

## TRAINING KIT – PY02

# ESTIMATION OF FOREST ABOVE-GROUND BIOMASS WITH SENTINEL-2

Case Study: Ethiopia, 2017



Research and User Support for Sentinel Core Products

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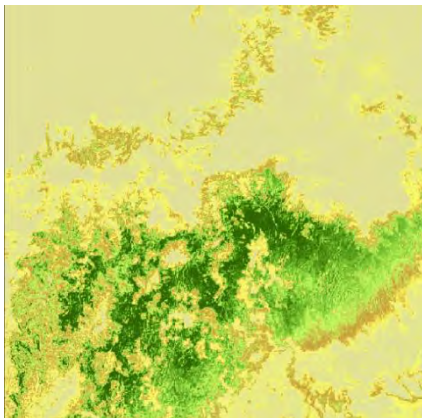
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## 1 Introduction to RUS

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 webinar we will employ RUS to run linear and non-linear machine learning regression models in order to estimate values of above-ground biomass in forest area in Ethiopia. As input data we will use Sentinel-2 product.

## 2 Forest above-ground biomass estimation – background



Above-ground biomass over the study area in Ethiopia retrieved from ESA BCCI database (<https://catalogue.ceda.ac.uk/uuid/84403d09cef3485883158f4df2989b0c>)

Forests cover more than 31% of the total land area in the Earth (FAO, 2020). Forest ecosystem do not only provide a shelter for animals and maintain biodiversity but also supply the oxygen, provide timber and are preferred places for recreation. They play very important role in global carbon cycle as they store approximately 861 gigatons of carbon totally (WRI, 2021) from which 42% in live biomass (above and below ground biomass). Tropical forests are known as the greatest carbon stock containers, they account for only 30% of total global forest cover but contain about 50% of the world's forest carbon stock.

Above-ground biomass is very important parameter in forest management as it allows to estimate forest resources and the dynamics of these resources. It has its crucial role in the studies of carbon cycle and the capabilities of carbon storage, as well as in the climate change debate. Because of its importance, forest biomass has been measured by foresters since decades, so different approaches exist to make these estimations. These methods mostly include field measurements which are believed to be the most accurate, but also time-consuming and costly taking into account the labor needed. Remote sensing technology enables the accounting of forest biomass. Among most commonly used sensors applied to forest above-ground biomass estimation we can list LIDAR, UAV, RADAR but also airborne hyperspectral images or satellite-based optical data are used.

In this webinar we will examine the possibility to estimate above-ground biomass in forested area in Ethiopian forest: Harenna Forest and Bale Mountains National Park. For estimation we will be using a combination of Sentinel-2 derived vegetation indices. As a reference in the estimation process we will use publicly available database produced by the ESA Biomass Climate Change Initiative for the year 2017 (Santoro, M., Cartus, O., 2021). We will estimate the above-ground biomass on the selected area in Africa using different machine learning methods: multiple linear regression, and non-linear random forest regression model. At the end of the exercise we will see differences in output of both models and produce biomass maps which can be used in the future to for example predict carbon amount stored in the forest.

### 3 Training

Approximate duration of this training session is **one and a half** hour.

The Training Code for this tutorial is **PY02**. If you wish to practice the exercise described below within the RUS Virtual Environment, register the RUS portal and open a User Service request from your RUS service -> Your dashboard.

#### 3.1 Data used

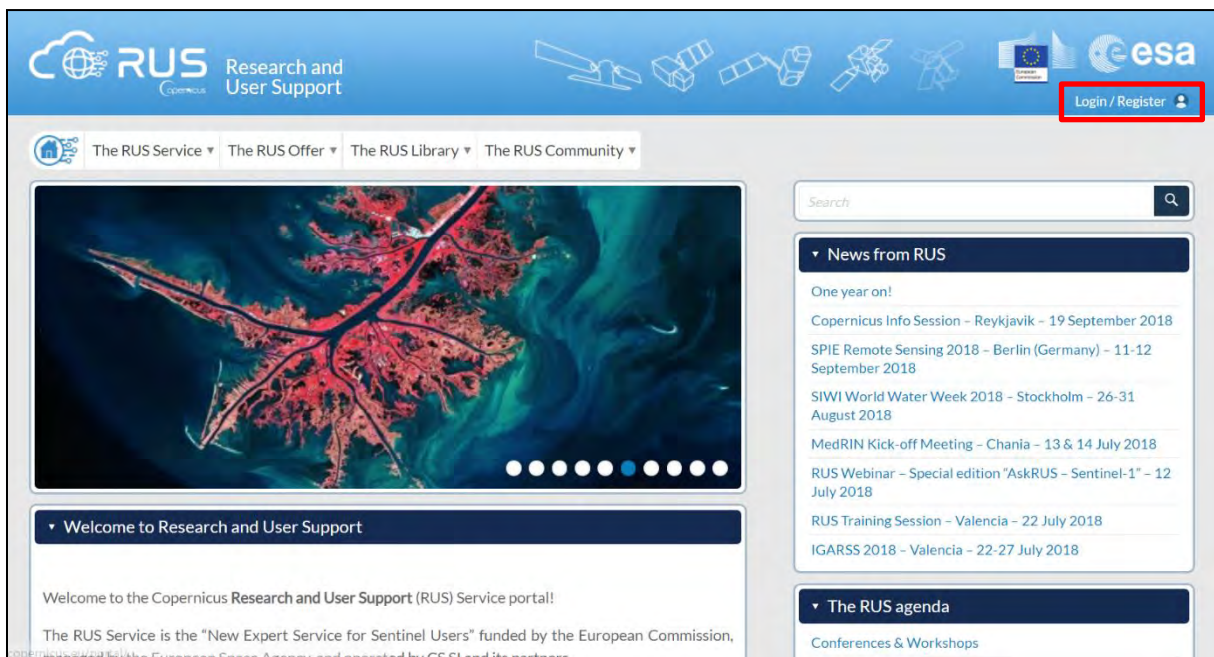
- 1 Sentinel-2A image acquired during January 2017, full name of the product: **S2A\_MSIL1C\_20170119T074231\_N0204\_R092\_T37NEH\_20170119T075734**
- Pre-processed data stored locally  
`@/shared/Training/PY02_ForestBiomass_Sentinel2/AuxData/`

#### 3.2 Software in RUS environment

Internet browser, Jupyter Lab, Python, Anaconda, *snappy*, *Sen2Cor280*

### 4 Register to RUS Copernicus

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



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



### Login / Register

Registered RUS users, as well as persons who already own a Copernicus SSO account, can directly access our service.

[Login](#)

---

Newcomers shall first create an account on the **Copernicus Single Sign-On (SSO)** authentication server used to support registration to the RUS service.

