PLANET CHANGE

Agriculture in Space:
Space for crop optimisation

Teachers manual

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Erasmus+ Programme
of the European Union

Planet change is the short name of an EU Erasmus+ project aimed at VET teachers and their students. With small activities, the idea is to create awareness about sustainability and acquire 21st century skills. All this is done in a technical context, mostly from space technology.

www.planetchange.eu

Contents:

1. General information

Duration: 2 x 45 minutes

Target group: 16-20 y.o.

European qualifications framework level: 3-4

Teacher preparation: study background information, materials listed with the activity.

Students will use *EO Browser* to complete the activity. An overview/tutorial is included as part of the activity. It is recommended a basic approach to the use of this application before starting the task. This can be done by following the tutorial that can be found at this link. Note that this is not using the latest version of *EO Browser* so some details of the user interface may appear a little different. However, it gives a nice overview about the main functionalities needed for this activity. It is also recommended to see this video to review the basic principles about how satellites images are built.

Topic

Themes: Agriculture, climate change

Keywords: sustainability, satellite images, agriculture, food production, data analysis, earth observations, automation, 21st century skills

Activity

Goals

The objective of the task is to explore how the use of satellite images can help to improve monitoring and automation for food production, being an important tool for agricultural development in difficult areas and for the optimization of crops.

Learning Objectives

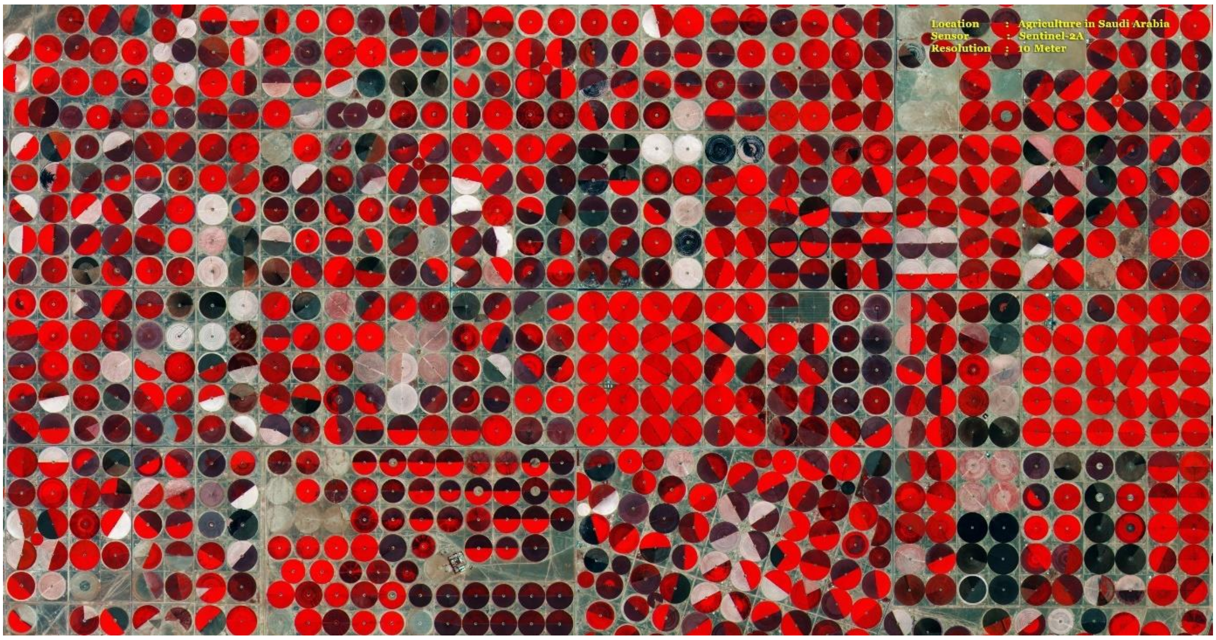
The student will get better knowledge and training about

1. The importance of using space:
    a. How space helps in achieving Sustainable Development goals from the United Nations
    b. How to use satellite images to monitor agriculture and crop optimization

2. Earth Observations basic concepts.
3. How satellite images can help to optimise process for food production.
4. Use of online tools to analyse how satellite imagery provides information on the state of the crop, including how to differentiate between different vegetation, the optimum time for harvest and when to irrigate the fields.
5. Training of 21st Century skills including:
    a. Problem solving
    b. Innovation
    c. Technology skills and digital literacy
    d. Collaboration and communication skills
6. How the abilities learned in the school can help to a future career in the space sector

Summary
Food production optimization strategies are extremely relevant to achieving some of the main United Nations sustainable development goals, including non-poverty and zero hunger. In this assignment, students will learn how to use satellite imagery to obtain information about crop fields to help optimize food production. They will explore how these images can help to analyse the state of the vegetation, optimize harvests, and develop new agricultural fields in difficult areas, for example, in dry fields. They will actively use satellite images and real data and discuss how to automate the food production process. As an extra challenge, they will learn to program a simple code to display a particular vegetation status, for example, only the crop that is ready to be harvested in an area.

