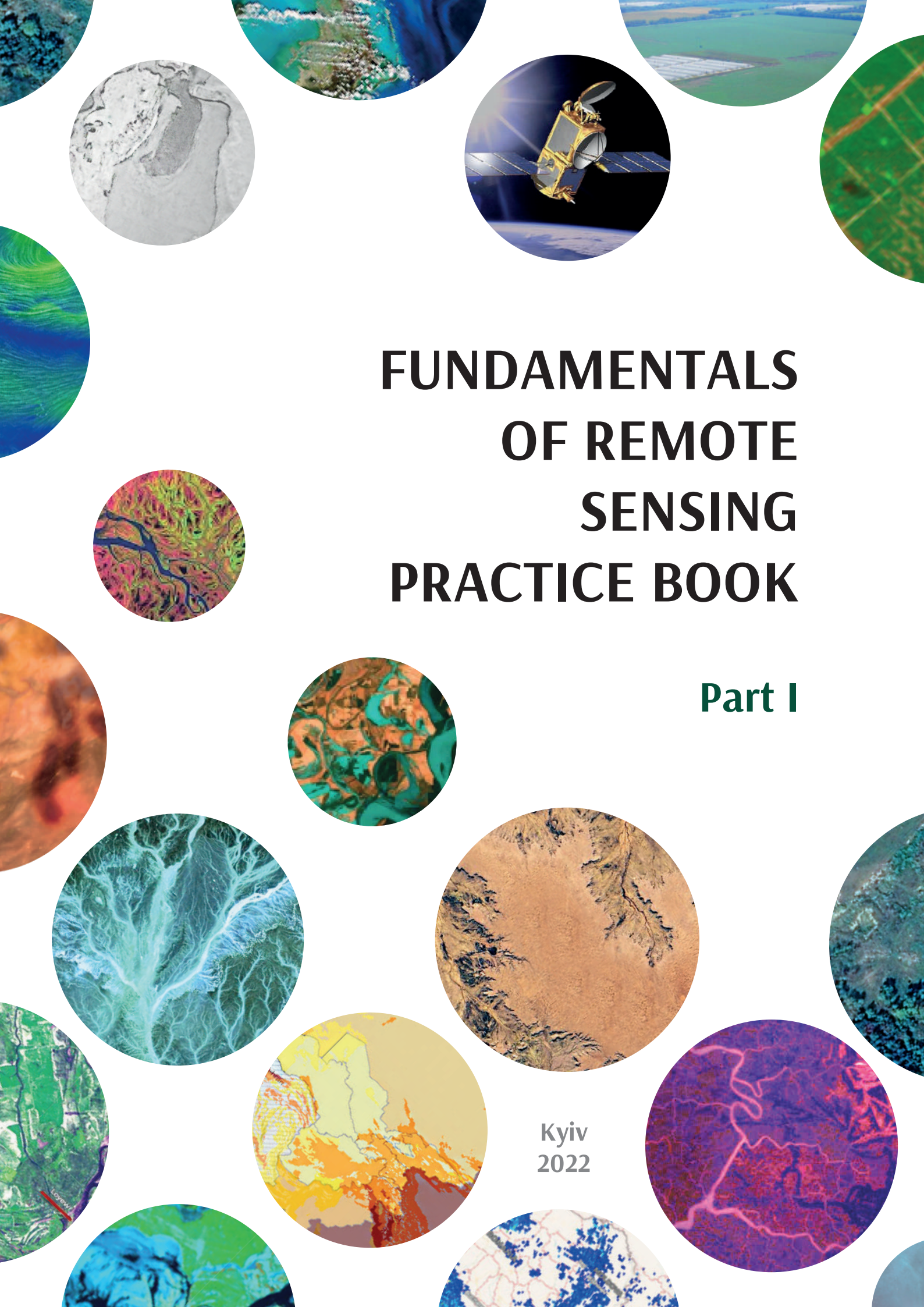


FUNDAMENTALS OF REMOTE SENSING PRACTICE BOOK

Part I

Kyiv
2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
NATIONAL CENTER "JUNIOR ACADEMY OF SCIENCES OF UKRAINE"

S. M. Babiichuk, L. Ya. Yurkiv, O. V. Tomchenko, T. L. Kuchma

FUNDAMENTALS OF REMOTE SENSING

PRACTICE BOOK

Part I

Edited by S. Dovgyi
Academician of the National Academy of Sciences of Ukraine

Kyiv
National Center
"Junior Academy of Sciences of Ukraine"
2022

UDC 528.8
F 97

Authors:

S. M. Babiichuk – Head of Geographic Information Systems and Remote Sensing Laboratory at the National Center "Junior Academy of Sciences of Ukraine", Ph.D. in Pedagogy;

L. Ya. Yurkiv – Coordinator of International Projects at the Geographic Information Systems and Remote Sensing Laboratory, Teaching Methodology Expert at the National Center "Junior Academy of Sciences of Ukraine";

O. V. Tomchenko – Research Fellow at the State Institution "Scientific Centre for Aerospace Research of the Earth of the Institute of Geological Sciences of the NAS of Ukraine", Teaching Methodology Expert at the National Center "Junior Academy of Sciences of Ukraine", Ph.D. in Engineering;

T. L. Kuchma – Senior Lecturer at the National University of Kyiv-Mohyla Academy, Research Fellow at the Institute of Agroecology and Environmental Management of the NAAS of Ukraine, Teaching Methodology Expert at the National Center "Junior Academy of Sciences of Ukraine", Ph.D. in Agriculture

Editors:

V. O. Yemelianov – Director of the State Scientific Institution "Center for Problems of Marine Geology, Geoecology and Sedimentary Ore Formation of the NAS of Ukraine", Corresponding Member of the NAS of Ukraine, Dr. Sci. in Geology and Mineralogy;

R. Hilbert – Doctor of Natural Science, GIS Expert at the Technical University in Zvolen (Slovakia)

Translated from Ukrainian by O. L. Savychenko

Recommended by the Scientific and Methodological Council of the National Center "Junior Academy of Sciences of Ukraine" (Minutes No. 1 dated January 27, 2022)

Fundamentals of Remote Sensing : Practice Book. Part 1. / S. M. Babiichuk, L. Ya. Yurkiv, O. V. Tomchenko, T. L. Kuchma. – Kyiv : National Center "Junior Academy of Sciences of Ukraine", 2022. – 120 p.

F 97

ISBN 978-617-7945-43-6

This Practice Book accompanies the Textbook, Fundamentals of Remote Sensing: History and Practice (S. O. Dovgyi, V. I. Lyalko, S. M. Babiichuk, T. L. Kuchma, O. V. Tomchenko, L. Ya. Yurkiv).

It is packed with hands-on tasks aimed to help students explore the opportunities for application of imagery and data from Sentinel and Landsat Earth observation satellite systems in different research, namely climatic, hydrologic, forestry, agricultural, etc.

This Practice Book may be used by teaching methodology experts and educators of the Junior Academy of Sciences of Ukraine, teachers, and students of higher educational institutions, educators and students who get science-oriented education at specialized educational institutions, as well as by anyone seeking to master the fundamentals of remote sensing and geographic information systems.

UDC 528.8

ISBN 978-617-7945-43-6

CONTENTS

Introduction

Information technology (IT) has become an integral part of our lives. One can hardly imagine a modern student unable to use the Internet, e-mail, or social media. IT, however, may be applied not only in entertainment or communication; in fact, it is also a powerful educational tool. The question is how we can help modern students to reasonably use IT in their learning cycles.

It is difficult not only to explore and systematize large arrays of information we receive daily but also to critically evaluate and apply them to formulate or improve our hypotheses or ideas. Therefore, the pedagogical approaches to the formation of the mid-21st century citizen should be developed at the junction of two paradigms – science education and the use of IT in teaching and learning practices.

The Concept of the New Ukrainian School declares the need to shape students' competence in natural sciences and technologies. Given the fact that natural sciences are inextricably linked with technologies such as geographic information systems and remote sensing, the modern educational cycle must be organized in such a way as to ensure that students both acquire basic theoretical knowledge and learn how to apply such knowledge along with IT in hypothesis formulation, geodata accumulation, research, and analysis.