[Create my Copernicus SSO account](#)

*NB: persons using a Google e-mail address for registration shall check their mailbox spam folder regularly as Google tends to filter RUS e-mails.*

[Close](#)

CDS-SSO

### Copernicus Users' Single Sign On Registration

**Registration form**

☐ I'm already registered

CDS SSO ID

Secret question

Answer

Password

Confirm password

Email

Confirm email

First name

Last name

Institution

Country of residence

Type the characters

[Register](#)

© Copernicus Single Sign On 2.6.0 - 2016-05-21

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

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

### Login / Register

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

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

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

[REGISTER COPERNICUS SSO account](#)

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

[Login](#)

[Close](#)

### Credentials

CDS-SSO ID

Password

Max Idle Time

Max Session Time

[Login](#) [Reset](#)

[Forgot your password?](#)

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

Research and User Support

The RUS Service

- Your RUS service
- Your profile
- Your dashboard
- Your training

Do you want to subscribe for a new RUS account?

Your ESA-SSO subscription data:

Login

First Name

Last Name

Email

Organization

Country

Additional subscription information

Please complete the following information:

Where did you hear about the RUS service?  
Select one or more items

☐ outreach event  
☐ colleagues  
☐ newsletter  
☐ conference  
☐ social media  
☐ other

☐ Select one item --

Institution type

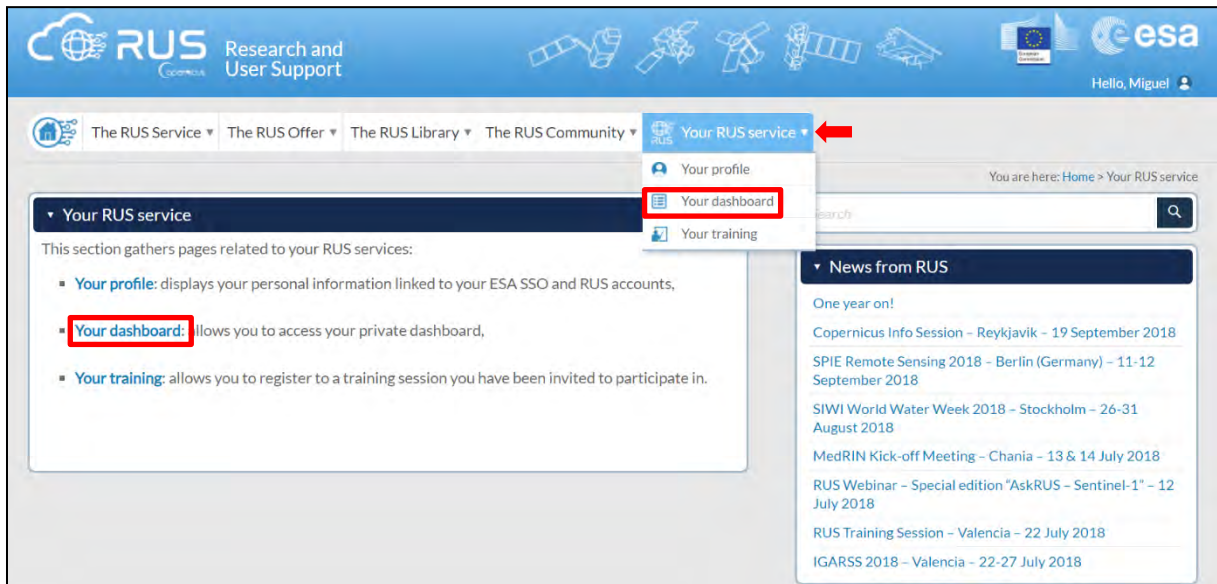
Phone number

Title

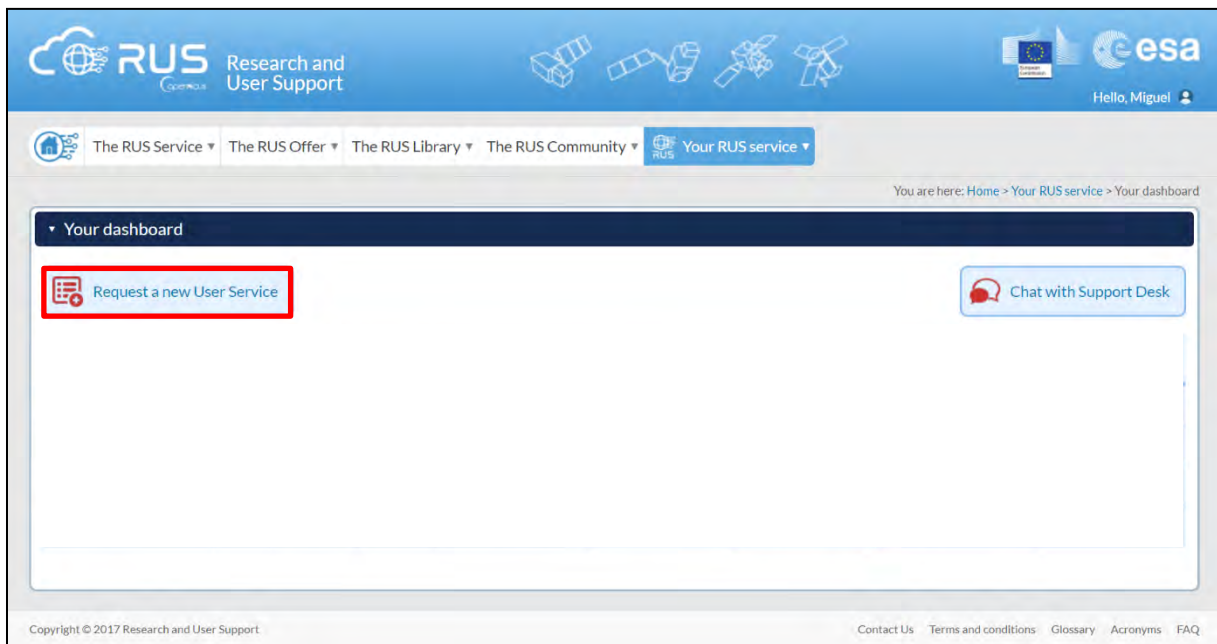
[Subscribe](#) [Cancel](#)

## 5 Request a RUS Copernicus Virtual Machine

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



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



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

User Support Request

Step 1/3 Your experience

Please help us learn more about your background by answering a few questions. This 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
☐ 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  
OCEA01 - Ship Detection in Gulf of Trieste

If you wish to request another tutorial exercise that doesn't appear in the above list, please type here its name or code. Note that you can request multiple tutorial exercises.

Cancel

Next

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

User Support Request

Summary information on your request:

This is a collection of information selected across the USR forms.  
You can go back and edit this information if necessary.

General Information on your request:

Years of experience in Remote Sensing

5-10 years

Downloaded Copernicus data?

✓

Handled/processed Copernicus data?

