

TRAINING KIT – LAND06

URBAN CLASSIFICATION WITH SENTINEL-1 Case Study: Germany, 2018









Research and User Support for Sentinel Core Products

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The following training material has been prepared by Serco Italia S.p.A. within the RUS Copernicus project.

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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 run a supervised classification using the Random Forest algorithm and Sentinel-1 SLC data as input data over an area in Bochum, Germany.

2 Urban mapping – background



As the world is facing a large increase in population, reliable information on urban areas is required to assist and help in the decision-making process. Different methods can be used to gather this information but satellite earth observation offers a suitable approach based on the coverage and type of data that are provided.

A few years ago, the European Union (EU) started an ambitious program, Copernicus, which includes the launch

of a new family of earth observation satellites known as the Sentinels. Amongst other applications, this new generation of remote sensing satellites will improve the observation, identification, mapping, assessment, and monitoring of urban areas and their dynamics 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 LANDO6. 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

- Sentinel-1A images acquired from April until July 2018 [downloadable at <u>https://scihub.copernicus.eu/</u> using the .meta4 file provided in the Original folder of this exercise]
- Pre-processed data stored locally
 @/shared/Training/LAND06_UrbanClassification_Germany/AuxData/

3.2 Software in RUS environment

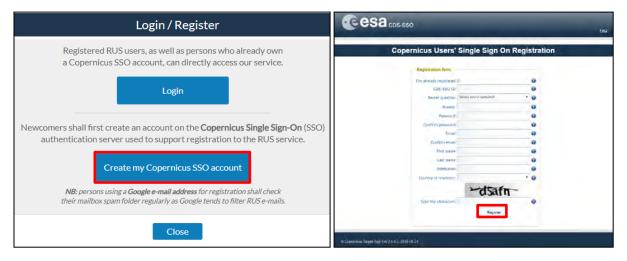
Internet browser, SNAP + S1 Toolbox

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 *	
	Semeli
	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
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.

Login / Register	Credentials			
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 enail sent by the Copernicus vervice. 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	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close Login Reset Eorgot your password?	¥ ¥	00000

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

	RUS Research and Gene User Support			Here Travil 🛔
(m)s n	e RUSService + The RUS C Do you	a want to subscribe for a new RUS acc	ount?	
	Your ESA-SSO sub	scription data:	You are for	ng Hand - Your D. Storten
* Your	RUS service Login			Q
This section	on gathers pages related to ye First Name			
- You	corofile displays your person Last Name	The second se	US	
	Email	and the second se	Est Forirm - Strasb	ourg - 28 & 29 Nov.
- You	dashboard allows you'ld an Organization	and the second s	est-21 & 22 Nov.	ana l
· You	Country Country			njolnop - Prague -
		Additional subscription information		
			vcier Velocity - 8 N	
	Please complete th	e following information:		76 Outobes 2018
	Where did you hear		ation @ week - Fre	stall - 12-16 Nov.
	RUS service? Select one or more h	colleagues tems newsletter	Hum - Pokind - 6.1	10.6.17 Nov. 2018
		conference	itton - Toulouse-	26-5-27 Oct. 2018
		social media other		
	Institution type	- Select one item	🗸 nda	
	Phone number Italy (IT):	+39	prestops	1 Star
	Title	- Select one item	×	

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	\$ 75 I	Helto, Miguel 🔒
	Your RUS service Your profile Your dashboard	You are here: Home > Your RUS service
		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 - Sentinei-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	Helio, Miguel 😩
The RUS Service * The RUS Offer * The RUS Library * The RUS Community * 👯 Your RUS service *	
Your dashboard	You are here: Home > Your RUS service > Your dashboard
Request a new User Service	Chat with Support Desk
Copyright © 2017 Research and User Support	Contact Us Terms and conditions Glossary Actonyms FAQ

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

Please help us learn more about your background by answering a few questions. To information will be stored in your User Profile. How many years of experience in Remote Sensing do you have? Choose one Item Have you already downloaded Copernicus data via the Copernicus Open access hubs? * Yes * Yes * No No Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections). HAZAD01 - Flood Mapping in Malawi HAZAD02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping ver Northern Poland LAND04 - Land Monitoring in Cyprus OCEAD1 - Ship Detection in Guit of Trieste		
Choose one Item Have you already downloaded Copernicus data via the Copernicus Open access hubs? Yes No Have you already handled/processed Copernicus data? Yes No Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections). HAZA01 - Flood Mapping in Malawi HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland LAND01 - Crop Mapping in Seville LAND01 - Land Monitoring in Cyprus		jestions, Ti
Have you already downloaded Copernicus data via the Copernicus Open access hubs? Yes No Have you already handled/processed Copernicus data? Yes No Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections). HAZA01 - Flood Mapping in Malawi HAZA02 - Burned Area Mapping in Portugal HYDR01 - Vater Bodies Mapping over Northern Poland LAND04 - Land Monitoring in Cyprus	How many years of experience in Remote Sensing do you have?	
 Yes No Have you already handled/processed Copernicus data? Yes Yes No Do you wish to practice a tutorial exercise shown in a RU5 webinar? If yes, please select your choice (hold down CTRL key for multiple selections). 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 	Choose one Item	
No Have you already handled/processed Copernicus data? Yes No Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections). 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	Have you already downloaded Copernicus data via the Copernicus Open access hubs?	
Have you already handled/processed Copernicus data? Yes No No Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections). HAZA01 - Flood Mapping in Malawi HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland LANID01 - Crop Mapping in Seville LNND04 - Land Monitoring in Cyprus	• Yes	
Yes No	⊙ No	
No N	Have you already handled/processed Copernicus data?	
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(hold down CTRL key for multiple selections). 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	© No	
HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland LAND01 - Crop Mapping in Seville LAND04 - Land Monitoring in Cyprus		your choice
HYDR01 - Water Bodies Mapping over Northern Poland LAND01 - Crop Mapping in Seville LAND04 - Land Monitoring in Cyprus		
LAND01 - Crop Mapping in Seville LAND04 - Land Monitoring in Cyprus		
OCEA01 - Ship Detection in Gulf of Trieste		
	OCEA01 - Ship Detection in Gulf of Trieste	
	its name or code. Note that you can request multiple tutorial exercises.	
its name or code. Note that you can 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.