The GIS and Remote Sensing Laboratory at the Junior Academy of Sciences of Ukraine, National Center (JASU), focuses on the development, adaptation, and testing methods of GIS and Remote Sensing application in the educational cycle through the prism of science education. In September 2018, the JASU became the first organization in Ukraine to receive the status of the Copernicus Academy. The Copernicus Academy connects European universities, research institutions, and business schools around the world. The goal of the network is to promote and develop the use of Earth Observation data in various fields. The Copernicus Academy is a programme launched by the European Union that offers educational and information services provided by the Sentinel satellites.

In this revised and updated edition of the Practice Book on the fundamentals of remote sensing, you will find information about artificial satellites orbiting Earth, learn how remote sensing data may be used to assess emergencies, monitor water bodies, agricultural lands, and volcanic activity in *EO Browser*, and explore the educational opportunities offered by Google Earth Pro virtual globe, ArcGIS Online and NASA resources.

Artificial Satellites Orbiting Earth

In addition to the Moon, a well-known natural satellite, our planet is orbited by a large number of man-made satellites that monitor Earth and collect various information every day.

Are all artificial satellites used for their intended purpose these days? Apart from satellites designed for gathering information, what else orbits our planet?

Task 1

Find out how many people are in space right now.

Consult www.howmanypeopleareinspacerightnow.com for the latest number of astronauts and their details.

Check yourself

How many astronauts are currently aboard the International Space Station?

_____

What countries are they from?

_____

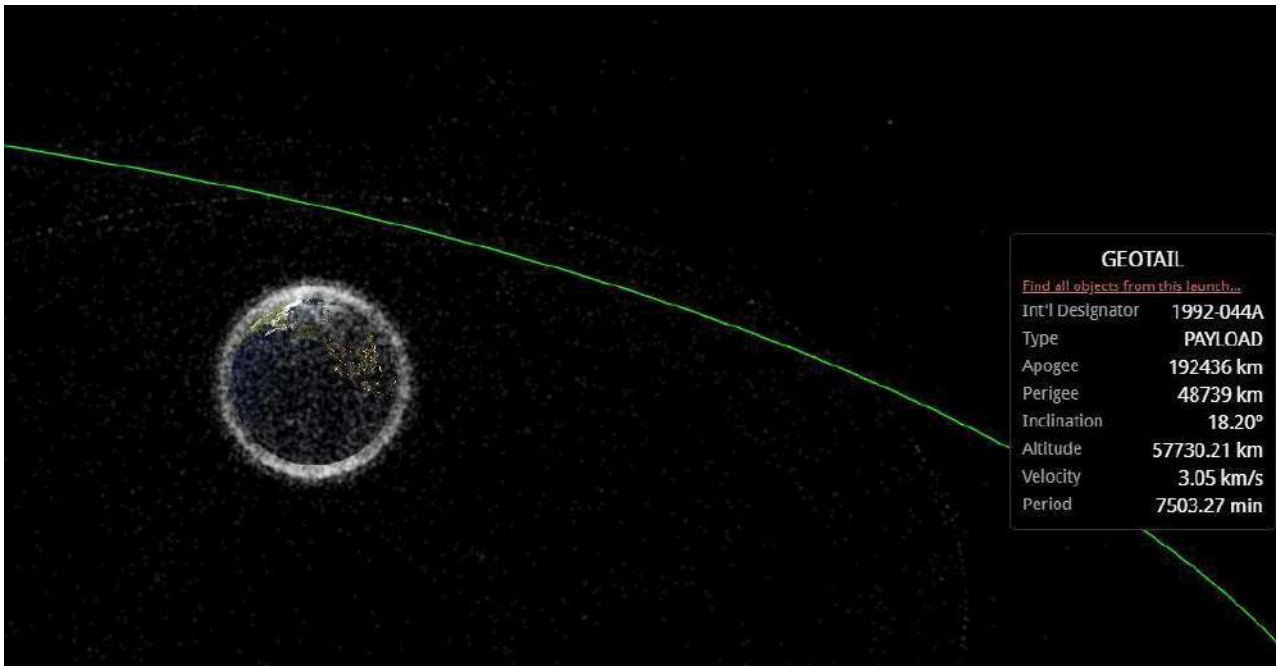
Task 2

Find the spacecraft with the longest rotation period, i.e. the largest orbit.

For more information go to http://stuffin.space/.

The satellites are highlighted on the map in blue while spacecraft are shown in red and space debris in grey.

Using the mouse, you can zoom in or out to focus on any object. When you hover over an object with the mouse cursor, its orbit and name are highlighted, and when you left-click on the object, a pane with detailed information about this object appears on the right side of the screen.

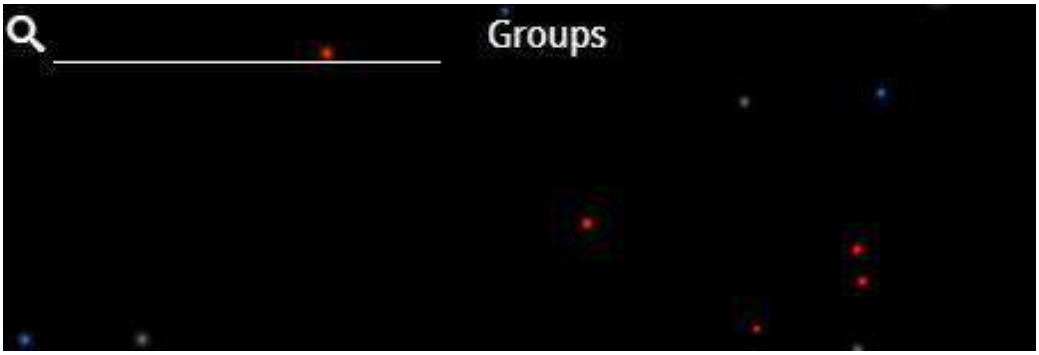


Check yourself

Name	
Year of launch	
Orbital velocity	
Rotation period	

Task 3

Find Sentinel-2A (ESA) and Landsat 8 (NASA) satellites using the search bar in the upper-left corner of the screen.



Check yourself

Name	Sentinel-2A	Landsat 8
Year of launch		
Orbital velocity		
Rotation period		

Task 4

Find information about one piece of space debris at your discretion *(highlighted in grey)*.

Check yourself

Name	
Year of launch	
Orbital velocity	
Rotation period	

Task 5

What do you think is the most prevalent type of objects orbiting Earth: satellites, spacecraft, or space debris?

Check yourself

_____

On February 6, 2018, Elon Musk's Tesla Roadster electric car was launched into space on the debut flight of the world's most powerful operational rocket, the Falcon Heavy, aimed to promote the Tesla brand. "Starman", a mannequin dressed in a spacesuit, occupied the driver's seat. Shortly before the launch, Elon Musk said that the car would travel at a speed of 11 km per second and reach a maximum of 400 million km away from Earth. Following the launch, the electric vehicle was given the Satellite Catalog Number 43205, named "TESLA ROADSTER/FALCON 9H", along with the designation by NASA Space Science Data Coordinated Archive 2018-017A. Elon Musk hopes that three cameras that the car is equipped with will provide «epic views.» The calculations suggest that Tesla Roadster will eventually hit Venus or Earth within a few tens of millions of years. The same calculations show that the car has a 6 percent chance of crashing into Earth in the next 1 million years and a 2.5 percent chance of hitting Venus during that same stretch.

Introduction into EO Browser (Illustrated by Downloading Satellite Image of Kyiv)

With numerous Internet resources, you may both explore our planet from space without leaving home and download the required satellite images to your device. One of such resources is discussed below in more detail.

EO Browser allows you to visualize medium- and low-resolution images available online from the European Space Agency's satellites Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, Landsat, Envisat Meris, MODIS, Proba-V, GIBS.