2. Introduction



Sentinel 2 monitoring agriculture in Saudi Arabia. Light red means healthy crop. Credits: ESA

Sustainable Development Goals:

The Member States of the United Nations adopted in 2015 an ambitious agenda for Sustainable Development. The main objective is to provide a shared blueprint for peace and prosperity for people and the planet, now and in the future. At the Center are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries working together in a global partnership. They recognize that ending poverty and other deprivations must go hand in hand with strategies that improve health and education and reduce inequality, while promoting actions to reduce climate change and preserve our oceans and forests.

Several important SDGs can only be achieved using the important information and new opportunities that satellites can provide. For example, the first two SDGs "no poverty" and "zero hunger" imply a lot of development to optimize new strategies for food production, as well as to open up new agricultural fields in remote and difficult areas. The use of satellite images is crucial to achieve these goals.

Satellites and food production:

Satellites are an important tool in optimizing agriculture. Satellite-based monitoring of soil properties and crop conditions, provides valuable information to assess land use, predict yields, analyse seasonal changes, and help implement policies. for sustainable development. This valuable information can also be used to monitor drought-induced changes in agricultural production, declining land productivity, and soil degradation due to overcultivation, or inadequate irrigation. Maps of agricultural areas taken from satellites allow estimates of production of large extensions of the crop that can be used to develop strategies to guarantee food security in vulnerable areas.

Satellites for agriculture: how?

Several satellites are equipped with complex sensors that allow special images to be taken to help in various fields, for example, in agricultural monitoring. We will use one of the most important satellites for this purpose, Sentinel 2. This satellite is part of the Copernicus family developed by the European Space Agency. All the information produced by Sentinel 2 is not only very powerful but also gratis, and easily accessible from platforms like *EO Browser*, that we will use in this activity. If you are interested in reading more about Copernicus family visit this site, and about Sentinel 2 from this site.

But how is it possible to extract so much information from these images? To understand how the process works, it's important to start by clarifying that satellites like Sentinel 2 don't take normal images like we take with our mobile cameras. Instead, they take multiple images simultaneously. For example, Sentinel 2 does not take a single normal colour image, but rather at least 3 simultaneous images in different areas of visible light that are then combined to create a normal colour image. Sentinel 2 cameras have filters that only allow an area of visible light to be received. This is called a band. Think about the components of visible light. These are colours, like in a rainbow. To build a normal true-colour image, Sentinel 2 takes one image that is only sensitive to the red part of visible light, one to green, and one to blue. Combining these 3 bands creates a true colour image!

But why so much complexity? The reason is that by using this strategy, the satellites can not only create a true colour image, but also calculate how much energy is received from these different bands. And this comparison can provide a lot of valuable information! Satellites observe reflected sunlight from an object. The relative amount of energy reflected in the different bands, red, green, and blue, gives information about what we are observing and various characteristics. For example, fresh vegetation is green because it reflects more green light than red and blue. But when it's drying, it starts to reflect less green and a little more red. That is why it begins to change to a yellowish colour. Knowing these relationships, we can infer from space a lot of information about what we are observing.

Furthermore, the most important feature that satellites have for monitoring vegetation is the possibility to observe not only visible light but also infrared (IR) radiation. Infrared gives information about temperatures. If an object inherently emits a large amount of IR, it has a high temperature. On the other hand, if an object absorbs IR radiation from the sun it also heats up, but if it reflects it, its temperature will not increase. We cannot see infrared light, but it is emitted and reflected from everywhere, day and night. Cats' eyes are somewhat sensitive to infrared and therefore can "see" much better at night. The amount of infrared radiation reflected by different objects is an intrinsic characteristic. Mapping this different amount of reflected IR radiation produces another type of image where we can recognize different bodies and access additional important information.

Fresh vegetation reflects a lot of infrared light, much more than green. This allows the vegetation to avoid heating and consequently death. The amount of IR reflection depends largely on the type of vegetation and its state: whether it is fresh, dry, diseased... Plotting images that combine the infrared and some visible bands, particularly the red band, is the best approach to study the vegetation. These images are called *false color images* since the colors are not real. In these images a color is selected, for example red, not to plot the red band but to indicate how much IR is reflected. In this case, brilliant light red will mean a lot of IR is being reflected, and dark red areas will mean less IR. In this way, the colors are not real, but we can "see" and analyze the infrared information.