'his is a collection of information selected 'ou can go back and edit this information		
General information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data? Handled/processed Copernicus data?	1	
Webinar codes	V HAZA02, LAND04	
About your RUS project:	hazadz, zarody	
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	4	
S1 - Polarisation	a	
S1 - Orbit direction		
Sentinel-2	x	
Sentinel-3	X	
Other	x	
I don't know	×	
Region of Interest: Min Latitude	39,3303	
Max Latitude	40.5877	
Min Longitude	-4.6736	
Max Longitude	-4,6730	
Reference polygons	-2.7203	
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** → **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 Servie	ce						Chat with Support Desk
		Date of						
Project Name	ID	submission	Status		Actions		Virtual	Environment
S		1000		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.



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 .		
	1		
	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 analyze 10 Sentinel-1A images during 2018. The following table shows the date and reference of the images that will be used:

SATELLITE	DATE	IMAGE ID
	2018-04-12	S1A_IW_SLC1SDV_20180412T171648_20180412T171715_021437_024E95_BDA1
	2018-04-24	S1A_IW_SLC1SDV_20180424T171648_20180424T171715_021612_02540A_BB21
	2018-05-06	S1A_IW_SLC1SDV_20180506T171649_20180506T171716_021787_025996_98AB
	2018-05-18	S1A_IW_SLC1SDV_20180518T171649_20180518T171716_021962_025F27_A15C
Sentinel-1A	2018-05-30	S1A_IW_SLC1SDV_20180530T171650_20180530T171717_022137_0264C8_5D94
Sentinel-IA	2018-06-11	S1A_IW_SLC1SDV_20180611T171651_20180611T171718_022312_026A3D_BBFC
	2018-06-23	S1A_IW_SLC1SDV_20180623T171652_20180623T171719_022487_026F7C_450E
	2018-07-05	S1A_IW_SLC1SDV_20180705T171652_20180705T171719_022662_027499_1B8F
	2018-07-17	S1A_IW_SLC1SDV_20180717T171653_20180717T171720_022837_0279EC_5E5E
	2018-07-29	S1A_IW_SLC1SDV_20180729T171654_20180729T171721_023012_027F72_97F6

To improve the data acquisition process, we will use a download manager (See 1 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 \square NOTE 2. Follow the instructions and create your cart file, download it and save it in the following path:

Path: /shared/Training/LAND06_UrbanClassification_Germany/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) and type the following 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 \sim 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 - 🕅. 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. SIA SAR-C S1A_IW_SLC__1SDV_20180717T171653_20180717T171720_022837_0279EC_5E5E Download URL: https://scihub.copernicus.eu/dhus/odata/v1/Products('abea4dea-8223-4235-a336-fc540b571067')/Śvalu Mission: Sentinel-1 Instrument: SAR-C Sensing Date: 2018-07-17T17:16:53.506Z Size: 7.36 GB @esa opernicus Copernicus Open Access Hub **B** Q 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

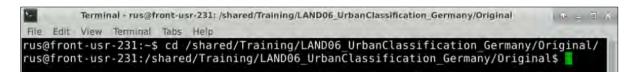
When requested, type:

Once finished, test the installation as explanied before.

γ

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/LAND06_UrbanClassification_Germany/Original/



Next, type the following command (in a single line) to run the download tool. Replace *username* and *password* (keep 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

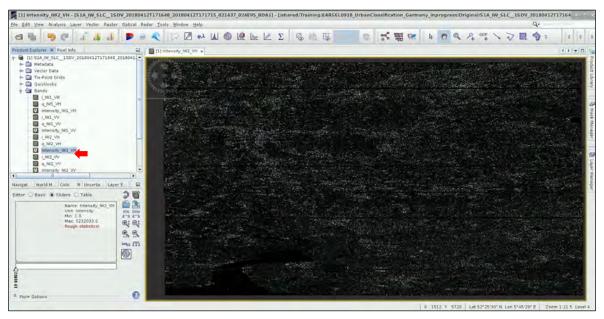
The Sentinel products will be saved in the same path where the *products.meta4* is stored.

6.3 Sentinel-1 SNAP Preprocessing

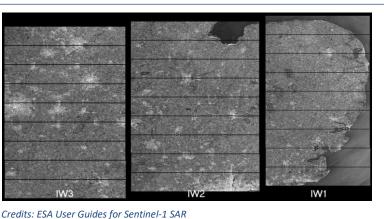
Once the Sentinel-1 images are downloaded, we need to run some pre-processing steps before they can be used for the classification. For this purpose, we will use the SNAP software. In *Applications -> Processing* open **SNAP Desktop**; click **Open product** *(*, navigate to the following path and open the two first S1 images (2018-04-12 and 2018-04-24)

Path: /shared/Training/LAND06_UrbanClassification_Germany/Original/

The opened product will appear in Product Explorer. Click + to expand the contents of the first image, then expand the *Bands* folder and click on *Intensity_IW2_VH* to visualize it. (See NOTE 4).