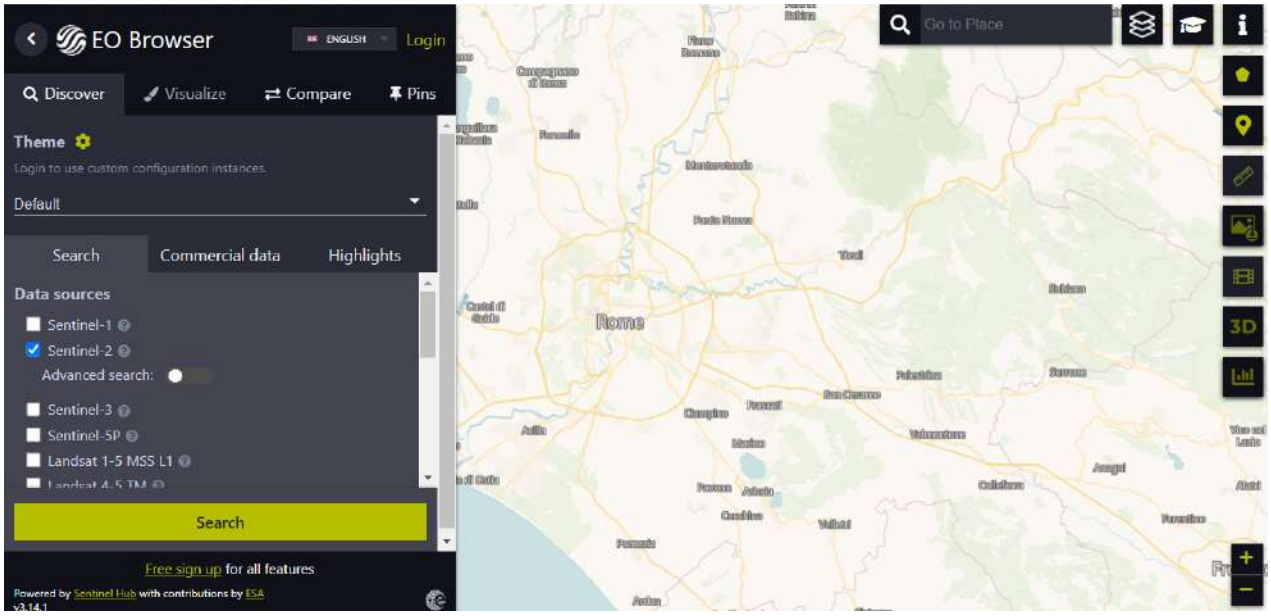
Official webpage: https://apps.sentinel-hub.com/eo-browser/.

Task

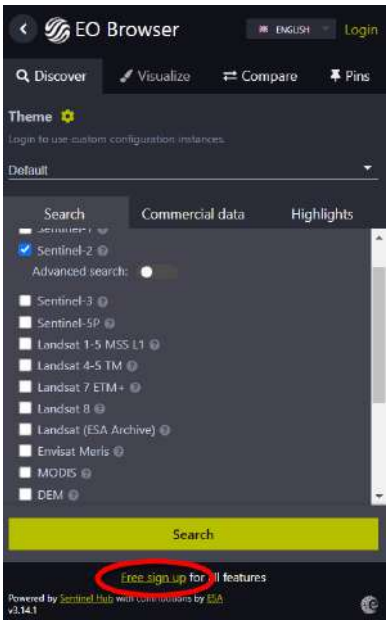
Create an account with *EO Browser* and explore the images of Kyiv from Sentinel-2 satellite.

Instructions for self-guided work:

1. Open *EO Browser* webpage (type *eo browser* in the Google search bar and click the first link, *Sentinel-hub EO-Browser* https://apps.sentinel-hub.com/eo-browser/).

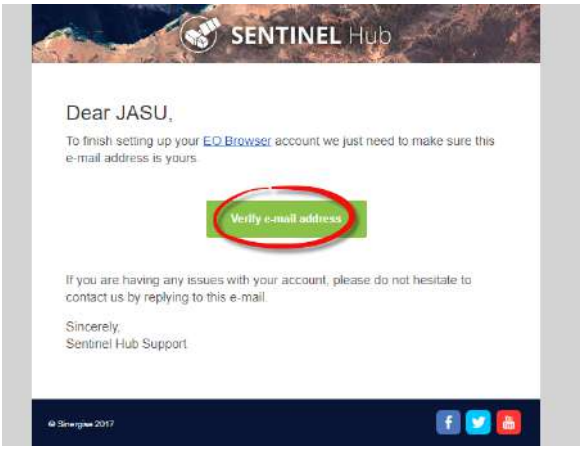


2. Create an account by clicking the ***Free sign up*** button in the bottom left-hand toolbar.

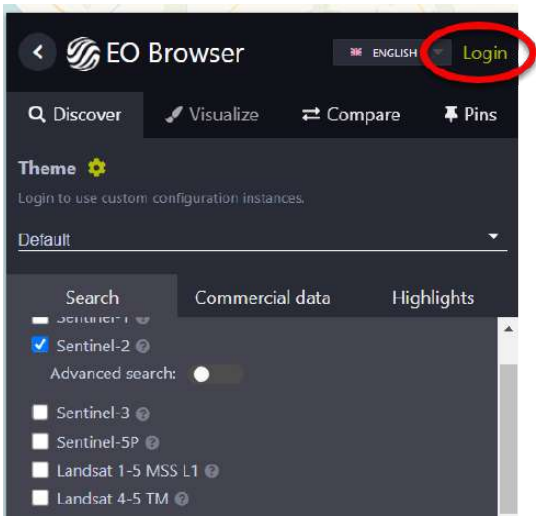


Enter all required information in the popup box and confirm registration in the verification email you will receive from Sentinel Hub.

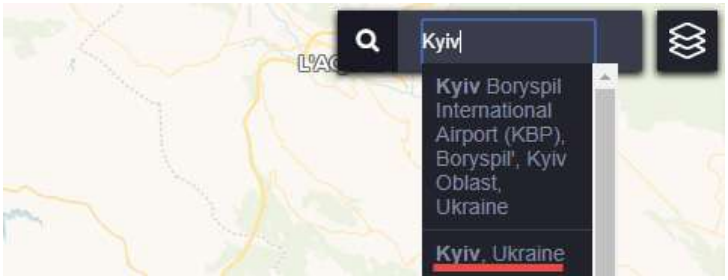
Check your spam folder to make sure the verification email didn't end up there!



3. Log in on the website using your username and password. Click ***Login*** and enter your data.



4. Enter *Kyiv* in the search field. Select *Kyiv, Ukraine* from the dropdown list and click on the magnifying glass icon to zoom into the location.



You can move across the map by pressing and holding down the left mouse button, and in this way, you may drag the map in the desired direction.

5. In the ***Search*** tab of the toolbar on the left of your screen, select:

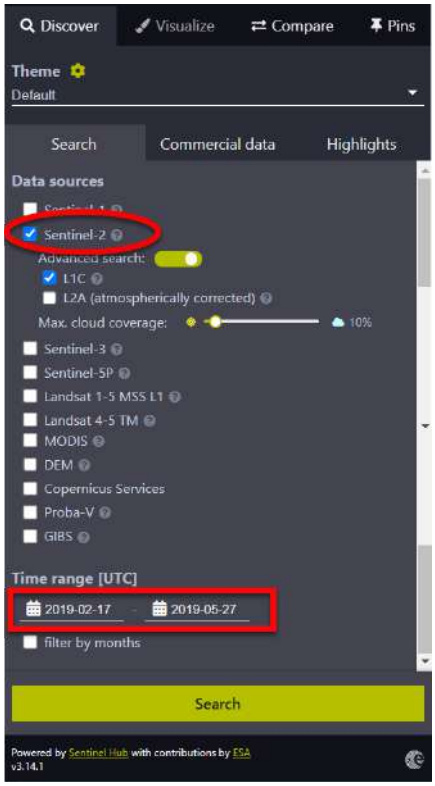
- ***Data sources*** *(satellite)* – Sentinel-2 (L1C) (by clicking on the question icon ⍰, you can read detailed information about a satellite);

Sentinel-2 is an Earth observation mission developed and operated by the European Space Agency (ESA) as part of the Copernicus programme. The mission supports a broad range of services and applications such as forest monitoring, monitoring land cover change, emergencies management, and is currently a constellation with two similar satellites, Sentinel-2A and Sentinel-2B.