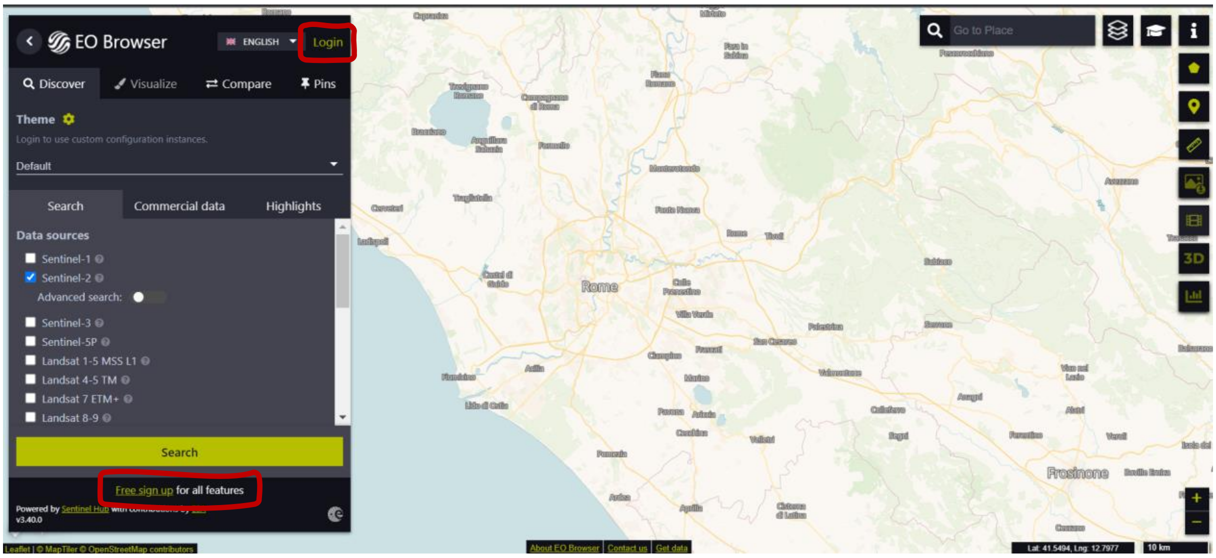
If you want to know more about these basic principles, check this video (30 min) *Description of the activity*

3. Part 1: Satellites eyes help from space

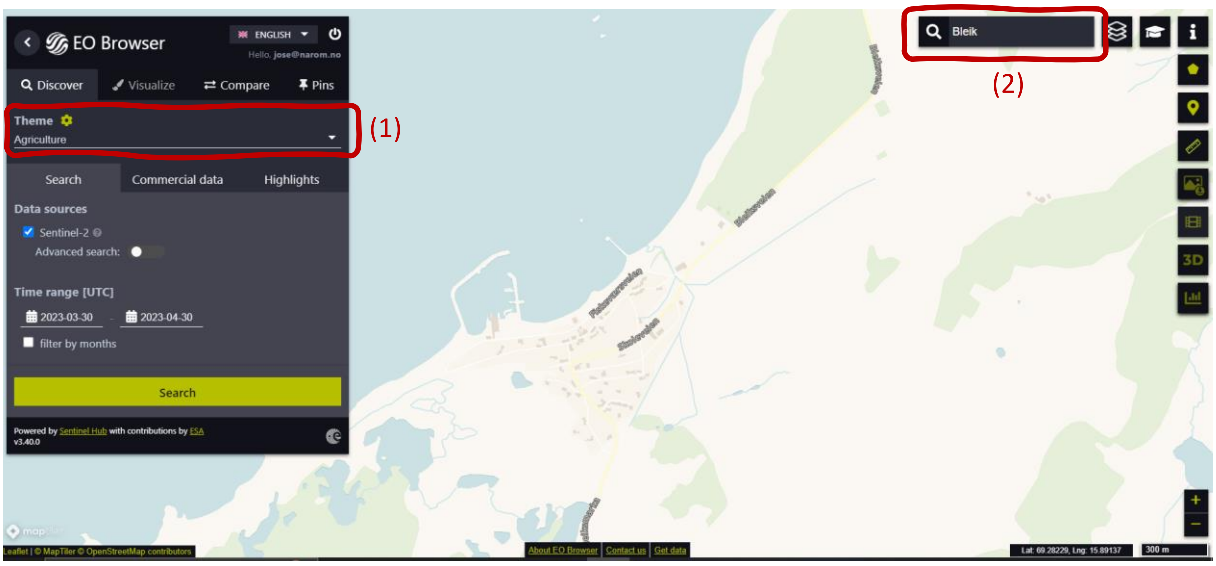
Preparations: *EO Browser* introduction

This activity uses *EO Browser*. This section goes through the basic functionalities. This should be enough to learn the main features needed to complete this activity. You can find a more complete tutorial at this link but note that this does not use the latest version of *EO Browser* so some details of the user interface may appear a little different.
EO Browser is a free application to access to satellite images. All the Copernicus family is included. Using *EO Browser* we can analyse the entire collection of Sentinel 2 images, which is the satellite we will use for the task. We can access not only to the raw information but also to processed images ready to show relevant information for several purposes, including vegetation and agriculture monitoring.

Follow the steps below to practice the main features of *EO browser* needed for this task:
Open the application using the following link: https://apps.sentinel-hub.com/eo-browser/ . You need to register to be able to access all the functionalities needed for this activity. This is a free and easy task. Click over "Free sign up" and fill up the form. After receiving your account user and password, login using this information.