✓

Webinar codes

HAZA02, LAND04

About your RUS project:

Thematic area

Cryosphere (ice and snow)

Operations to perform on RUS

Algorithm development

Preference for downloading process

Self-downloading

Foreseen activities and support needs

Develop a land cover classification

Project name

RUS\_Project1

Earth Observation Data Information:

Type of Earth Observation Data:

Sentinel-1

✓

S1 - Product type

S1 - Product 1

S1 - Sensor mode

GRD

S1 - Polarisation

-

S1 - Orbit direction

-

Sentinel-2

X

Sentinel-3

X

Other

X

I don't know

X

Region of Interest:

Min Latitude

39.3303

Max Latitude

40.5877

Min Longitude

-4.6736

Max Longitude

-2.7205

Reference polygons

Data acquisition date(s):

None

Additional data specifications

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

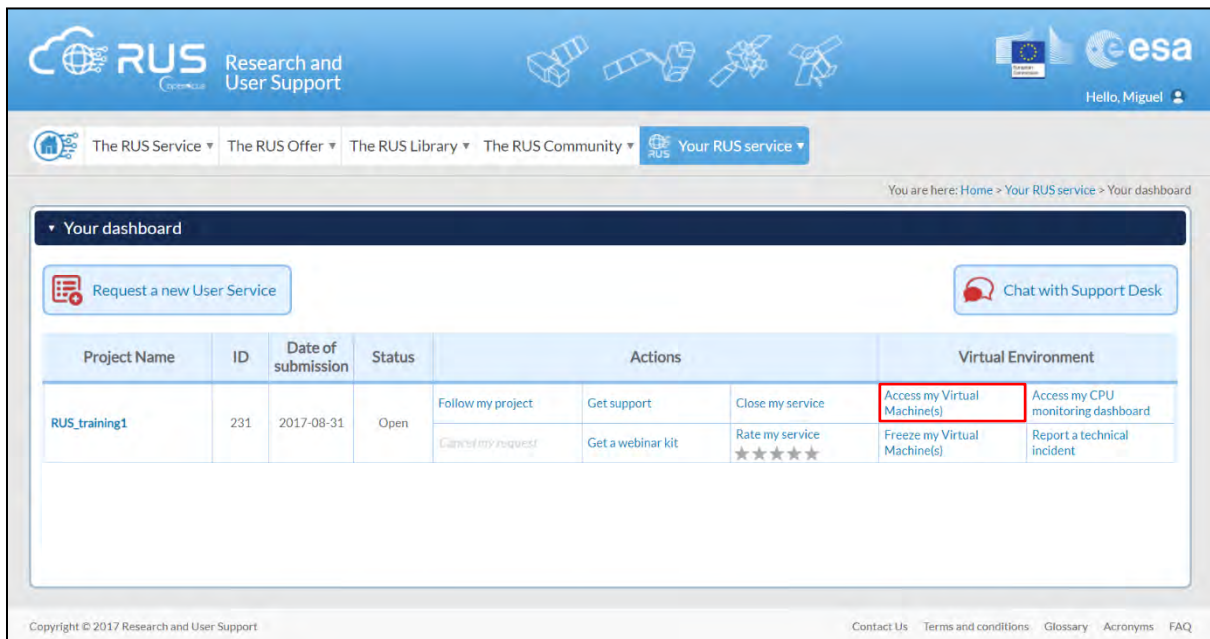
Back and edit

Submit the request

8



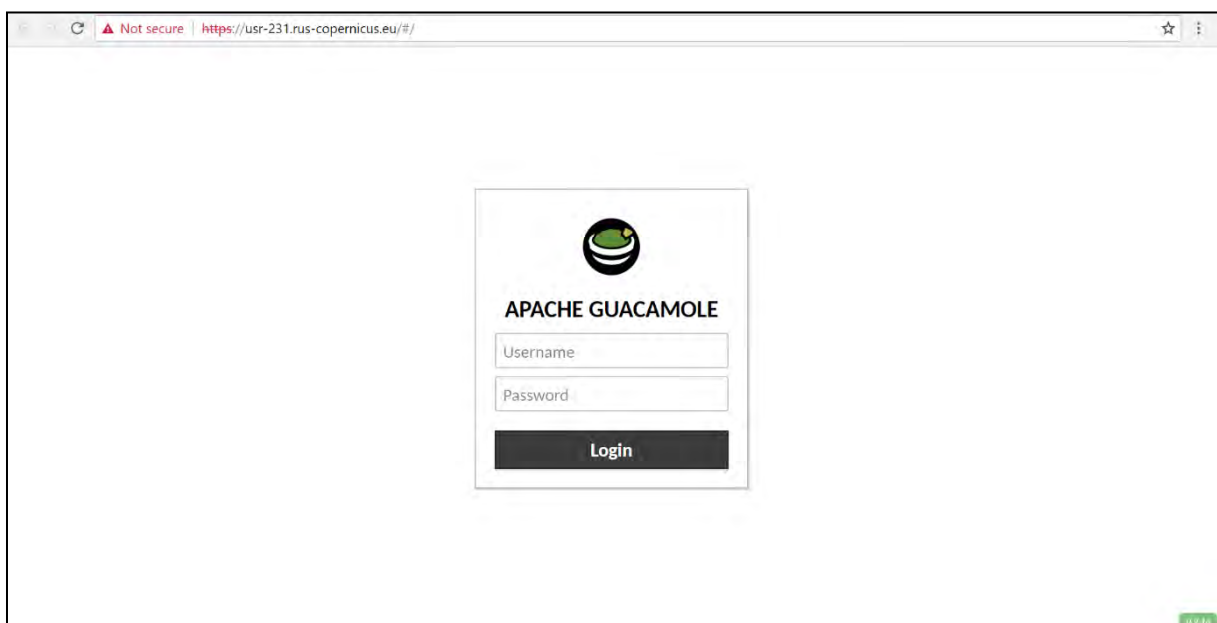
Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to **Your RUS Service → Your Dashboard** and click on **Access my Virtual Machine**.



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Contact Us Terms and conditions Glossary Acronyms FAQ

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



Not secure | https://usr-231.rus-copernicus.eu/#/

APACHE GUACAMOLE

Username

Password

Login

This is the remote desktop of your Virtual Machine.

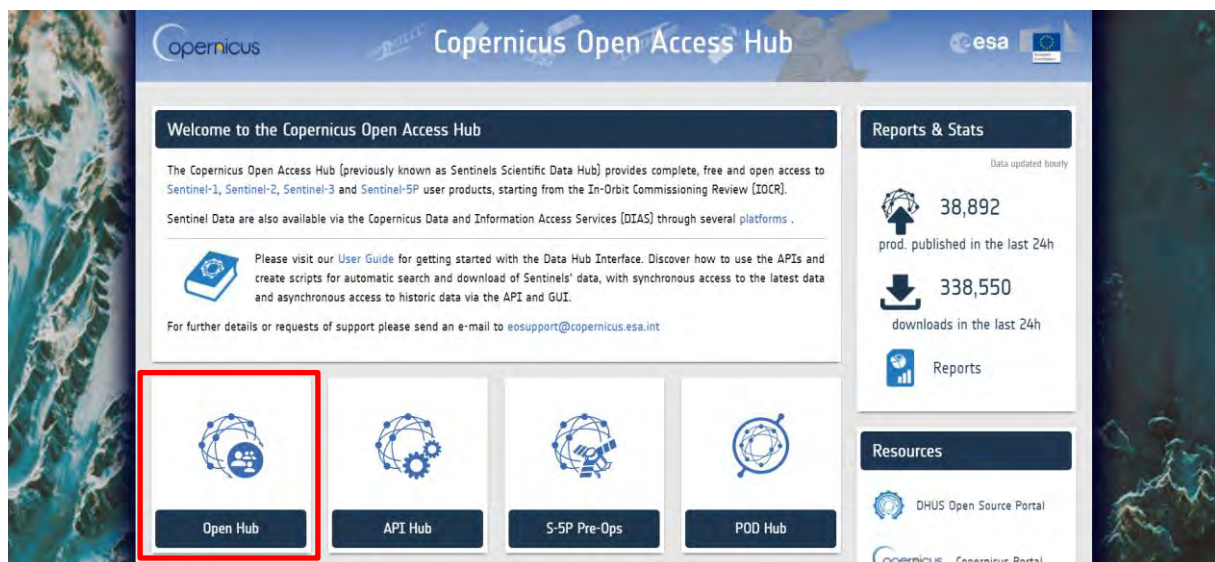


## 6 Step by step

### 6.1 Data download – ESA SciHUB

Before starting the exercise, we need to make sure that we are registered in the Copernicus Open Access Hub so that we 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 please sign up in the upper right corner, fill in the details and click 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.