- ***Max. cloud coverage*** – 10%;
- ***Time range*** – February 17, 2019 – May 27, 2019;

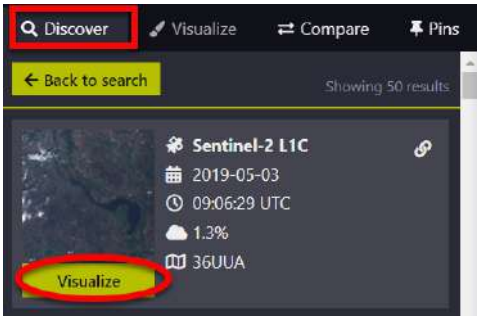
Important! To select a date, choose it from the calendar rather than type.

- Click the ***Search*** button.



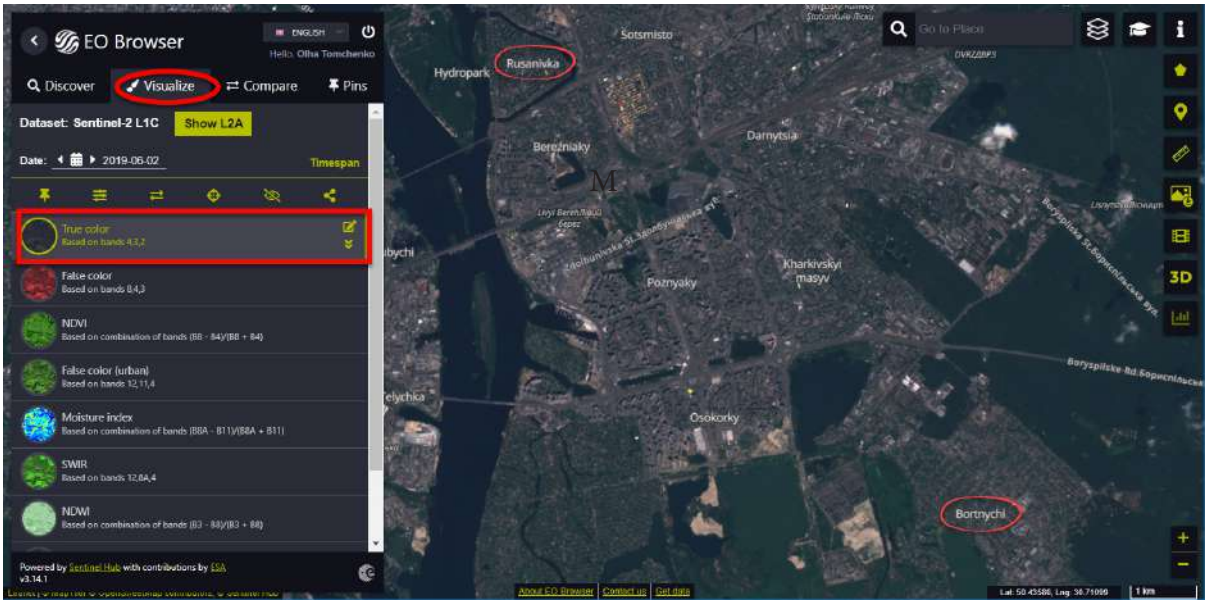
Once you heat ***Search***, you get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

6. View the images by scrolling through the list in the left toolbox, find the image taken on 03.05.2019 and click the ***Visualize*** button to display it in the *EO Browser* window.



7. The selected image will show up in the *EO Browser* window and a ***Visualize*** menu will open in the left pane where you can adjust the image display. By default, the image is displayed in a ***True color***, which means that it looks like a photo of the location taken from above. Explore the location also in ***False color***.

Using your mouse wheel or + – icon in the bottom right corner of your screen, zoom to the location to visualize simultaneously Rusanivka and Bortnychi districts of Kyiv (left bank).



Check yourself

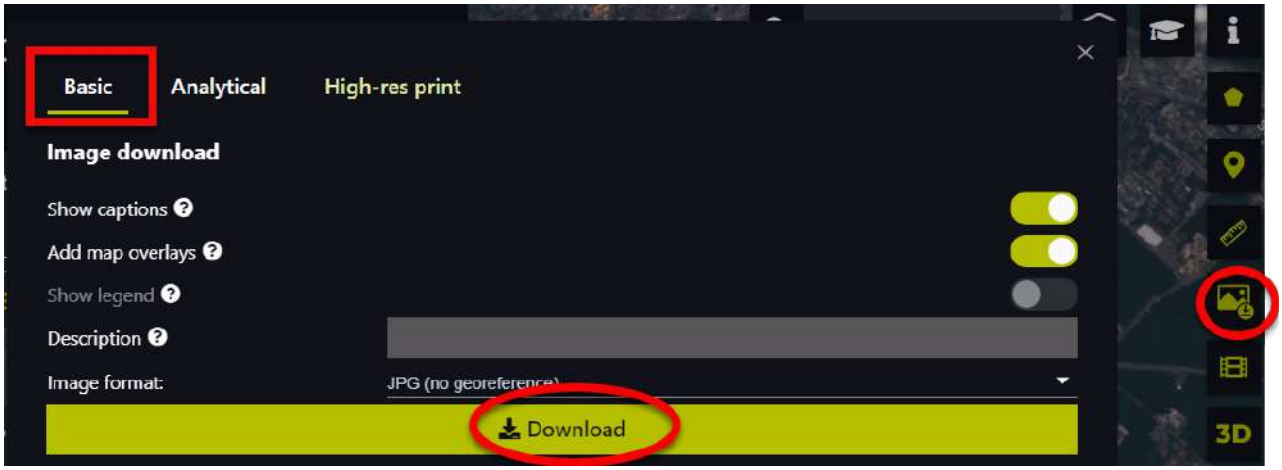
In your opinion, how do the ***True color*** and ***False color*** visualizations of the location differ?

How do they appear	In a true-color image	In a false-color image
Vegetation		
Rivers and lakes		
Urban areas		

8. To access quickly the selected image and avoid searching for it again in the list, click on the ***Pin to your favorite items*** icon in the toolbar on the left side of your screen, and the image will appear in the list of your favorite images in the ***Pins*** tab.

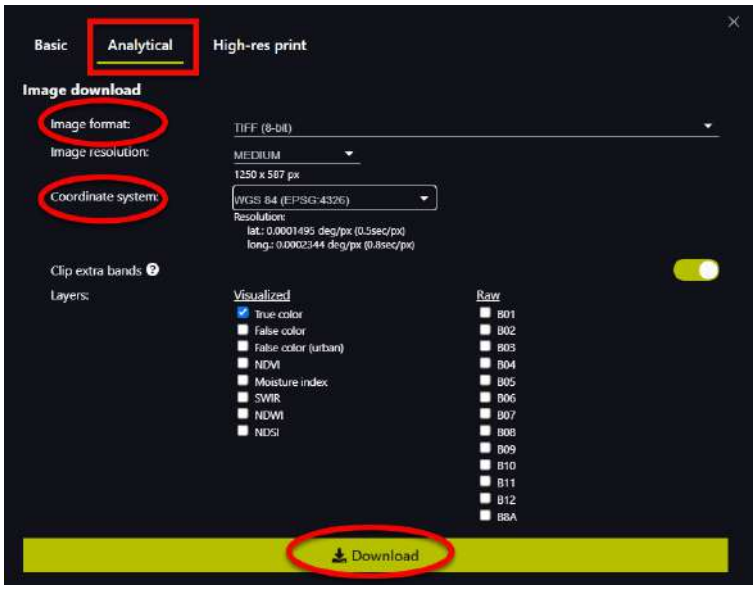
9. Go back to the ***Discover*** tab and find the image taken on 17.02.2019 in the list. Click the ***Visualize*** button and add this image to your favorites by clicking the icon.