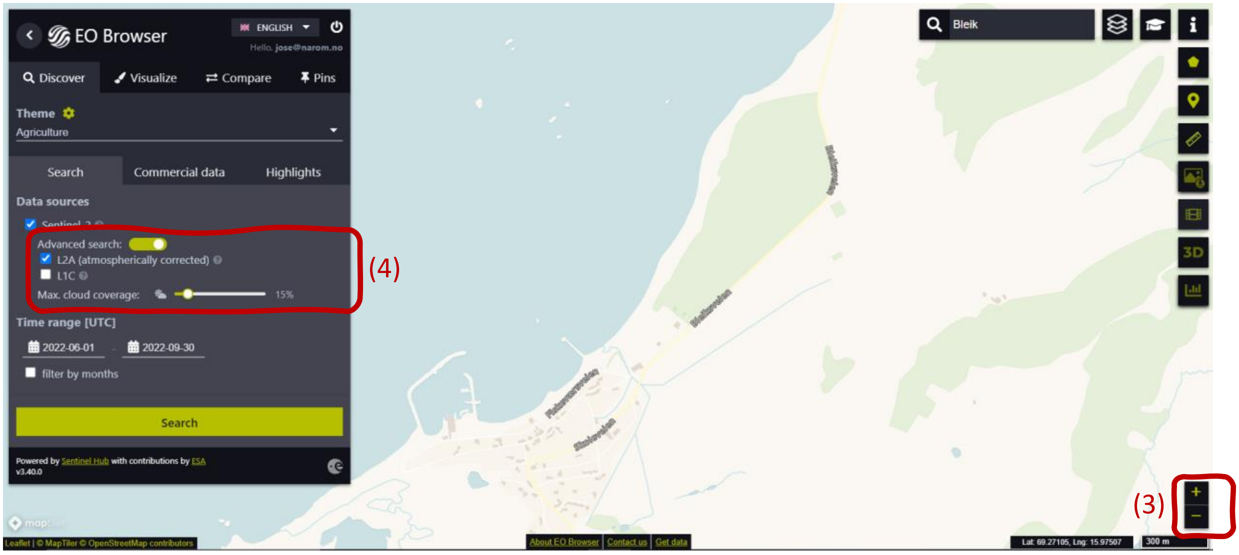


Up to the left, you can find the *Theme* selected. This is set to "Default" when the application starts. We can access to other themes by clicking and selecting in the theme list. Select "Agriculture" – see next image (1). The application will display only the relevant features for this theme. For example, now we see only Sentinel 2 in data sources since this is the satellite for monitoring agriculture. The area we will explore is Bleik, in the north of Norway. This is done by writing this info in the searching place area (top-right in the user interface) (2).

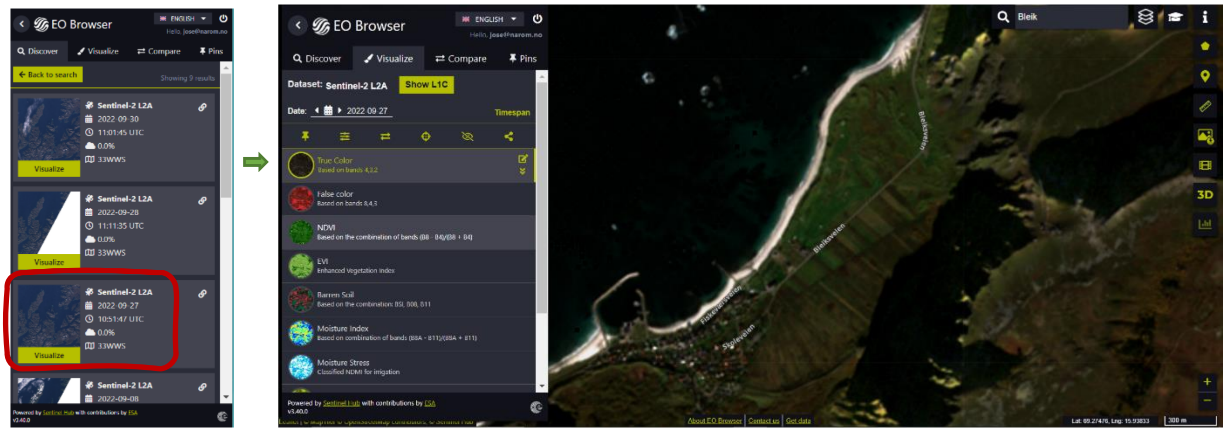


The next steps are the following (see next image):

- Select the area to explore like the one presented below: to proceed use the Zoom buttons (3) and move around by moving the mouse while holding down the left button.
- Activate "Advanced search" (4): Select L2A (normally is selected by default") and set "Max cloud coverage" down to around 15%. This will discard all the relative cloudy images.



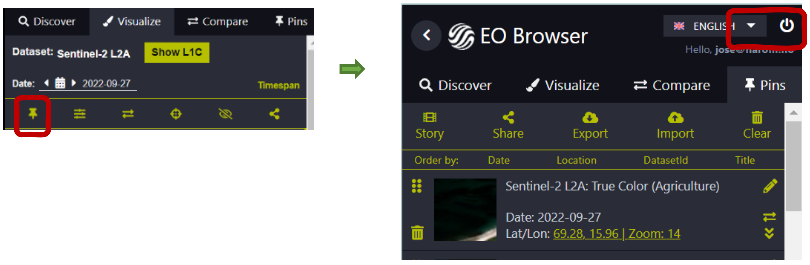
Now we proceed selecting the "Time range" to define the time interval for searching images. Click in the two dates (small calendars). In this case, we select from **2022-06-01** to **2022-09-30**. Click over the button Search (green button, see picture above). The Search windows changes into a new window showing the Results. We proceed choosing one image. Select the image taken the **27 September**.



