edit	1] [" invert	×
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For the remaining images, repeat the same procedure and open the following color palettes respectively. *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 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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