10. To save the image, click the ***Download image*** button in the toolbar on the right side of your screen, and click ***Download*** in the window that opens. The image will appear as visualized on the screen.



You can also save the image as a georeferenced file to be usable in any GIS application. In the ***Analytical*** tab in the same window, you can change the ***Image format***, ***Coordinate system***, and select the visualization parameters – spectral indices, ***True color*** (real colors), or ***Raw*** (primary data), which allows you to save individually selected satellite imagery bands, e.g. B2, B3, B4, etc.

The last tab in this window is ***High-res print*** (high-resolution printing), which allows image download for high-quality printing.



Please note that only the part of the image that is displayed on your screen will be saved.

Check yourself

What is the difference between the bodies of water shown in the first and second images?

_____

Can you identify the Comfort Town residential neighborhood in the images? What features are indicative of this residential neighborhood?

_____

Assessing the Consequences of Emergencies (Case Study: Effects of Forest Fire in Kherson Oblast)

Case

May 27, 2018. A large forest fire is continuing for several hours already in Kherson Oblast, according to the report by UNN with reference to the press office of the State Emergency Service of Ukraine. "… at about 13:25, the National Police officer on duty notified the Operations Coordination Center of the Main Office of the State Emergency Service of Ukraine in Kherson Oblast of the fire in the 3rd and 4th compartments of the Radensk Forestry of Oleshkivskyi District."

Task

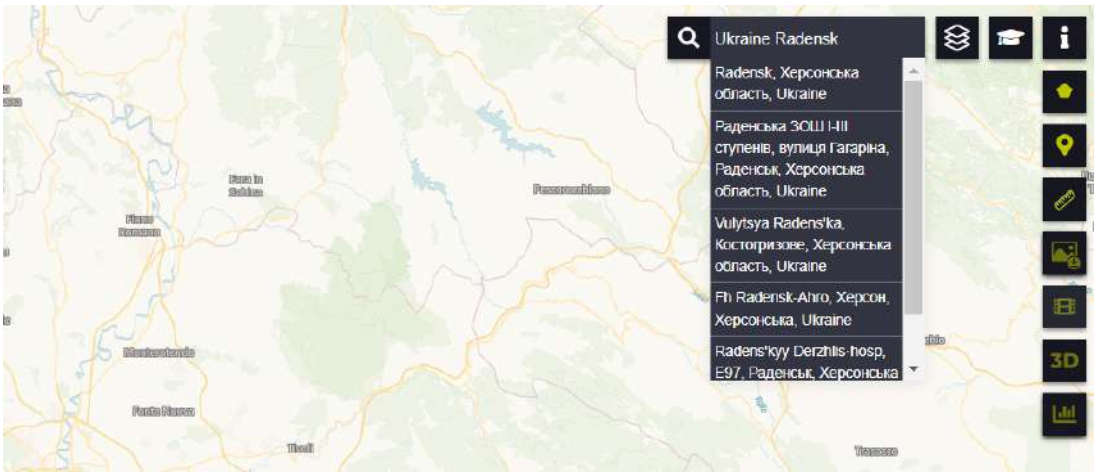
Identify the site of a fire, determine burned-down forest area, and analyze the state of reforestation in the affected territory.

Instructions for self-guided work

1. Open *EO Browser* webpage (type "*eo browser*" in the Google search bar and click on the first link, *Sentinel-hub EO-Browser*, or go to https://apps.sentinel-hub.com/eo-browser).

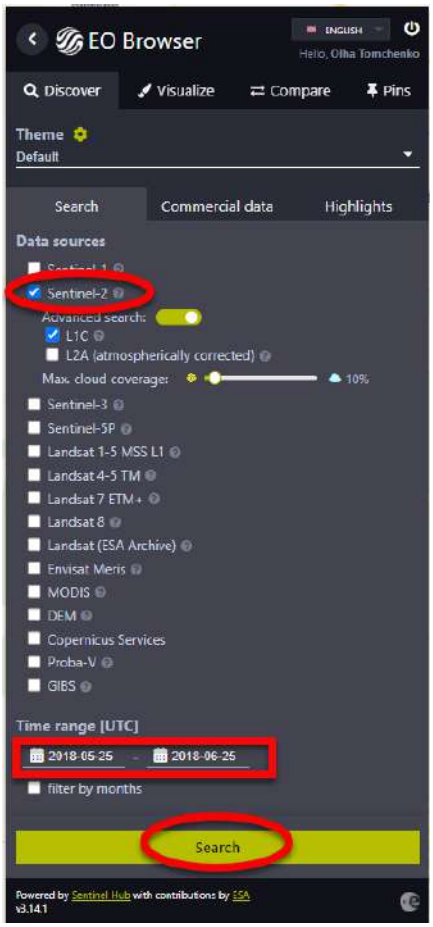
2. Log in on the website.

3. Enter *Radensk* in the search bar and click on the magnifying glass button to zoom into the location:



4. 4. In the settings toolbar, select:

- ***Data sources*** (Satellite) – Sentinel-2 / L1C;
- ***Max. cloud coverage*** – 10%;
- ***Time range*** – May 25, 2018 – June 25, 2018;
- Click the ***Search*** button.



A list of all images available in the catalog that match the established criteria will be displayed.

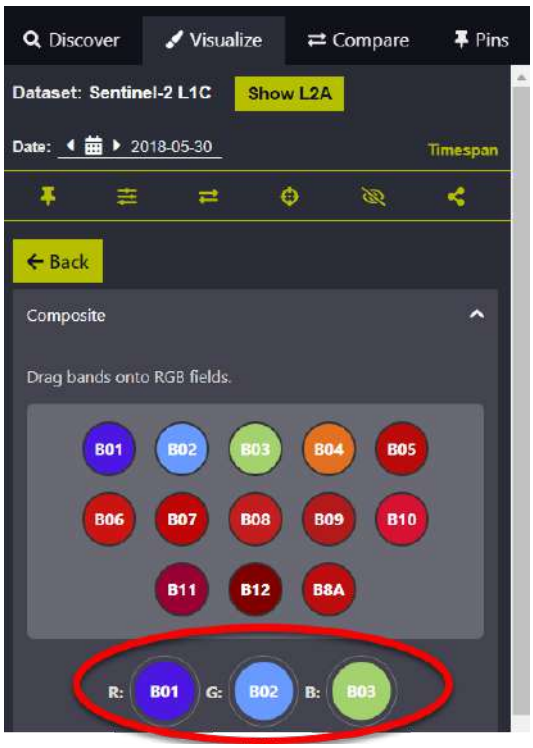
5. Review the images by scrolling through the list in the left toolbox; find the first available image following the date of fire start; click the ***Visualize*** button.

The selected image will display on the map, and a menu for image adjustment will open in the left-hand pane ***(Visualize)***.

6. Take a look at the territory in the image and find the forest area, a settlement, a river, a road, and Oleshky Sands. By default, the image is displayed in the visible range, i.e. the image looks like the photo of the area taken from above.

7. Click the ***Custom*** button in the left-hand pane of the menu to adjust visualization using other spectral bands.

A window for selecting various spectral band combinations will open.



By dragging the circles with specified band numbers of Sentinel-2 image to the bottom R:.. G:.. B:.. row, you can create the color picture. The color of the circle with band number denotes the respective spectral band.

Check yourself

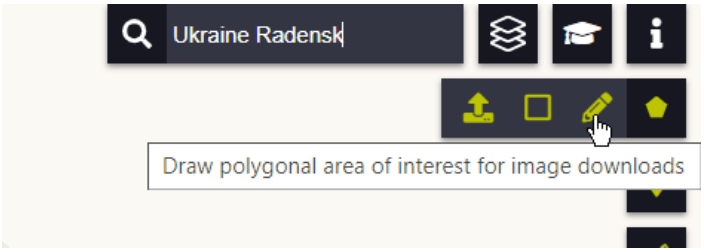
Fill in the table below. For this purpose, move the mouse cursor over each circle specifying spectral band number:

Band	Spectral range
B01	
B02	
B03	
B04	
B05	
B06	
B07	
B08	
B09	
B10	
B11	
B12	
B8A	

Choose the combination of bands that gives a clear image of the burned-down area in the forestland to the north of Radensk. The combination of bands in the infrared range will make it possible to identify burned down and affected vegetation.