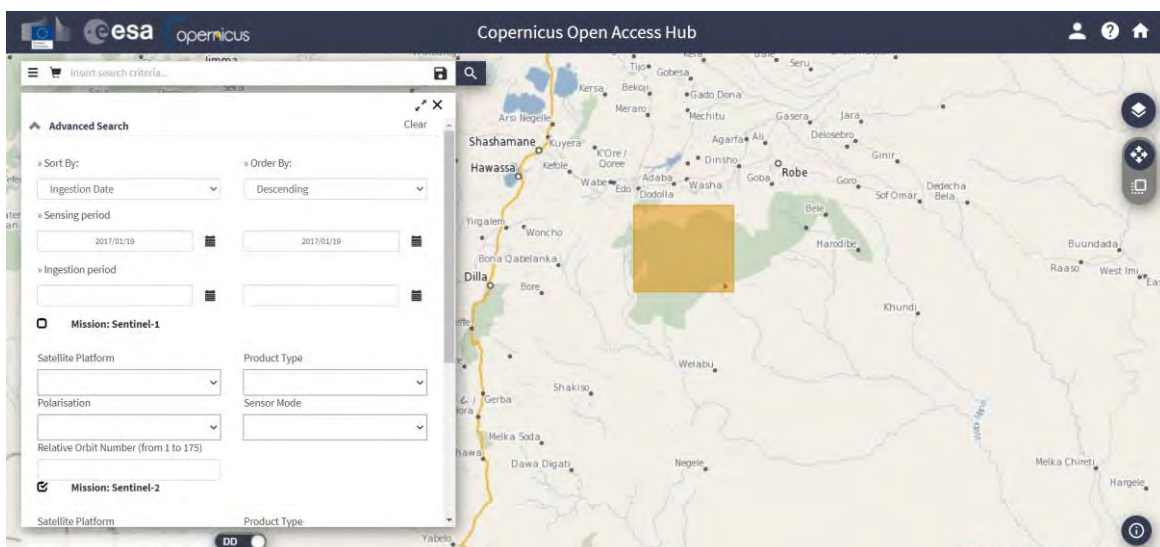
Once your account is activated – or if you already have an account – log in.

## 6.2 Download data

In this exercise, we will describe the procedure to download the Sentinel-2 product. Make sure you repeat the same procedure and download the product for January 2017 for our area of interest. First of all you need to define the study area over the central-southern forest area in Ethiopia (as presented below). Then, open the search menu by clicking to the left part of the search bar (☰) and specify the parameters below. Press the search button (🔍) after that.


**Sensing period:** From 2017/01/19 to 2017/01/19

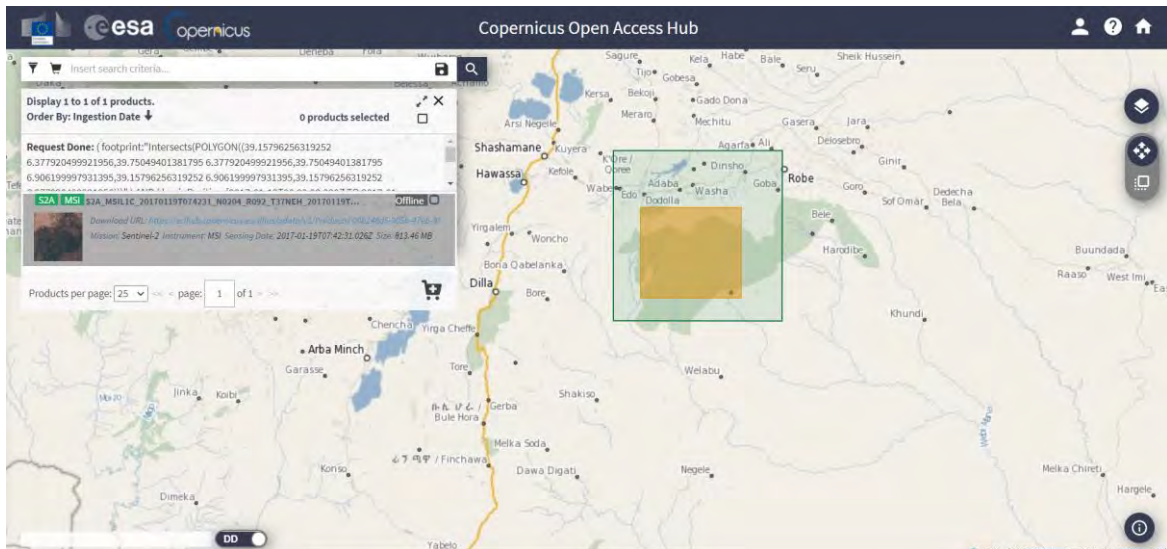
**Check mission:** Sentinel-2




In this case the search returns 1 results. Full product name is: **S2A\_MSIL1C\_20170119T074231\_N0204\_R092\_T37NEH\_20170119T075734**. This product does not

have atmospheric correction applied so later we will need to convert it to atmospherically corrected product.

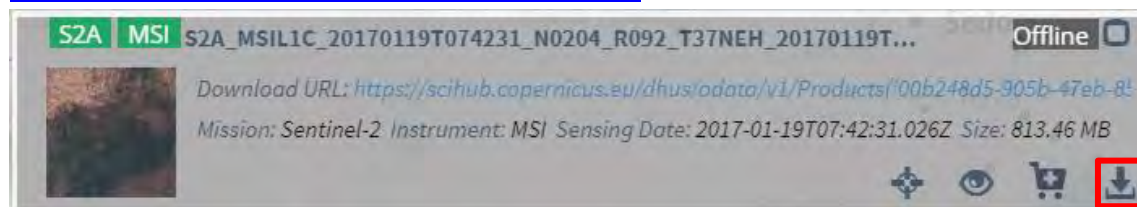
Download the product (it will be saved in `/home/rus/Downloads`) and move it to the following path: `/shared/Training/PY02_ForestBiomass_Sentinel2/Original/`. (See  NOTE 1).