NOTE 4: The Interferometric Wide (IW) swath mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). Each sub-swath image consists of a series of bursts. The input product contains 3 IW bands, and 8 bursts. Mexico City is located on the IW3 sub-swath of the



In order to process this and the other Sentinel-1 images, we will take advantage of the batch processing option available in SNAP. In this way, we can define a specific processing chain and apply it to several images in an automatic way. This allows reducing processing time and storage requirement since no intermediate steps are created. Only the final product is physically saved.

Before running batch processing, it is necessary to create a graph containing all the processing steps. Go to *Tools -> Graph Builder*. So far, the graph only has two operators: Read (to read the input) and Write (to write the output). By right-clicking on the white space at the top panel, you can add an operator while a corresponding tab is created and added at the bottom panel. To avoid confusion, delete the *Write* operator.

6.3.1 Read

In this analysis, we will derive coherence using as input two independent Sentinel-1A products. Due to this, we need to add a second *Read* operator. For that, right click and go to *Add -> Input-Output -> Read*.). The corresponding tabs are created and added on the bottom panel. In the first *Read* tab set the first image ([1] – 2018-04-12) as input. In the second *Read(2)* tab, set the second image ([2] – 2018-04-24) as input.

Read(Z)	
Read Read(2)	
Source Product	
Name:	
[1] S1A_W_SLC_1SDV_20180412T171648_20180412T171715_021437_024E95_BDA1	
Data Format Any Format V	
Read Read(2)	
Source Product	
Name:	
[2] S1A_IW_SLC1SDV_20180424T171648_20180424T171715_021612_02540A_BB21	
Data Format. Any Format 💌	

6.3.2 TOPSAR-Split

Since the area of interest is included in 2 bursts of the Sentinel-1 image, there is no need to process the whole sub-swath with the 8 bursts (See \square NOTE 5). The extraction of Sentinel-1 TOPSAR bursts will be made per acquisition and per sub-swath. This process will reduce the processing time in the following processing steps and it is recommended when the analysis is focused only over a specific area. To add the TOPSAR-Split operators, right click and go to Add -> Radar -> Sentinel-1 TOPS -> TOPSAR-Split. Connect the operators as shown below by clicking to the right side of the **Read** operator and dragging the red arrow towards the TOPSAR-Split operator.

NOTE 5: The extraction of bursts in a sub-swath covering the area of interest may differ in Sentinel-1 images acquired on different dates.

Read TOPSAR-Split		
Read(2)		

In the TOPSAR-Split tabs, make sure to select the following parameters:

- Subswath: IW2
- Bursts: **1 to 2** (To do so, click on **I** and drag it to the left until you reach *Burst 2*)

Do not click on any polarization. By default both are selected.

Read Re	ad(2)	TOPSAR-Split	TOPSAR-Split(2))				
Subswath:	IW2							-
Polarisations	VH VV							
Bursts:	1 to 2	2 (max number o	f bursts: 9)	2	Ţ.	3		

Read Re Subswath:	ead(2) TOPSAR-Split TOPSAR-Split(2)	1.1
Subswaar.	IW2	•
Polarisations	s: VH	
	W	
Bursts:	1 to 2 (max number of bursts: 9)	
	the first of the second s	A. 0.1
	and the second	and the second sec
		the state of the s

6.3.3 Apply Orbit File

Next, we will update the orbit metadata (See \square NOTE 6) of the product to provide accurate satellite position and velocity information. To add the operators to our graph, right click and go to Add -> Radar -> Apply-Orbit-File. Connect the Apply-Orbit-File operators as shown below.

NOTE 6: 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 TOPSAR-Split Apply-Orbit-File		
Read(2)		

In the corresponding tabs, keep the default settings and click the option *Do not fail if new orbit file is not found*.

Read	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	
Orbit Sta	te Vectors:	Sentinel Precis	e (Auto Download)			
Polynomi	al Degree:	3				
		Do not fail if	f new orbit file is no	t found		

6.3.4 Back Geocoding

Now we will co-registers the two S-1 SLC split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM). To add the operator, go to Add-> Radar -> Corregistration -> S1 TOPS Corregistration -> Back-Geocoding. Set the two Apply Orbit File operators as input. In the corresponding parameters tab, leave the default values.

Read TOPSAR-Split	Apply-Orbit-File Back-Geocoding	
Read Read(2) TOPSAR-Split	t TOPSAR-Split(2) Apply-Orbit-File Apply-Orbit-File(2) Back-Geocoding	
Digital Elevation Model:	SRTM 3Sec (Auto Download)	-
DEM Resampling Method:	BICUBIC_INTERPOLATION	-
Resampling Type:	BISINC_5_POINT_INTERPOLATION	-
Mark out areas with no elevat		

Output Deramp and Demod Phase

6.3.5 Enhanced Spectral Diversity

This operator first estimates a constant range offset for the whole sub-swath of the split S-1 SLC image using incoherent cross-correlation. Then, estimates a constant azimuth offset for the whole sub-swath using an Enhanced Spectral Diversity (ESD) method. Finally, it performs range and azimuth corrections for every burst using the range and azimuth offsets previously estimated. Right click and go to Radar -> Coregistration -> S-1 TOPS coregistration -> Enhanced-Spectral-Diversity. Connect the Back-Geocoding operator as shown below and leave all the parameters as default in the Enhanced-Spectral-Diversity tab.