More information about various band combinations is given in Section *Common Sentinel-2A and Landsat Band Combinations* (see Annex 1 and Annex 2).

8. Select ***Draw area of interest*** icon in the right-hand toolbar to digitize the polygon, and enclose the forest area damaged by the fire into the polygon using the tool.



To finish digitizing the polygon, click on the first marker.

The area enclosed in the polygon will display in the *Measure distance* pane. Therefore, you have determined the area of forest damaged by the fire.

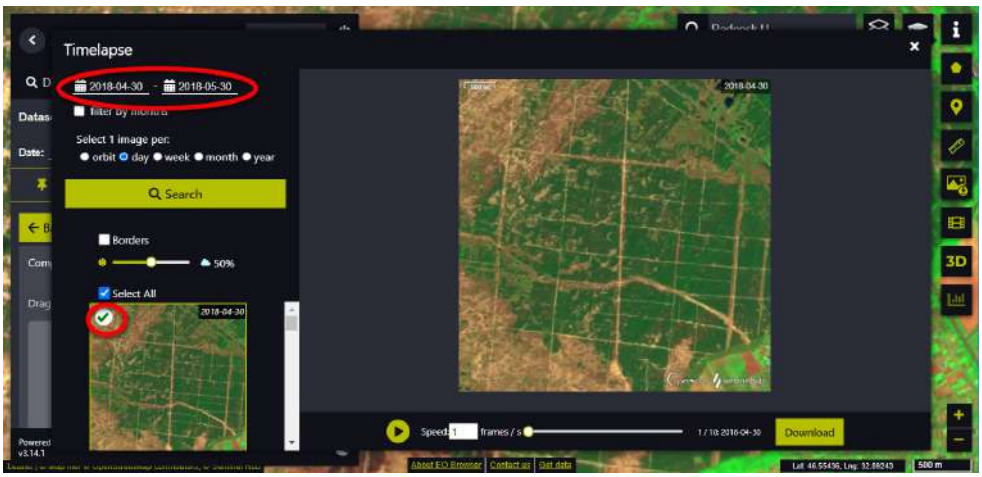
Check yourself

Write below the actual area of the largest forest fire which took place near Radensk in May 2018.

_____

To analyze the progress of reforestation in this territory, use the ***Create timelapse animation*** tool from the bottom-right menu to browse the series of images over time.

An animation adjustment box will show up:



9. Adjust animation specifying the time range (01.04.2018 – 12.12.2019), and cloud coverage (15%), and click the search button (magnifying glass); review the list of images and clear checkboxes of incomplete and poor-quality images. Increase the speed of animation to 3 in the bottom ***Speed*** pane and press the *Enter* button.

10. Click the ***Download*** button. The animation will be stored as a separate GIF file, which can be opened thereafter whilst offline.

Check yourself

Watch the animation, identify other forest fires within the studied area and determine the dates they broke out:

1.	
2.	
3.	

Assessing Tree Cover Based on Remote Sensing Data (Case Study: Territory of Drevlians Nature Reserve in Zhytomyr Oblast)

Case 1

The 2020 Chornobyl Exclusion Zone wildfires were a series of forest fires that broke out on April 4 in the Chornobyl Exclusion Zone in the territory of Kotovske Forestry between Poliske town, Tarasy, and Volodymyrivka villages, and later spread to Zhytomyr Oblast. Large-scale wildfires in the restricted zone around Chornobyl were extinguished after 10 days of firefighting efforts. On April 16, however, due to a strong wind, a blazing fire broke out again. The firefighting was complicated by frequent changes in wind direction, as well as the lack of fire safety roads in the places where vehicles could not access (Wikipedia).

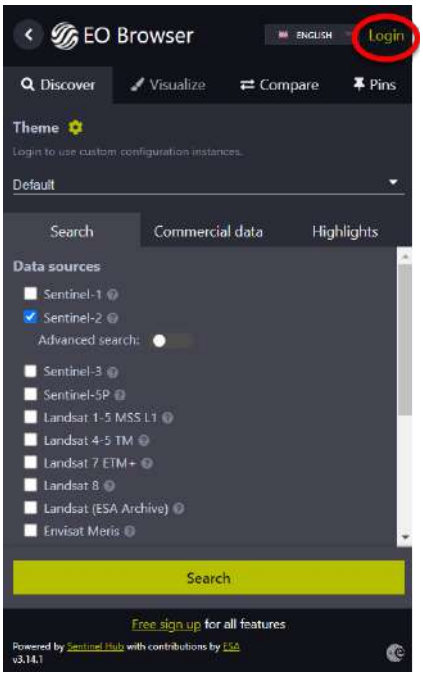
Task 1:

Check how far did the large-scale wildfires in April 2020 take place from the Chornobyl Nuclear Power Plant.

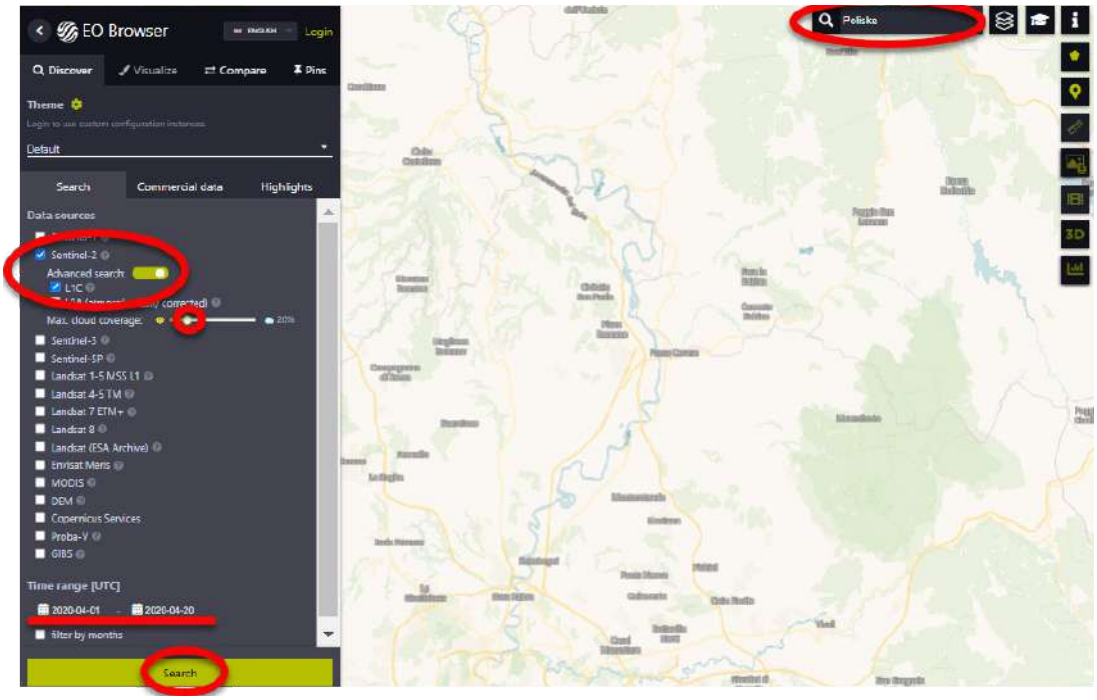
Instructions for self-guided work

1. Open *EO Browser* webpage (type *eo browser* in the Google search bar and click on the first link, *Sentinel-hub EO-Browser*, or go directly to https://apps.sentinel-hub.com/eo-browser).

2. Create an account and/or login on the website.



3. Enter *Poliske* in the search bar and click on the first highlighted line in the list to zoom to the territory of Ukraine on the map.