EO Browser displays the satellite image. The interface offers different kind of images (products). By default, it displays the *True Color* image, like these from our normal cameras. This is the one we use in this introduction.

Pin your image! Before proceeding, we need to *pin* this image. This option will save it so we can use it afterwards. Click over the pin button to save it. In the main menu, the window will change to display the *Pins* section. Now can see the image added to your list (see below).

Visualize again the image by selecting *Visualize* Visualize from the main menu.



Activity 1:

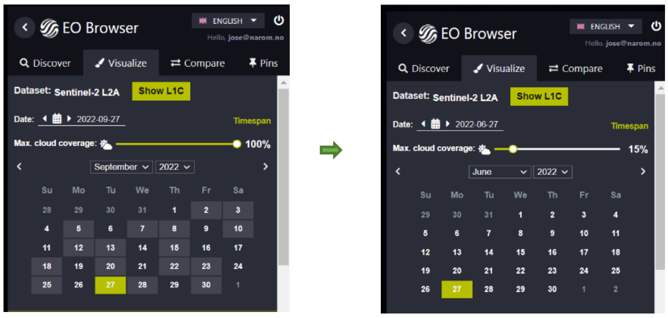
Use the satellite image obtained in the preparations.

i. Analyse the satellite image. Describe the place. Take notes of your analysis.

ii. Now concentrate in the vegetation features and explain further details about what you can see. Do you think we have agriculture in the area? Explain. Do you see interesting features? Remember to take notes.

Activity 2:

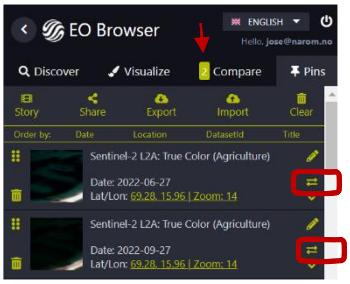
Let's compare this satellite image with another taken earlier in the summer. Click over the calendar icon of the "Date" field (see below). The calendar opens showing all the days that Sentinel 2 has observed the area. By default, the calendar shows all images, with no cloud restrictions (100%). Set the *Max. cloud coverage* back to 15%. Select June to consult the available images. We only have one image for this coverage, taken on June 27. Select it by clicking on the day.



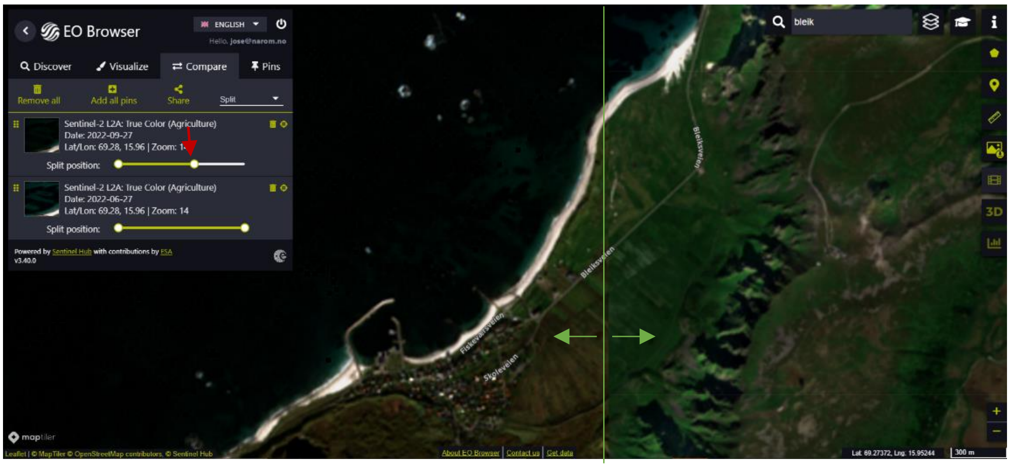
Pin the image! Proceed as before and pin this image. Use the button . Now you will see the two images in *Pins* section. Remember that you can go back to visualize the image by selecting *Visualize* from the main menu.

Let's compare the images: You can easily compare the images. Proceed as follow:

- In the main menu click in the *Pins* section
- Select the images you want to compare by clicking in the "add to compare" icon . In this case we will select 2 images. You can see that the number showing the images selected appears in the Compare section.



- Select the section *Compare*. The program will display the two images, one on the top of the other. You can uncover to see the one below by using the "Split position" bar. You can gradually uncover and cover to compare the images:



Compare the images:

i. Describe the main differences in the vegetation. Take notes of your analysis.

ii. **Work in groups** of 3 students. Discuss your findings and notes of the previous tasks. Designate one person of the group to take notes about your answers.