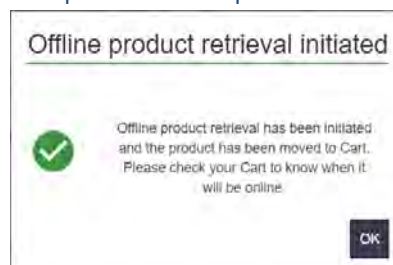
 NOTE 1: Due to ESA policy on the availability of Sentinel data on Copernicus Open Access Hub and to ensure the continued access to all Sentinel data at all time, the Long-Term Archive (LTA) Access has been implemented to roll-out the oldest data from the online access. More information about the LTA can be found in the following links:

[https://scihub.copernicus.eu/userguide/#LTA\\_Long\\_Term\\_Archive\\_Access](https://scihub.copernicus.eu/userguide/#LTA_Long_Term_Archive_Access)

<https://scihub.copernicus.eu/userguide/LongTermArchive>.



To download a product from the LTA, click on the Download Product icon - . A confirmation message will appear informing you that your request has been queued and the product added to your Cart.






You will have to manually check your Cart from time to time to know when the product is available to be downloaded (no automatic notification will be sent). Once online, the product will remain available for 4 days until been roll-out to the LTA again.


Please note that every user account is only allowed to request 1 offline product every 30 minutes, if there is free space in the queue. The number of concurrent requests for offline products from all users is limited. You may receive an error when trying to download. If so, try again later.



### 6.3 Anaconda environment installation

In this exercise we will use *snappy* module, *Sen2Cor plugin* and Python code in JupyterLab to perform atmospheric correction (*Sen2Cor in Python*), process the image (resampling, subset, band combinations – with *snappy*), calculate vegetation indices and at the end perform machine learning regression models. However, before starting the analysis, we need to set up both the Anaconda environment and the *snappy* module to work (See  NOTE 2 and  NOTE 3).

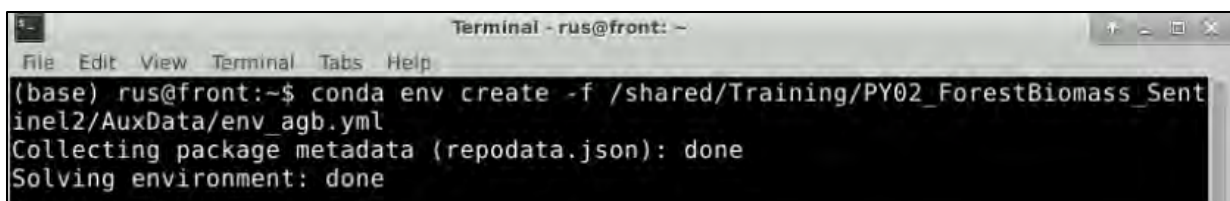
 NOTE 2: Project Jupyter is a non-profit, open-source project, born out of the IPython Project in 2014 as it evolved to support interactive data science and scientific computing across all programming languages. Notebook documents (or “notebooks”, all lower case) are documents produced by the Jupyter Notebook App, which contain both computer code (e.g. python) and rich text elements (paragraph, equations, figures, links, etc...). Notebook documents are both human-readable documents containing the analysis description and the results (figures, tables, etc..) as well as executable documents which can be run to perform data analysis. More info at: [www.jupyter.org](http://www.jupyter.org)

 NOTE 3: Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python's design philosophy emphasizes code readability through use of significant whitespace. Its language constructs and object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects. Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including procedural, object oriented, and functional programming. Python is often described as a "batteries included" language due to its comprehensive standard library. More info at: [www.python.org](http://www.python.org)

Anaconda is a free and open-source distribution of the Python and R programming languages for scientific computing (data science, machine learning applications, large-scale data processing, predictive analytics, etc.), that aims to simplify package management and deployment. Package versions are managed by the package management system *conda*. More info at: <https://www.anaconda.com/distribution/>

To create the same conda environment as the one used for the creation of this training material open Terminal in your RUS Virtual Machine and copy-paste the following command. Then, press *Enter* to run it (this step may take several minutes, do not interrupt it). The conda environment will be called PY02\_agb.

```
conda env create -f
/shared/Training/PY02_ForestBiomass_Sentinel2/AuxData/env_agb.yml
```



```
Terminal - rus@front: ~
File Edit View Terminal Tabs Help
(base) rus@front:~$ conda env create -f /shared/Training/PY02_ForestBiomass_Sentinel2/AuxData/env_agb.yml
Collecting package metadata (repodata.json): done
Solving environment: done
```

...

```
# To activate this environment, use
#
#   $ conda activate PY02_agb
#
# To deactivate an active environment, use
#
#   $ conda deactivate
```


Next, we will generate the *snappy* module in that environment so that it can be called and used later.


#### 6.4 *snappy module generation*

SNAP provides the Python module *snappy* which allows you to access the SNAP Java API from Python. *snappy* requires either a SNAP installation or a SNAP build. The following instructions will guide you through the installation process to have *snappy* working in the RUS Copernicus Virtual Machine. Generic instructions on how to install *snappy* can be found in the following website: <https://senbox.atlassian.net/wiki/spaces/SNAP/pages/24051781/Using+SNAP+in+your+Python+programs>

To start, open a Terminal window and navigate to the bin folder inside the SNAP installation directory (in RUS Copernicus Virtual Machines - */usr/local/snap/*).

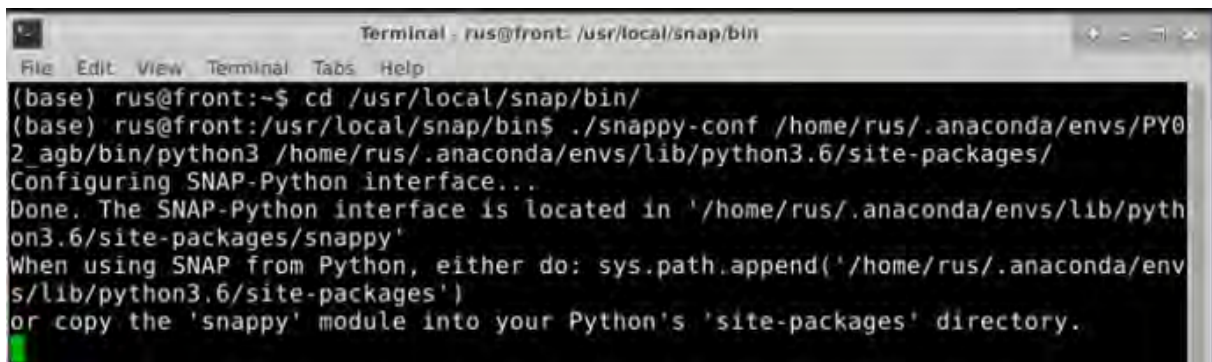
```
cd /usr/local/snap/bin
```

Next, we will generate the Python module *snappy* configured for the current SNAP installation and the Python interpreter of choice set in the *<python-exe>* parameter. In addition, instead of generating it in the default folder (*.snap/snap-python* in the home directory), we will place it in the site-package folder of our recently created conda environment. For that, we will make use of the *<snappy-dir>* parameter (see  NOTE 4).