Read TOPSAR-Spilt Apply-Orbit-File Back-Geocoding Finhanced-Spectral-Diversity Read(2) TOPSAR-Spilt(2) Apply-Orbit-File(2)									
Read TOPSAR-Split Apply-Orbit-File	Read(2) TOPSAR-Split(2) Apply-Orbit-File(2) Back-Geocoding Enhanced-Spectral-Diversity								
Registration Window Width:	512	-							
Registration Window Height	512	-							
Search Window Accuracy in Azimuth Direction:	16	-							
Search Window Accuracy in Range Direction:	16	-							
Window oversampling factor:	128	-							
Cross-Correlation Threshold:		G.1							
Coherence Threshold for Outlier Removal:		0.15							
Number of Windows Per Overlap for ESD:		10							
Use user supplied shifts (please enter the	m below)								
The overall azimuth shift in pixels:		0.0							
The overall range shift in pixels:		0.0							

6.3.6 Coherence

Next, we will add the operator to derive the coherence image (See \square NOTE 7). Right click and go to Add -> Radar -> Interferometric -> Products -> Coherence. Connect the Coherence operator as shown below, select the option Subtract flat-earth phase and change the Square pixel parameter to 20.

Read TOPSAR-split Apply-Orbit-File Back-Geocoding Enhanced-Spectral-Diversity Coherence	
Read(2) TOPSAR-Split(2) Apply-Orbit-File(2)	

Apply-Orbit-File	Read(2)	TOPSAR-Split(2)	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Coherence	4
Subtract flat-e	earth phase						
		5					-
		501					-
		3					-
Subtract topog	graphic pha	ise					
Digital Elevation M	1odel:	THEFT	1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 - 1990 -				-
Tile Extension (%)	1	Dan					+
Square Pixel		🔲 Independent	Window Sizes				
		20					
		5					

NOTE 7: Coherence is the fixed relationship between waves in a beam of electromagnetic (EM) radiation. Two wave trains of EM radiation are coherent when they are in phase. That is, they vibrate in unison. In terms of the application to things like RADAR, the term coherence is also used to describe systems that preserve the phase of the received signal.

6.3.7 TOPSAR Deburst

We continue the processing steps with Sentinel-1 TOPSAR Deburst. We have seen that each subswath image consists of a series of bursts, where each burst has been processed as a separate SLC image. The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image with black-fill demarcation in between. There is sufficient overlap between adjacent bursts and between sub-swaths to ensure the continuous coverage of the ground. The images for all bursts in all sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information.

To add the TOPSAR-Deburst operator, go to *Add -> Radar -> Sentinel-1 TOPS -> TOPSAR-Deburst*. In the TOPSAR-Deburst tab, select Polarizations: VV. Connect the *Coherence* operator as shown below and keep all the parameters as default.

Read(2)		Spilt Apply-Orbit	ck-Geocodine	Enhanced-Spec	tral-Diversity – Cohe	rence — TOPSAR-De	uurst			
Read	TOPSAR-Split	Apply-Orbit-File	Read(2)	TOPSAR-Split(2)	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Coherence	TOPSAR-Deburst	
Polarisa	itions: VH VV									

6.3.8 Multi-look

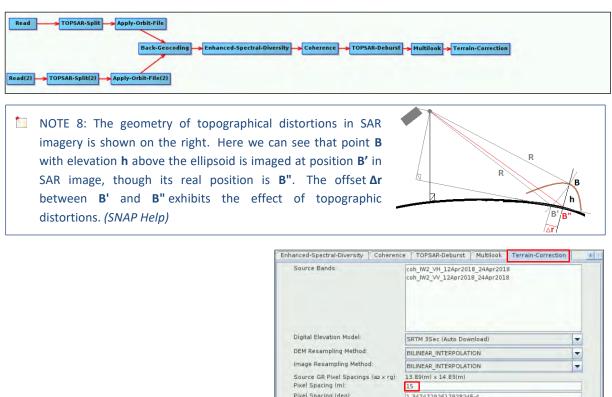
As the original SAR image contains inherent speckle noise, multilook processing is applied at this moment to reduce the speckle appearance and to improve the image interpretability. To add the Multilook operator go to Add -> Radar -> Multilook. Connect it to the TOPSAR-Deburst operator and keep the default parameters.

Read TOPSAILSplit Apply-Orbit-File	
Hack-Geocoding -> Enhanced-Spectral-Divercity -> Coherence -> TOPSAR-Deburst -> Multilask	
R#ad(2) -> TOPSAR:split(2) -> app(>:0*bit=File(2)	

Read	TOPSAR-Split	Apply-Orbit-File	Read(2)	TOPSAR-Split(2)	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Coherence	TOPSAR-Deburst	Multilook.
Source I	3ands.	coh_IW2_VH_12A coh_IW2_VV_12A								
Contract of the	quare Pixel	Independent	Looks							
Number	of Range Looks:	4								
Number	of Azimuth Looks	1								
Mean GP	R Square Pixel.	14.361344								
Outp	ut Intensity									
		Note: Detection f is done without r		data						

6.3.9 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 to our graph, right click and go to Add -> Radar -> Geometric -> Terrain Correction -> Terrain-Correction. Connect it to the Multilook operator, change the pixel spacing to 15 at the corresponding tab and make sure you select UTM / WGS 84 (Automatic) as Map Projection.