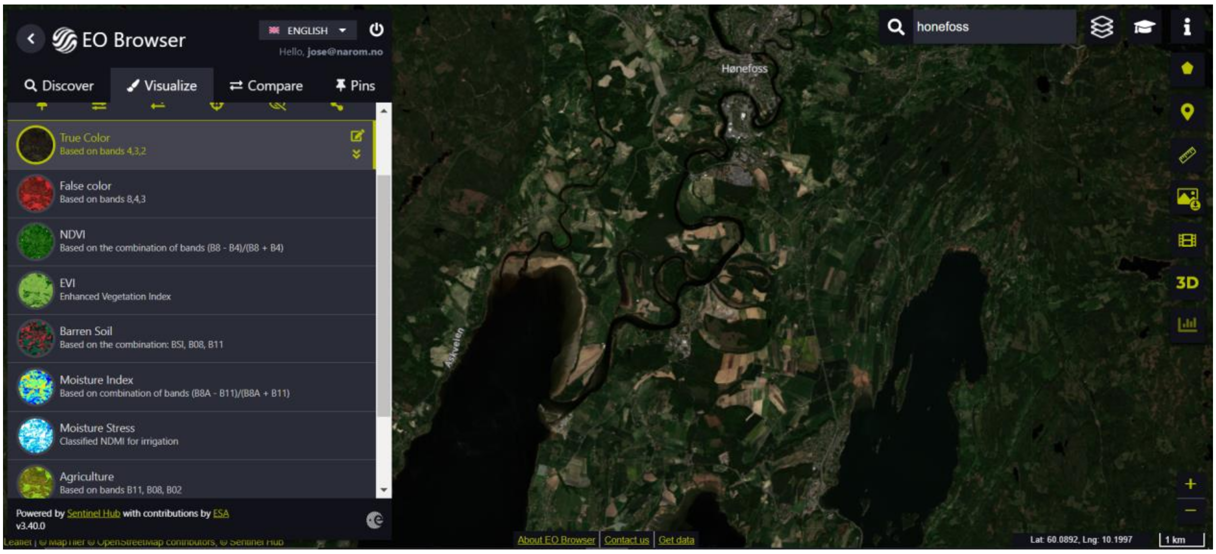
   a. Do you think these True Colour images can be helpful for agriculture. Explain
   b. Do you think they can help to improve productivity in the agriculture sector?
   c. Discuss the advantages and limitations of these Sentinel 2 images comparing to other, for example those provided by *Google Earth*.

4. Part 2: Satellites for optimising agriculture: How?

We will analyse further types of images available from *EO Browser* and how they can provide information about the crop status. As it was mentioned in the introduction, these images will use a combination of infrared and optical bands. We will use an area close to Oslo as example where we can see different kind of land use. This example you can apply afterwards to analyse a local area dedicated to agriculture close to where you live.

Activity 1:

We start displaying a *True Colour* image of the mentioned area. Proceed step by step following the previous section (preparations). Remember to ***log in*** to be able to access to all features and to set the theme to ***agriculture***. Note that this case uses the area "Honefoss" (Norway), but you can use your own area of interest. Search "Honefoss", set the time range from the 1st to 30th June 2022, and select the image taken the **6th of June 2022**. Zoom and move around to show an area like the following:



Remember to **pin this image** as indicate in the previous tasks. Come back to the visualisation by selecting *Visualize* from the main menu.

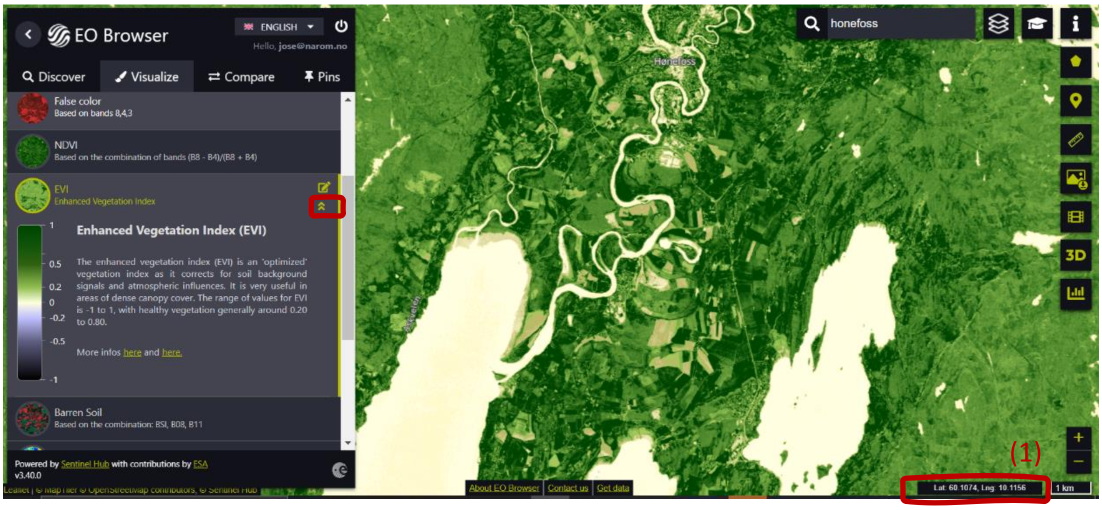
To proceed with further analysis for agriculture we will start analysing the **vegetation index**. This is a number, normally from -1 to 1, to indicate how much fresh vegetation we have in an area. A higher number normally means more healthy vegetation. This is calculated by combining the reflection from infrared and visible bands. Sentinel 2 uses for (near) infrared the band B8, and for visible the bands B4 (red), B3 (green) and B2 (blue).