 NOTE 4: The parameter must be the full path to the Python interpreter executable which you want to use with SNAP (supported versions are 2.7, 3.3 to 3.6)

Following the previous command in Terminal, copy-paste the next one and press *Enter*.

```
./snappy-conf /home/rus/.anaconda/envs/PY02_agb/bin/python3 /home/rus/.anaconda/envs/PY02_agb/lib/python3.6/site-packages/
```



```
Terminal: rus@front: /usr/local/snap/bin
File Edit View Terminal Tabs Help
(base) rus@front:~$ cd /usr/local/snap/bin/
(base) rus@front:/usr/local/snap/bin$ ./snappy-conf /home/rus/.anaconda/envs/PY02_agb/bin/python3 /home/rus/.anaconda/envs/lib/python3.6/site-packages/
Configuring SNAP-Python interface...
Done. The SNAP-Python interface is located in '/home/rus/.anaconda/envs/lib/python3.6/site-packages/snappy'
When using SNAP from Python, either do: sys.path.append('/home/rus/.anaconda/envs/lib/python3.6/site-packages')
or copy the 'snappy' module into your Python's 'site-packages' directory.
```

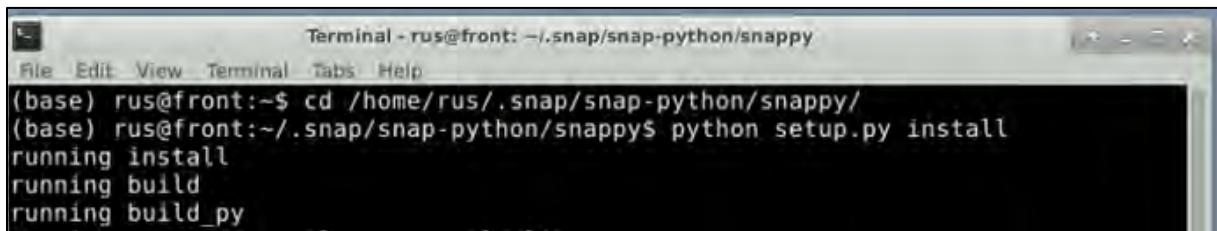
When the message starting with “Done” appears, but the code does not seem to finish, press CTRL+C.

Then change the directory to the directory where we have just generated the *snappy* python module:

```
cd /home/rus/.snap/snap-python/snappy/
```

And finally, we will install the generated module by running the following command:

```
python setup.py install
```



```
Terminal - rus@front: ~/.snap/snap-python/snappy
File Edit View Terminal Tabs Help
(base) rus@front:~$ cd /home/rus/.snap/snap-python/snappy/
(base) rus@front:~/.snap/snap-python/snappy$ python setup.py install
running install
running build
running build_py
```

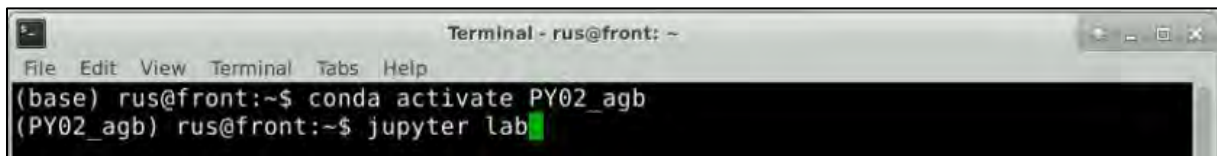
## 6.5 Performing the exercise using Sentinel-2 data in JupyterLab

Once the *snappy* module has been properly generated, we can start our exercise. Activate the *PY02\_agb* conda environment by running the following script in a new Terminal window.

```
conda activate PY02_agb
```

Next, write “*jupyter lab*” and press enter to launch the application. When the environment is activated you will see that the *(base)* at the beginning of the line has changed to *(PY02\_agb)*.

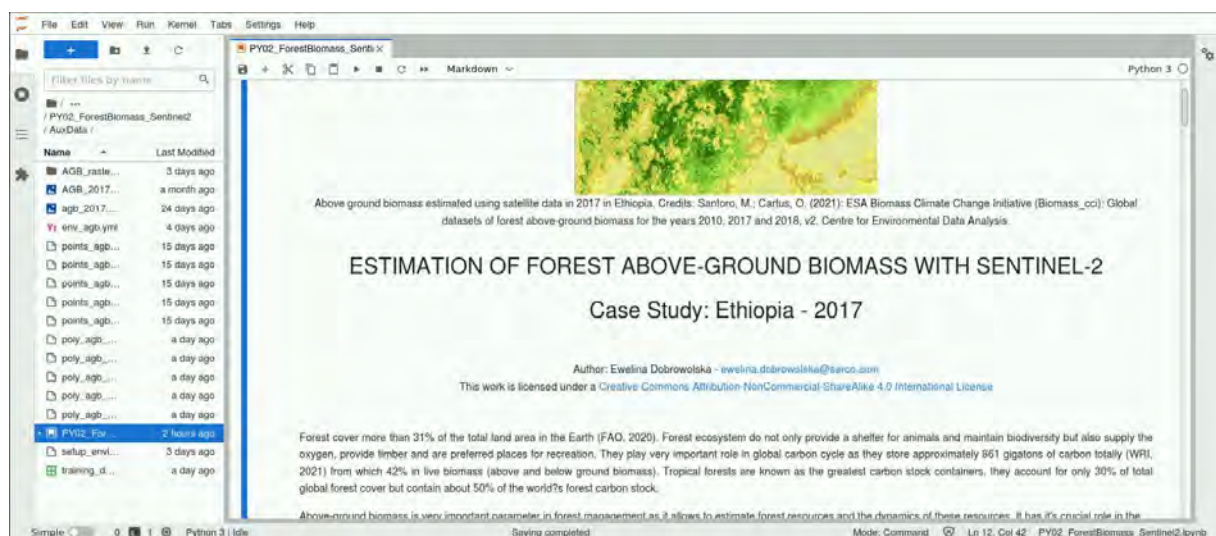
Once open, navigate to the following path inside the Jupyter Lab and open the file *PY02\_ForestBiomass\_Sentinel2.ipynb*



```
Terminal - rus@front: ~
File Edit View Terminal Tabs Help
(base) rus@front:~$ conda activate PY02_agb
(PY02_agb) rus@front:~$ jupyter lab
```

Path → */shared/Training/ PY02\_ForestBiomass\_Sentinel2 /AuxData/*

Once the interface opens, double click on the notebook *PY02\_ForestBiomass\_Sentinel2.ipynb* to open the next tab. The next steps of this exercise are described in detail in the notebook.