	Pixel Spacing (m):	15		
	Pixel Spacing (deg):	1.3474729261792824	E-4	
	Map Projection:	UTM Zone 32	/ World Geodetic System 1984	•
	Mask out areas without elevation	Output complex da	ta	
Map Projection	Output bands for:			
Coordinate Reference System (CRS)	Selected source band	DEM	Latitude & Longitude	
Custom CRS	incidence angle from ellipsoid	Local incidence angle	e 🔲 Projected local incidence angl	le
Geodetic datum	Apply radiometric normalization			
Projection: UTM / WGS 84 (Automatic	Save Sigma0 band	the second second	ndenne (r.g. dr. m. 28	\propto
Projection Parametere	🗋 Save Gammaŭ band	the second second second	e da esta presidente a la completa de la completa d	~
O Predefined CRS Select I	Save Betal band			
QK Cancel Help	Auxiliary File (ASAR unly):	and the		-

6.3.10 Subset

Next, we need to reduce the spatial extent to focus on our study area. For that, add the *Subset* operator. Right-click and go to *Add -> Raster -> Geometric -> Subset*. Connect it to the *Terrain-Correction* operator. Select the option *Geographic Coordinates* and copy/paste the following coordinates in Well-Known-Text format. Click *Update* to load them and Zoom in to the area.

Read TOPSAR-split	Apply-Orbit-File Back-Geocodin	Enhanced-Spectral-Diversity Coherence TOPSAR-Deburst Hullifork Terrain-Correction Subset
		348 52.37328212685329, 8.210910785692109 52.37592581845208,
8.2146103294	430705 52.1	.670955892227, 7.888290792013983 52.16447160649477,
7.8830547973	352848 52.3	37328212685329))
	Source Bands:	PSAR-Deburst Multilook Terrain-Correction Subset
		es 💽 Geographic Coordinates

6.3.11 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 go to Add -> Input-Output -> Write. Connect the Write operator to the Subset operator. In the Write tab, make sure you set the following name and directory.

Name: Coherence_20180412_20180424

Path: /shared/Training/LAND06_UrbanClassification_Germany/Processing/

iead(2) → TOPSAR-Split(2) → Apply-Orbit	Back-Geocoding Enhanced-Spectral-Diversity Coherence TOPSAR-Deburst Multilook Terrain-Correction Subset	t
Coherence	e TOPSAR-Deburst Multilook Terrain-Correction Subset Write	
Target Produ Name:		
Coherence	e_20180412_20180424	
Save as: BE Directory		
/home/m	/rus/shared/Training/LAND06_UrbanClassification_Germany/Processing	

Once finished, click on the *Save* icon. Navigate to the following path and save the graph as **1_S1_Splt_Orb_Cor_Coh_Deb_ML_TC.xml**. Then, click *Run* to start the processing. It can take some time depending on your VM specifications (<u>3 hours approx. in a 16GB RAM and 4 cores VM</u>).

Path: /shared/Training/LAND06_UrbanClassification_Germany/AuxData/

6.4 Import vector data

To prepare the data for the classification, the shapefile of the training areas has to be imported. Select the *Coherence_20180412_20180424* product in the product explorer and go to *Vector -> Import -> ESRI Shapefile*. Navigate to the following path and click *Open* after selecting all the files. Click *No* in the import geometry dialog.

Path: /shared/Training/LAND06_UrbanClassification_Germany/AuxData/

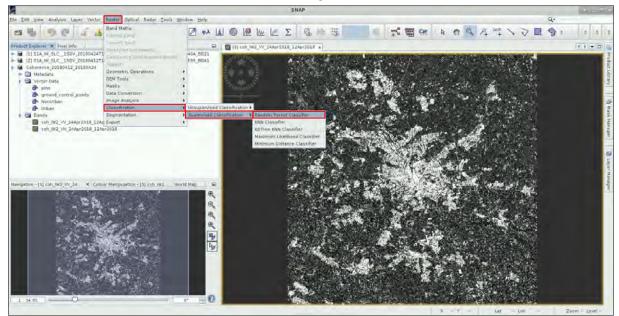
	Import Shapefile	* ± ×	Import Geon	netry	* 🗆 ×
Look In:	shp		The vector data set contains 6 p Shall they be imported separatel If you select Yes , the polygons of and they will be displayed on ind		ividual masks
File <u>N</u> ame:	"NonUrban.shp" "Urban.shp"		Attribute for mask/layer naming:		-
Files of <u>Type</u> :	ESRI Shapefiles (*.shp)	Open Cancel		Yes No	Help

Once the vector data have been imported, do not forget to save the changes. **Right click** on the subset product (index [3]) and click on **Save Product.** The vector data folder of the subset product should look like the following image. Expand the product and open the Vector Data folder to check it.

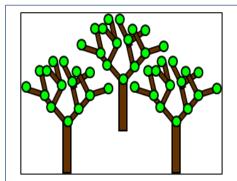
1) S1A_IW_SLC_1SDV_20180424T171648_20180424T171715_021612_02540A_BB21 2] S1A_IW_SLC_1SDV_20180412T171648_20180412T171715_021437_024E95_BDA1	
Coherence_20180412_20180424	
Metadata ⊉ Vector Data ⇒ pins magnetic points ⇒ NonUrban ⇒ Urban	
	궴 pins 궴 ground_control_points 궴 NonUrban

6.5 Random Forest Classification

For this exercise, the Random Forest classification algorithm will be used (See 1 NOTE 9).