The *NDVI* (Normalized Difference Vegetation Index) is the most widely used. It is based on the B8 (infrared) and B4 (red) bands. However, it becomes saturated very easily in areas of dense vegetation. For these cases, like ours, it is better to use the ***EVI*** index (Enhanced Vegetation Index). We begin our analysis using this index.

Let's proceed analysing the ***EVI*** image and comparing with the *True Colour*.

i. Display the EVI image from the list of available products (types of images). Remember to **pin the image**. You can access o further information about EVI using the icon at the right of the product name (see below).

Very dark green (over 0.5) means very healthy (dense, fresh) vegetation, while light greenish tonalities (between around 0.2 and 0.5) mean that the status and/or density is not so optimal. Values around 0 means no vegetation (water for example). This visualisation can give a good idea of the status of the crops.

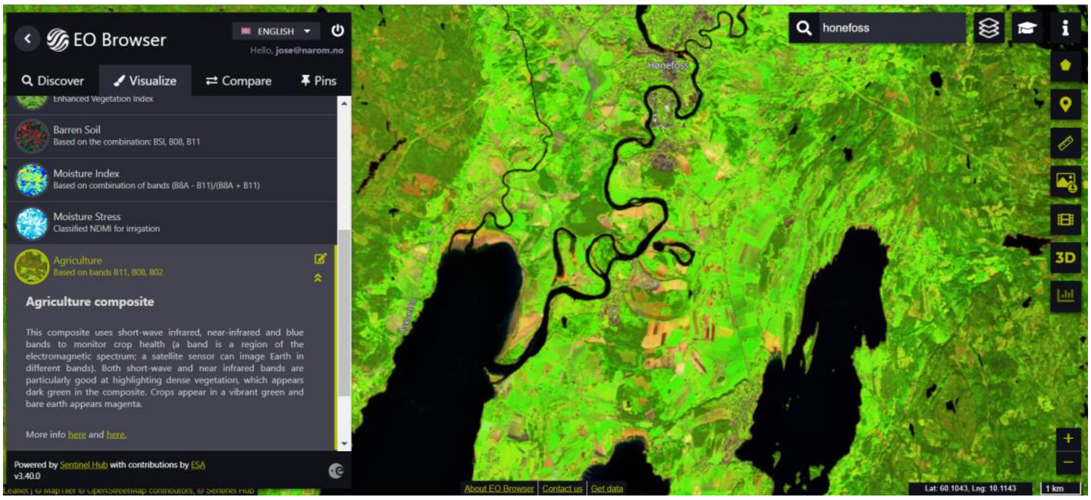


Analyse the satellite image obtained. Describe in general what you see. What it is more predominant: complete healthy vegetation, or other types? Use the coordinates values to select some examples -see above (1). Take notes of your analysis.

ii. Compare the *True Colour* and the *EVI* images using the procedure explained in the previous section. Focus in the area marked below. What can you see in the True colour image? What additional information add the EVI image? Search for additional areas and discuss the additional information that ENVI images add.

We now focus on the ***Agriculture*** product. This uses 2 infrared bands B11 and B8 and the blue band B2. These blend nicely to clearly show where the crops are! Both infrared bands are particularly good at highlighting dense vegetation. Using this combination, composite and non-agricultural vegetation, such as forest, appears dark green while crops appear in a vibrant green, shining brighter if their condition is very good. Soils lacking vegetation appears more brownish. The advantage is that we can now distinguish good crops from other vegetation, such as forests.