4. In the settings toolbar, select:

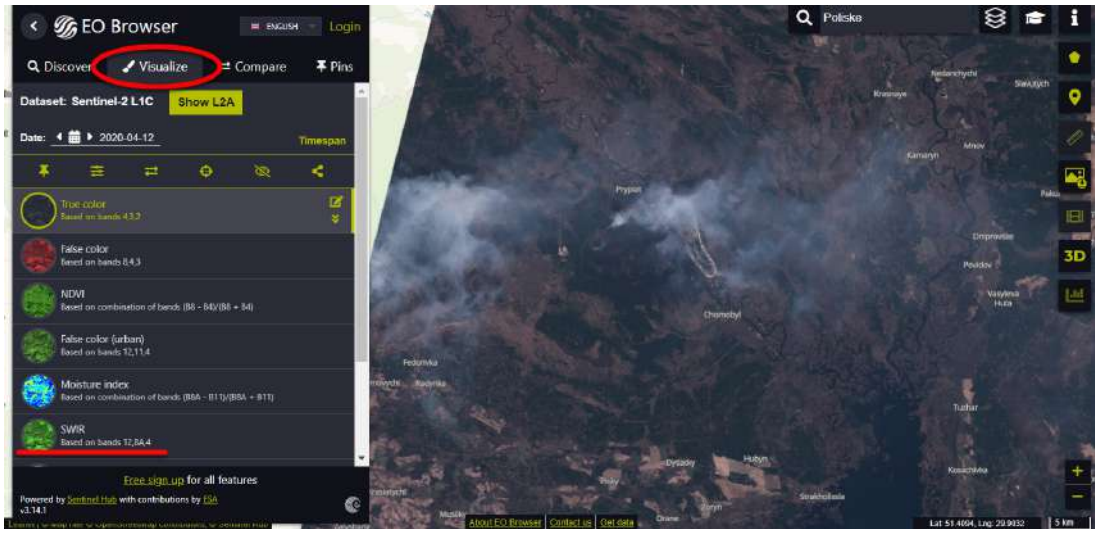
- ***Data sources*** *(satellite)* – Sentinel-2 (L1C) (by clicking on the question icon to the right of the satellite name, you can read detailed information about the satellite);
- ***Max. cloud coverage*** – 20%;
- ***Time range*** – April 1, 2020 – April 20, 2020;
- Click the ***Search*** button.

Important! To select a date, choose it from the calendar rather than type.

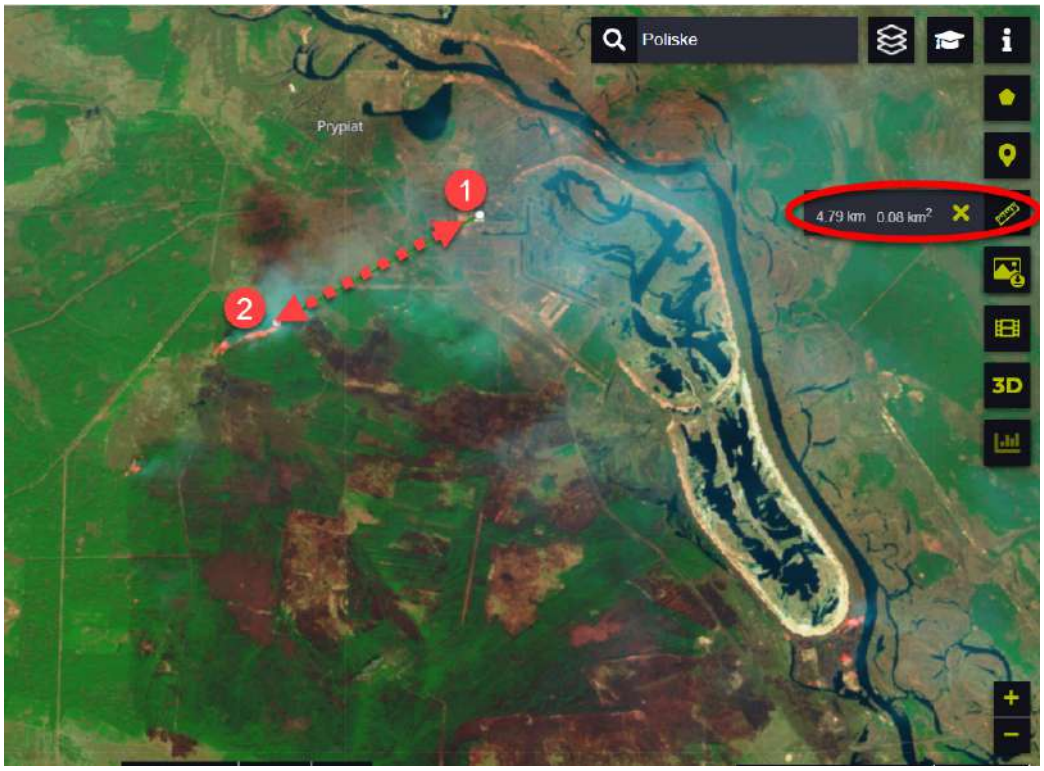
Once you heat ***Search***, you get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

5. View the images by scrolling through the list in the left toolbox, find the image taken on 12.04.2020 and click the ***Visualize*** button to display the image in the *EO Browser* window. The clouds of smoke are clearly visible in the image. Let's find the fire seat.

6. Select the visualization configuration – SWIR, i.e. based on bands 12, 8A, 4.



7. With this combination of bands, the seats of blazing fire become clearly visible. Zoom to the place of fire with your mouse wheel and measure the distance to the Chornobyl Nuclear Power Plant using the ***Measure*** function from the right-hand toolbar.



Optionally, you may explore the active seats of fire in the nearby area.

Check yourself

Determine the size of the area caught in the fire.

Case 2

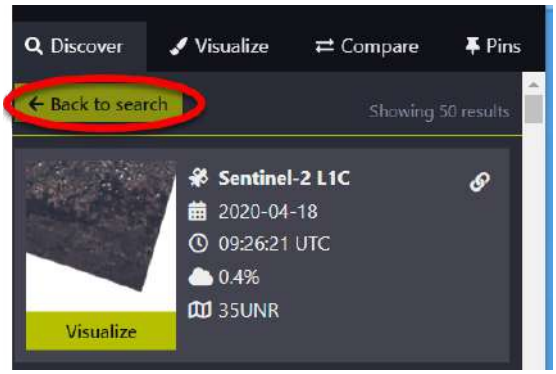
In the summer of 2017, the area of forest dieback caused by bark beetle in the territory of the Drevlians Nature Reserve in the north of Zhytomyr Oblast, as well as in the whole Polissia region dramatically increased. The Reserve took its name from the tribe of Early East Slavs, Drevlians, which inhabited this territory, and known by their later name – Polishuks. Both ethnonyms derive from the words meaning tree, forest. This Reserve was established to preserve the unique forested areas and wetlands of Ukrainian Polissya, and study the changes of ecosystems under the influence of natural and anthropogenic factors. A large part of the Reserve's forests was heavily contaminated with radionuclides as a result of the accident at the Chornobyl Nuclear Power Plant and became a part of the evacuation zone. Therefore, the territory has been under negligible human impact since the Chornobyl disaster. In total, thousands of pine trees were affected by bark beetle in the Reserve.

Task 2:

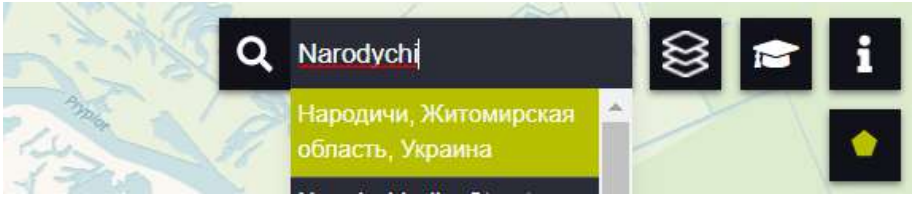
Identify the parts of the forest affected by bark beetle within the Drevlians Nature Reserve.