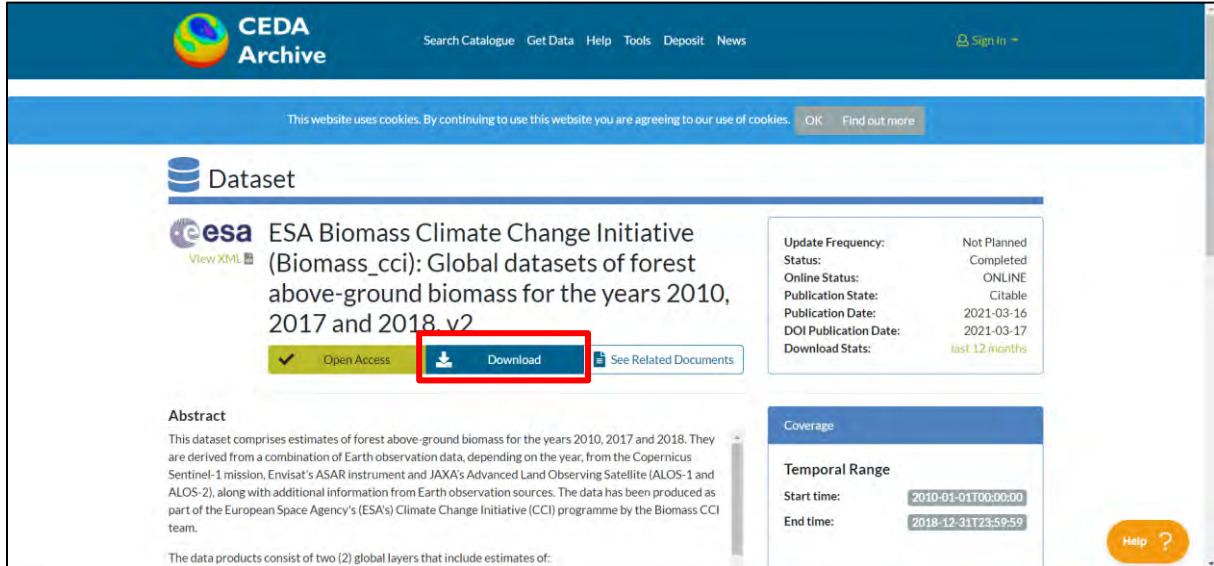


Follow the instructions there to proceed with the training.

## 7 Additional clarifications

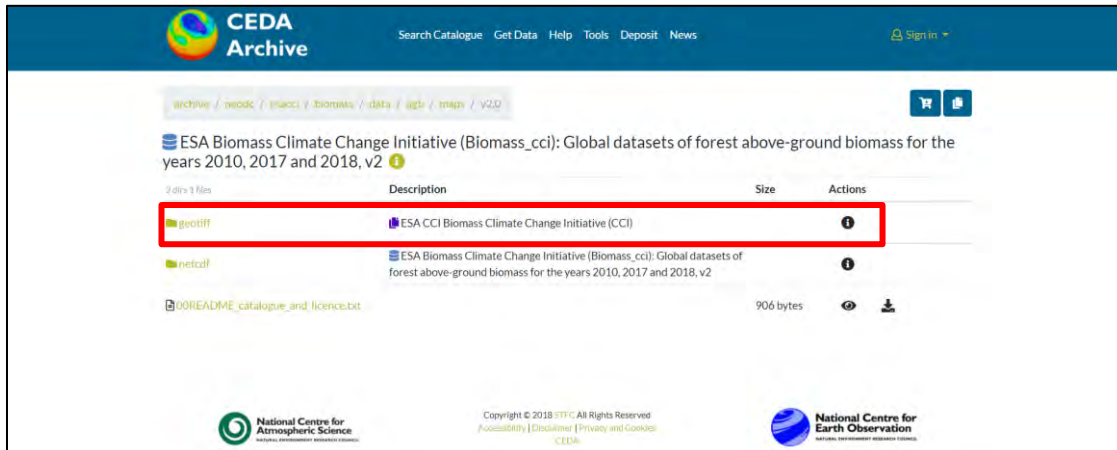
### 7.1 Download reference Above-ground biomass dataset

For this exercise the Above-ground biomass dataset has been downloaded and prepared for you. As a reference data for this exercise we are using a publicly available Global above-ground biomass database prepared by ESA Biomass Climate Change Initiative (Biomass\_cci), which can be accessed under the link: <https://catalogue.ceda.ac.uk/uuid/84403d09cef3485883158f4df2989b0c>



The screenshot shows the CEDA Archive website. The header includes the CEDA Archive logo and navigation links: Search Catalogue, Get Data, Help, Tools, Deposit, News, and a Sign In button. A cookie notice is displayed below the header. The main content area is titled 'Dataset' and features the ESA Biomass Climate Change Initiative (Biomass\_cci) dataset. The dataset title is 'ESA Biomass Climate Change Initiative (Biomass\_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2'. Below the title, there are three buttons: 'Open Access', 'Download' (highlighted with a red box), and 'See Related Documents'. To the right of the dataset title, there is a table with metadata: Update Frequency: Not Planned, Status: Completed, Online Status: ONLINE, Publication State: Citable, Publication Date: 2021-03-16, DOI Publication Date: 2021-03-17, and Download Stats: last 12 months. Below the dataset title, there is an 'Abstract' section. The abstract text states: 'This dataset comprises estimates of forest above-ground biomass for the years 2010, 2017 and 2018. They are derived from a combination of Earth observation data, depending on the year, from the Copernicus Sentinel-1 mission, Envisat's ASAR instrument and JAXA's Advanced Land Observing Satellite (ALOS-1 and ALOS-2), along with additional information from Earth observation sources. The data has been produced as part of the European Space Agency's (ESA's) Climate Change Initiative (CCI) programme by the Biomass CCI team. The data products consist of two (2) global layers that include estimates of:'. To the right of the abstract, there is a 'Coverage' section with a 'Temporal Range' table. The table shows the Start time: 2010-01-01T00:00:00 and End time: 2018-12-31T23:59:59. A 'Help' button is located at the bottom right of the page.

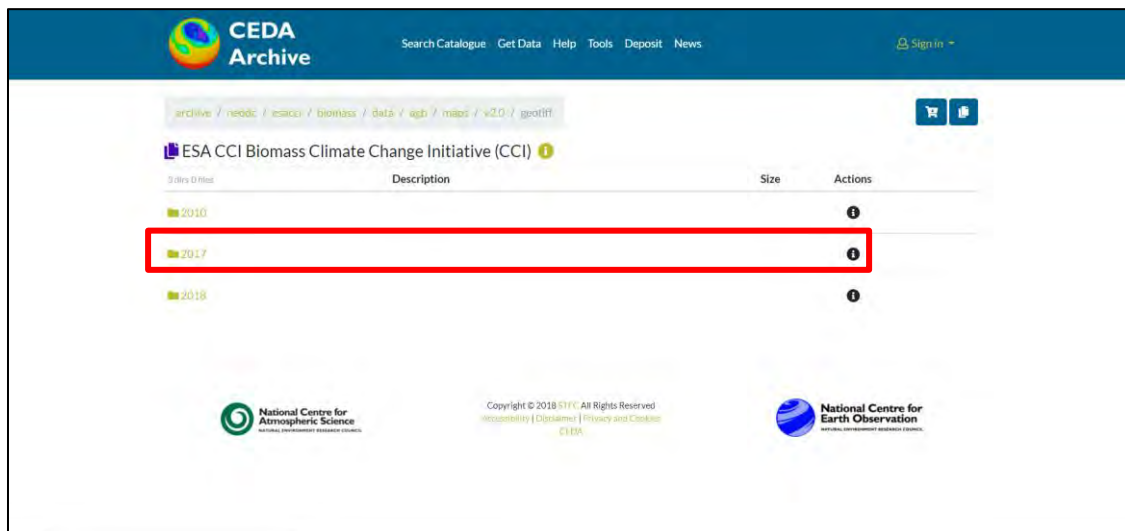
Press **Download** to retrieve reference raster database. Select **"geotiff"** as the format of images we want to use.