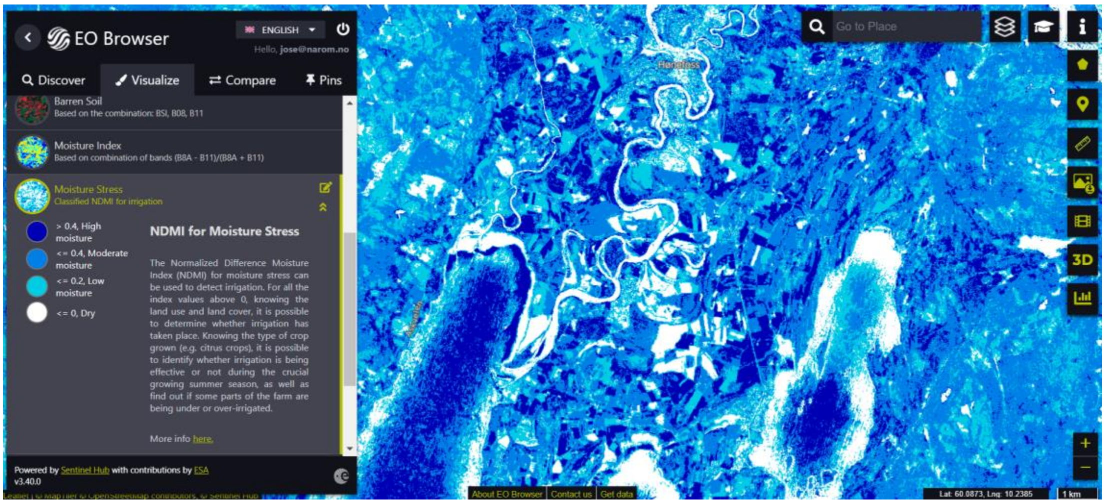
iii. Display the *Agriculture* image from the list of available products (types of images). Remember to **pin the image**. Analyse the satellite image obtained. Describe in general what you see. Use the coordinates values to indicate the following: two crop areas presenting a very good status, two crop areas in a non-optimal status, two other vegetation areas like forests. Take notes of your analysis.



iv. Compare the *Agriculture* and the *EVI* images using the procedure explained in the previous section. Use the coordinates selected above for the 2 crops areas presenting a very good status, 2 crop areas in a non-optimal status, and 2 other vegetation areas like forests. Explain the *EVI* information for these cases. Based on that explain a general correlation between the *Agriculture* and *EVI images*.

What about **irrigation**? Let's see how satellite images can provide information on when a field needs to be irrigated. The main index for this purpose is the *normalized difference moisture index* (NDMI). It uses a combination of 4 infrared bands to determine vegetation water content and monitor droughts. Another practical index to extract this information is the **Moisture Stress** index. This is based on NDMI and can be used in a simpler way to detect irrigation. In this case, for all the index values above 0, knowing the land use and land cover, it is possible to determine whether irrigation is needed or has taken place. Knowing the type of crop grown, it is possible to identify whether irrigation is being effective or not during the crucial growing summer season, as well as find out if some parts of the farm are being under or over-irrigated.

v. Display the *Moisture Stress* image from the list of available products (types of images). Remember to **pin the image**. You can access to the explanation of the different colours by using the icon at the right of the product name (see below). Analyse the satellite image obtained. Use the coordinates values displayed at the bottom-right of the interface to indicate the following: two crop areas presenting a high moisture status (no irrigation needed), two crop areas presenting a moderate moisture status (irrigation needed probably soon), and two presenting a low moisture status (irrigation now!). Take notes of your analysis.



vi. Compare the *Agriculture* and the *Moisture Stress* images using the procedure explained in the previous section. Search for a couple of good crops areas that are well irrigated, two that may need irrigation soon, and 2 that need irrigation urgently. Use the coordinates values to indicate where the areas are. Explain your selection.

Activity 2:

Let's gather new possibilities.

i. Explain the new possibilities we have now to agriculture production by using these new images based on infrared. Compare with the possibilities having only normal *True Colour* images?

ii. Repeat the previous task (*EVI*, *Agriculture* and *Moisture Stress* analysis) for an agriculture field close to your local area.

5. Part 3: Reflection and next steps

Activity 1

Work in groups. Use the same groups as in the Part 1. Designate one person of the group to take notes of your discussion and final conclusions. Discuss with the following questions.

i. Explain the new possibilities we have now to agriculture production by using these new images based on infrared. Compare with the possibilities having only normal *True Colour* images?

ii. List some decisions that are now possible to take by analysing the satellite images (for example to check if an expected good crop is having problems…)

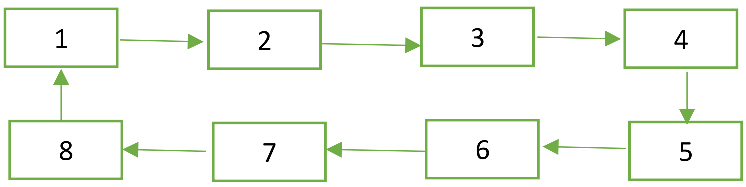
iii. Revise the 17 Sustainable Development Goals (SDGs) of the United Nations. Discuss in your groups how many SDGs will be benefited of improving food production. Explain.

6. Part 4: A possible future in the space sector

Work in groups. Use the same groups as in the previous sections. Discuss the following questions. Designate one person of the group to take notes of your discussion and final conclusions.

i. Lets produce a sequence to **automate agriculture industry based on satellite data**. Use the following actions (green boxes) and order them sequentially (numbers below).

Recommended actions based on computing results.	Waiting confirmation from farmer
Activation of automate processes (example irrigation)	Software to correlate the different products
Software to analyse each product (IR false colour images, EVI…).	Taking satellite images using in visible and infrared bands
Message to farmer (via app)	Data distribution based on geographical coordinates.



ii. Think together with your peers about possible missing actions in the sequence above.

iii. Identify and discuss about possible different specialities (careers) that are needed to achieve this process. Discuss the skills learned at your VET schools that are necessary to complete the process.