Click on Raster -> Classification -> Supervised Classification -> Random Forest Classifier



NOTE 9: 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.

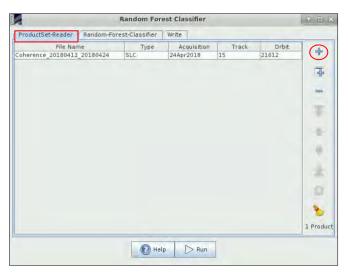
Decision trees are predictive models that recursively split a dataset into regions by using a set of binary rules to calculate a target value for classification or regression purposes. Given a training set with n number of samples and m number of variables, a random subset of samples n is selected with 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 coherence image as input (*Coherence_20180412_20180424*).

Path: /shared/Training/LAND06_UrbanClassification_Germany/Processing/



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

- 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

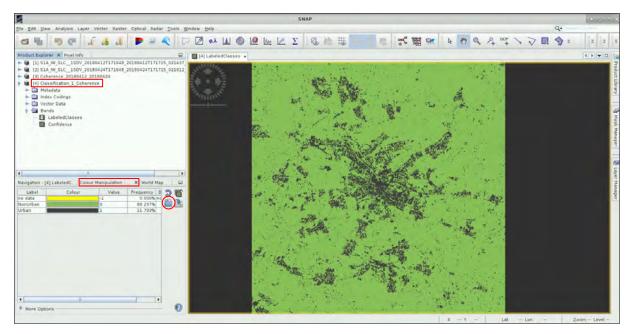
Click now on the *Write* tab, set the Output folder to the following path, and specify the output name according to the number of coherence images used: *Classification_1_Coherence*. Finally, click *Run*.

ProductSet-Reader Random-Forest-Classifier Write	
Classifier	
Train and apply classifier newClassifier	Random Forest Classifier
C Load and apply classifier	
Train on Raster () Train on Vectors	ProductSet-Reader Random-Forest-Classifier Write
Evaluate classifier	Target Product
Evaluate Feature Power Set	
Min Power Set Size Max Power Set Size	
Number of training samples 5000	
Number of trees. 500	
Vector Training	
Training vectors NenUrban Urban	Name:
	Classification 1 Coherence
	Save as: BEAM-DIMAP
	Directory:
	shared/Training/LAND06_UrbanClassification_Germany/Processing
Feature Selection	
Feeture bands- cuh mz vv 24Apr2/clil 32Apr2016	
rah m2_vH_24Apr2018_12Apr2018	
C Help D Run	🕑 Help 🕞 Run

Path: /shared/Training/LAND06_UrbanClassification_Germany/Processing/

To visualize the result, expand the *Bands* folder in the *Classification_1_Coherence* product and double click on *LabelledClasses*. 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*. Select your own colours or click on the 'Import colour palette' icon (\square). Navigate to the following path and select the *RF_Colour.cpd* file.

Path: /shared/Training/LAND06_UrbanClassification_Germany/AuxData/

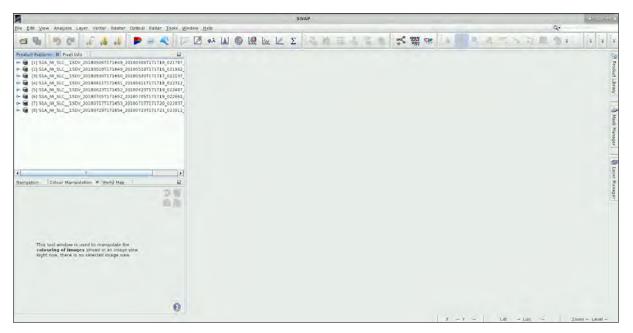


7 Extra Steps

7.1 Coherence images

The result produced by using a single coherence image can be improved if more coherence products are used for the classification. For this, we first have to produce them by following the same approach as before. In SNAP, close all previous products, go to *File -> Open product*, navigate to the following path and open the remaining 8 Sentinel-1 images that have not been used before. (2018-05-06 | 2018-05-18 | 2018-05-30 | 2018-06-11 | 2018-06-23 | 20180705 | 20180717 | 20180729)

Path: /shared/Training/LAND06_UrbanClassification_Germany/Original/



Next, go to *Tools -> GraphBuilder* click on *Load*, navigate to the following path and open the *1_S1_Splt_Orb_Cor_Coh_Deb_ML_TC.xml* graph file. Change the following parameters and click *Run*. Remember that processing this graph may take some time depending on your VM specifications.

- Read tab \rightarrow Make sure to select the Sentinel-1 product from 2018-05-06 (index [1]).
- Read(2) tab \rightarrow Select the Sentinel-1 product from 2018-05-18 (index [2]).
- Write tab → Change the output name to Coherence_20180506_20180518