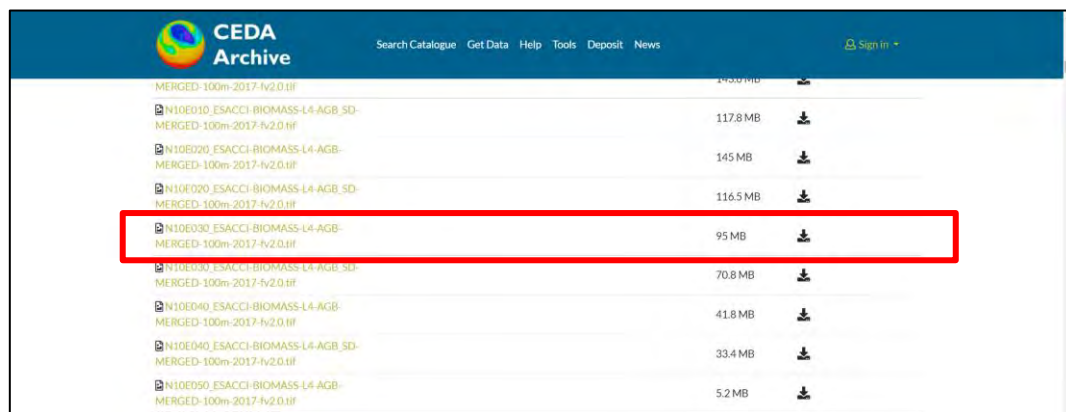
The screenshot shows the CEDA Archive website. The header includes the CEDA Archive logo and navigation links: Search Catalogue, Get Data, Help, Tools, Deposit, News, and a Sign In button. A breadcrumb trail is displayed: archive / metadata / biomass / data / geotiff / maps / v2.0. The main content area shows the dataset title: 'ESA Biomass Climate Change Initiative (Biomass\_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2'. Below the title, there is a table with columns: Description, Size, and Actions. The table lists three files: 'geotiff' (highlighted with a red box), 'netcdf', and '000README\_catalogue\_and\_licence.txt'. The 'geotiff' file is described as 'ESA CCI Biomass Climate Change Initiative (CCI)'. The 'netcdf' file is described as 'ESA Biomass Climate Change Initiative (Biomass\_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2'. The '000README\_catalogue\_and\_licence.txt' file has a size of 906 bytes. At the bottom of the page, there are logos for the National Centre for Atmospheric Science and the National Centre for Earth Observation, along with a copyright notice: Copyright © 2018 NERC. All Rights Reserved. Accessibility | Statement | Privacy and Cookies | CEDA.

Now navigate to the year **2017**.





Database consists of raster tiles which cover all the globe and represent Above-ground biomass values in tons/ha represented by pixels in resolution of 100 m. To download correct tile you need to know the geographical position of you study area. We are going to use database for Ethiopia so we will search for the tile which covers area at 10 degrees North latitude and 30 degrees East longitude.



Downloaded original product is stored in the Path:  
 /shared/Training/PY02\_ForestBiomass\_Sentinel2/AuxData/2017\_N10E030\_ESACCI\_BIOMASS\_L4-AGB-MERGED-100m-2017-fv2.tif

THANK YOU FOR FOLLOWING THE EXERCISE!

## 8 Further reading and resources

Askar, Nuthammachot, N., Phairuang, W., Wicaksono, P., & Sayektiningsih, T. (2018). Estimating aboveground biomass on private forest using sentinel-2 imagery. *Journal of Sensors*. <https://doi.org/10.1155/2018/6745629>

Haywood, A., Stone, C., & Jones, S. (2018). The potential of sentinel satellites for large area aboveground forest biomass mapping. *International Geoscience and Remote Sensing Symposium (IGARSS)*, 2018-July(July), 9030–9033. <https://doi.org/10.1109/IGARSS.2018.8517597>

Khan, M. R., Khan, I. A., Baig, M. H. A., Liu, Z. jia, & Ashraf, M. I. (2020). Exploring the potential of Sentinel-2A satellite data for aboveground biomass estimation in fragmented Himalayan subtropical pine forest. *Journal of Mountain Science*, 17(12), 2880–2896. <https://doi.org/10.1007/s11629-019-5968-8>

Pham, T., Yoshino, K., Le, N.N., & Bui, D. (2018). Estimating aboveground biomass of a mangrove plantation on the Northern coast of Vietnam using machine learning techniques with an integration of ALOS-2 PALSAR-2 and Sentinel-2A data. *International Journal of Remote Sensing*, 39, 7761 - 7788. DOI: [10.1080/01431161.2018.1471544](https://doi.org/10.1080/01431161.2018.1471544)

Santoro, M.; Cartus, O. (2021): ESA Biomass Climate Change Initiative (Biomass\_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2. Centre for Environmental Data Analysis, 17 March 2021. doi:10.5285/84403d09cef3485883158f4df2989b0c. Database can be access: <https://data.ceda.ac.uk/neodc/esacci/biomass/data/agb/maps/v2.0/>.

FAO. (2020). *Global Forest Resources Assessment 2020 – Key findings*. Rome. <https://doi.org/10.4060/ca8753en>

World Resources Institute. (2021) *Global Forest Watch* – accessed 17 July 2021. <https://www.wri.org/initiatives/global-forest-watch>

### 8.1 SW resources

Python tutorial: [Python for beginners](#)

Jupyter Notebook Documentation: [Documentation](#)

SNAP and snappy: <https://approach.readthedocs.io/en/latest/setup.html>

Sen2Cor Plugin: <https://step.esa.int/main/snap-supported-plugins/sen2cor/>

RUS training on [processing data with python and snappy](#) for Anaconda and Jupyter Notebook introduction.

### 8.2 Additional resources of information about global biomass distribution

ESA Biomass Climate Change Initiative (Biomass\_cci): Global datasets of forest above-ground biomass for the years 2010, 2017 and 2018, v2

<https://catalogue.ceda.ac.uk/uuid/84403d09cef3485883158f4df2989b0c>

Pan-tropical biomass map: <http://lucid.wur.nl/>

ESA DUE Globbiomass project: <https://globbiomass.org/products/global-mapping/>

Comparing Global Carbon Maps application on the Ecometrica Mapping

Platform: <https://carbonmaps.ourecosystem.com/interface/>

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[RUS Copernicus Training](https://www.youtube.com/channel/UCv33333333333333333333)



[RUS-Copernicus website](https://www.rus-copernicus.org)



[RUS-Copernicus Training website](https://www.rus-copernicus.org/training)