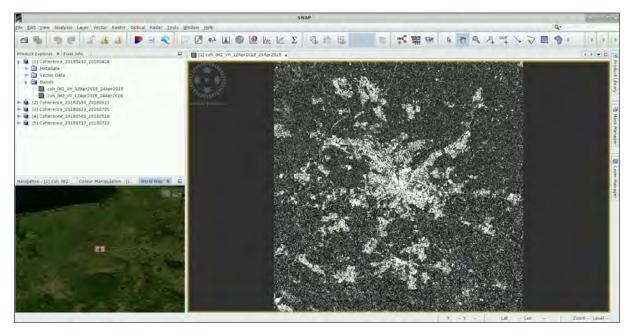
Source Product Name:	Read	TOPSAR-S	plit	Apply-Orbit-File	Read(2)	TOPSAR-Split(2)	Apply-Orbit-File(2)	Bac
I)SIA_IW_SLCISDV_20180506T171649_20180506T171716_021787_025996_98AB Data Format: Any Format Read TOPSAR-Split Apply-Orbit-File Read(2) TOPSAR-Split Apply-Orbit-File Source Product Name:	Source	Product						
Data Format: Any Format Read TOPSAR-Split Apply-Orbit-File Read(2) TOPSAR-Split(2) Apply-Orbit-File(2) Bac Source Product Name:	Name:							_
Data Format: Any Format 💌 Read TOPSAR-Split Apply-Orbit-File Read(2) TOPSAR-Split(2) Apply-Orbit-File(2) Bac Source Product Name:	[1] 51/	A IW_SLC_	15DV	20180506717164	9_20180506	T171716_021787_	025996_98AB	T 111
Source Product Name:			1000		(Dead(2))	TOPCAD Colif(2)	Annha Ochit Ella(3)	Bac
Name:		1	spiit	Apply-Orbit-File	Read(2)	TOPSAR-Split(2)	Apply-Orbit-File(2)	Bac
[2]S1A_W_SLC_1SDV_20180518T171649_20180518T171716_021962_025F27_A15C								
	[2])51	A IW_SLC_	ISDV	_20180518T17164	9_2018051	8T171716_021962	025F27_A15C	· · · ·

Coherence	TOPSAR-Deburst	Multilook	Terrain-Correction	Subset	Write	4
Target Prod	uct					
Name:						
Coherence	20180506_2018051	8				
Save as: BE	AM-DIMAP	-				
Directory	ľ.	-				
khared/	Fraining/LAND06 Ur	banClassifica	tion Germany/Process	sing		

Once finished, repeat the same procedure for the remaining pair of images. Please note that since this graph is computationally demanding, you may need to close and open SNAP in order to release memory before processing a new pair of Sentinel-1 SLC products.

Read → 2018-05-30 [3] | Read(2) → 2018-06-11 [4] | Write → Coherence_20180530_20180611 Read → 2018-06-23 [5] | Read(2) → 2018-07-05 [6] | Write → Coherence_20180623_20180705 Read → 2018-07-17 [7] | Read(2) → 2018-07-29 [48] | Write → Coherence_20180717_20180729

After all the coherence images have been produced, close all the products in SNAP except for the 5 coherence images.



7.2 Create Stack

To use all the images as input for the Random Forest classification, we first need to stack all the products together. For that, go to Radar -> Corresgistration -> Stack Tools -> Create Stack. In the ProductSet-Reader tab, click at the icon to add the opened products. Click also at the icon to update the metadata information.

1-ProductSet-Reader 2	-CreateStack	3-Write			
File Name	Type	Acquisition	Track	Orbit	
Coherence_20180412_20	. SLC	12Apr2018	15	21437	
Coherence_20180530_20.		30May2018	15	22137	
Coherence_20180623_20		23Jun2018	15	22487	규
Coherence_20180506_20		06May2018	15	21787	
Coherence_20180717_20	SLC	17Jul2018	15	22837	-
					香
					•
					*
					*

Move now to the *CreateStack* tab and set the following parameters and click on the *Find Optimal Master* button.

- Resampling type: NEAREST_NEIGHBOR
- Initial offset method: Product Geolocation

e	Create Stack	* = *
1-ProductSet-Reader	2-CreateStack 3-Write	
Master:	Coherence_20180506_20180518	
Resampling Type:	NEAREST_NEIGHBOUR	-
Initial Offset Method	Product Geolocation	-
Output Extents:	Master	
Find Optimal Master		
	Help Run	

In the *Write* tab, change the output name to *Coherence_Stack* and make sure the output directory is set to the following path and then click *Run*.

Path: /shared/Training/LAND06_UrbanClassification_Germany/Processing/

e	Create Stack	1 E X
1-ProductSet-Reader 2-C	reateStack. 3-Write	
Target Product		
Name: Coherence_Stack		
Save as: BEAM-DIMAP	T	
Directory:		
shared/Training/LAND06	UrbanClassification_Germany/Processing	
	Run Nelp	
	Null Kull	

7.3 Multi-temporal Random Forest classification

Once the images are stacked, we can use them as input for the classification. Click on *Raster ->* Classification -> Supervised Classification -> Random Forest Classifier

In the *ProductSet*-Reader tab, click on the symbol. Navigate to the following path and select the stacked product as input (*Coherence_Stack*).

	Randor	n Forest Classifi	er		• E.
Random	Forest-Class	sifier Write			
	Туре	Acquisition	Track	Orbit	
SLO	2	12Apr2018	15	21437	
					구
					-in-
					-
					-
					-
					100
					H 0 0 0 12
		Random-Forest-Class	Random-Forest-Classifier Write Type Acquisition	Type Acquisition Track	Random-Forest-Classifier Write Type Acquisition Track Orbit

Path: /shared/Training/LAND06_UrbanClassification_Germany/Processing/

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

- 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

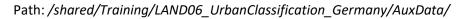
Click now on the *Write* tab, set the Output folder to the following path, and specify the output name according to the number of coherence images used: *Classification_5_Coherence*. Finally, click *Run*.

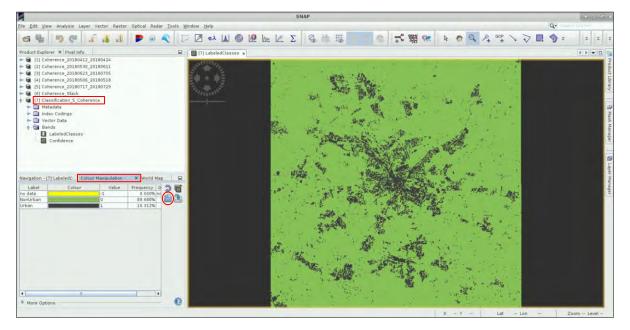
Path: /shared/Training/LAND06_UrbanClassification_Germany/Processing/

Training vectors Patient double Classifier Interiment of training Patient double ProductSet Reader Random Forest Classifier ProductSet Reader	Randam Forest Classifier	
Product de dapóy classifier Coad and apóy classifier Civilade classifier Divilade classifier Divilade frature Parer Set Number of training strates Soo Number of training strates Soo Year Arning Yraining vectors Man Romer Set Store Strates Soo Number of training strates Soo Number of training strates Soo Year Arning Yraining vectors Man Romer Set Store Strates St	ProductSet-Reader Random-Forest-Classifier Write	
Load and Apply classifier Image: Train on Vectors Evaluatior feature Brower Stert Image: Train on Vectors Evaluatior feature Brower Stert Image: Train on Vectors Mander of training standars 5000 Number of training Train on Vectors Vector Training Training Vectors Patters Selection Diff. Not New Years Selection Peators Selection Diff. Not New Years Selection Patter Faining Diff. Not New Years Selection Peators Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Peators Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection Diff. Not New Years Selection	Classifier	
Image: Train on Raster: Image: Train on Raster: Image: Train on Vectors Evaluate reature Priver: Image: Train on Vectors Evaluate reature Priver: Image: Solo Number of training sameles: Solo Number of training sameles: Solo Yeatur: Training vectors: Image: Training vecto	Train and apply classifier newClassifier	Random Forest Classifier
Evaluate //status /	Coad and apply classifier	ProductSet-Reader Random-Forest-Classifier Write
Evaluate Parter Striction Number of transport Number of transport Number of transport Wickstriction Parter Selection Patter Selection Patter Selection Patter Selection Patter Selection Patter Selection Patter Selection	C Train on Raster (Train on Vectors	Target Product
builde Peature Parer Set Am Power Set Stor Number of training Number of training Vector Praining Praining vectors Peature Selection Peature Selection Peature Selection Peature Selection Patire Selection Patire Selection Patire Selection	Evaluate classifier	
Number of training sameles 5000 Rumber of training sameles 5000 Rumber of training sameles 5000 Rumber of training sameles 5000 Pratice Sameles 500 Pratice Sameles 50		
Number of trees Loo Vector Paining Interview Vector Paining Interview Vector Paining Vector Paining Vector Interview Vector Paining Vector Vector Paining Interview Vector <td>Mm Power Set Size Max Power Set Size</td> <td></td>	Mm Power Set Size Max Power Set Size	
Vettor Training Training vettors Peators Selection Feators Selection Feators Selection Feators Selection Doi, no. vo. 2004.profile 320402016 Dailing VII Selection Sector	Number of training samples 5000	
Training vectors Production Classification Common Classification Germany/Processing Classification Germany/P	Number of trees. 500	
Interference Peators Selection Peators Selection DeviceTry Interference Directory Interference		
Peatire Seletion Elsevisit (Elsevitication 5, Coherence Save as (Elsevitication 6, Coherence <td></td> <td>Manie</td>		Manie
Feature Selfston Directory. Feature Selfston Directory. Entered TrainingLANDOG. UrbanClessification. Germany/Processing		
Peature Selection Directory. Peature Selection Directory. Directory. Phared/Training/LANDOG. UrbanClassification, Germany/Processing		
Peakurs Selenton Peakurs Dants Datum 2 vr. 2 Japr2018 (2 Japr2018) Int vr. 2 vr. 2 Japr2018 (2 Japr2018)		Save as: BEAM-DIMAP
Peature Selection Feature Sele		
Feature bands: Unit 102 yr 2 Jaar2016 Dai 102 yr 1 Daar2018 122ar2010 		shared/Training/LAND06_UrbanClassification_Germany/Processing
Feature bands: Unit 102 yr 2 Jaar2016 Dai 102 yr 1 Daar2018 122ar2010 	Easthing Calarting	
	Feature bands on m2 vv 2sApr2/18 32Apr2016	
Image: Second	untrim2 VH 24Apr2018 12Apr2018	
Image: Contract of the second seco		
Hub D Run		
Help Help		
Kelp D Sun		
1 Help D Run		
	P Help D Run	🕐 Help 🕞 Run

To visualize the result, expand the *Bands* folder in the *Classification_5_Coherence* product and double click on *LabelledClasses.* 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.*

Select your own colours or click on the 'Import colour palette' icon (¹). Navigate to the following path and select the file *RF_Colour.cpd*.





THANK YOU FOR FOLLOWING THE EXERCISE!

8 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

InSAR Principles – ESA

 $http://www.esa.int/About_Us/ESA_Publications/InSAR_Principles_Guidelines_for_SAR_Interferometry_Processing_and_Interpretation_br_ESA_TM-19$

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

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