Instructions for self-guided work

1. Open the ***Search*** tab to search for the images.



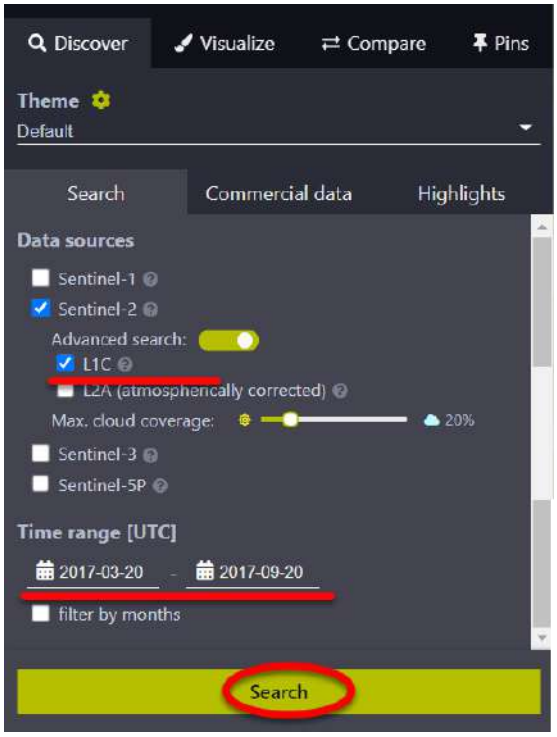
2. Enter *Narodychi* in the search bar and click on the first highlighted line in the list to zoom into the territory on the map.



3. In the settings toolbar, select:

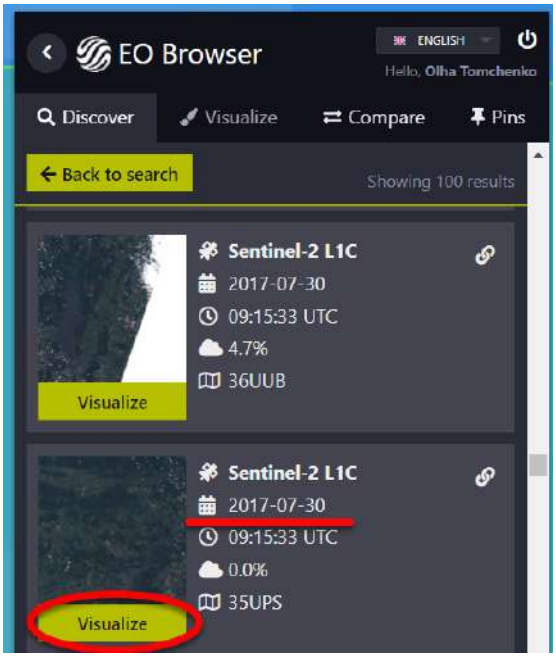
- ***Data sources*** *(satellite)* – Sentinel-2 (L1C) (by clicking on the question icon to the right of the satellite name, you can read detailed information about the satellite);
- ***Max. cloud coverage*** – 20%;
- ***Time range*** – July 1, 2017 – August 1, 2017;
- Click the ***Search*** button.

To select a date, choose it from the calendar rather than type.



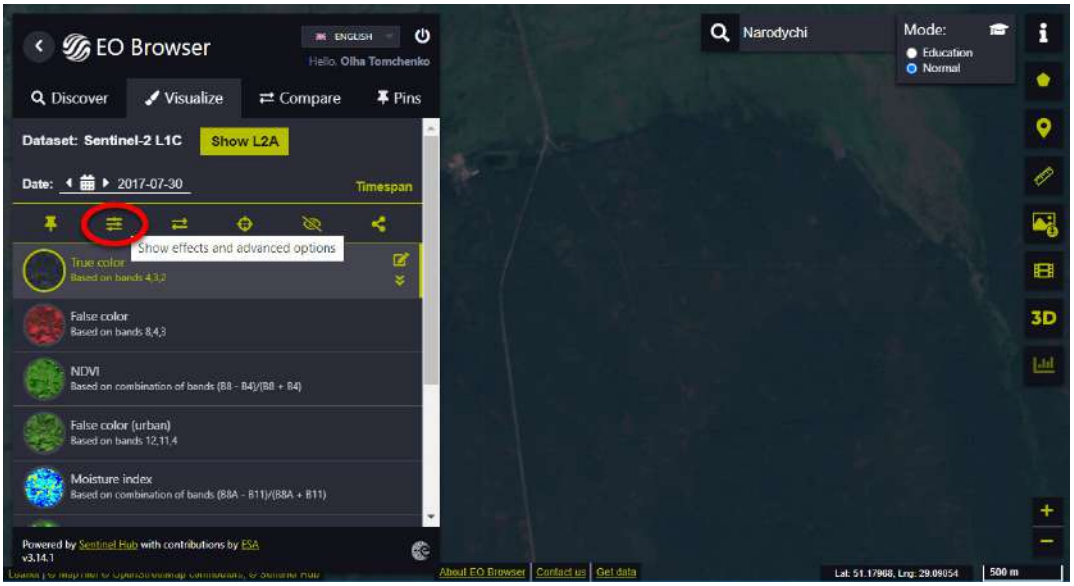
You will get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

4. View the images by scrolling through the list in the left toolbox, find the image of 30.07.2017 and click the ***Visualize*** button to display the image in the *EO Browser* window.

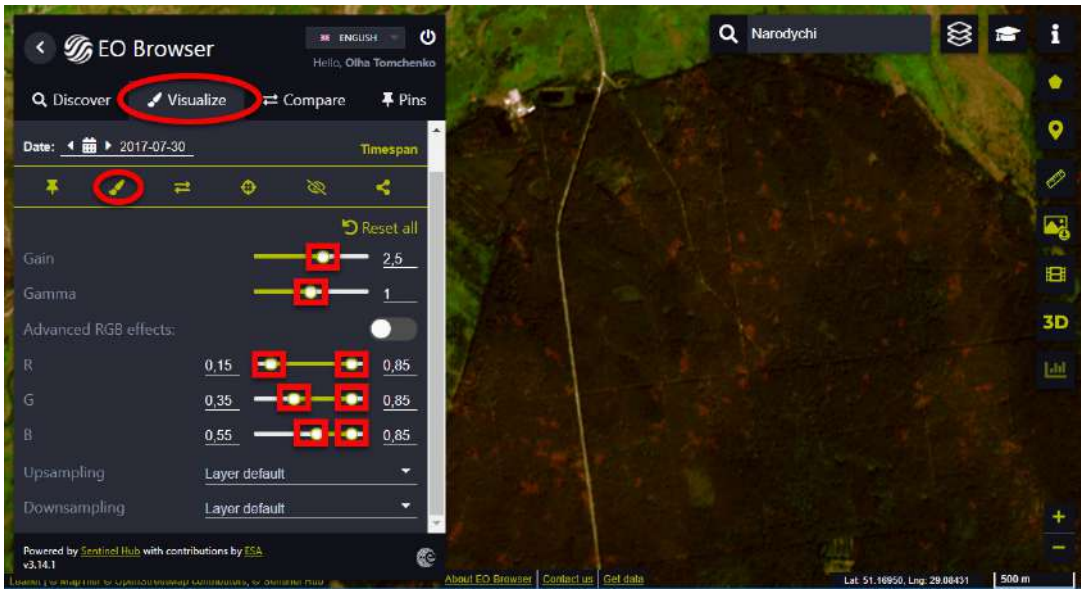


The selected image will display on the map. You may notice that the image is rather dark, so we need to improve its display quality.

5. Select ***Show effect*** at the top of the left-hand toolbar.



A menu for adjusting the image histogram will open. Move the slider of each band with your mouse and review the result. If the image is too dark or too light, use the smaller range of values for each band to filter out the highest or lowest pixel values, which are most likely erroneous or irrelevant for the analysis.



Now you may see that the image became brighter and the forest cover has visible red spots – areas of dead trees from invasive pests.

Check yourself

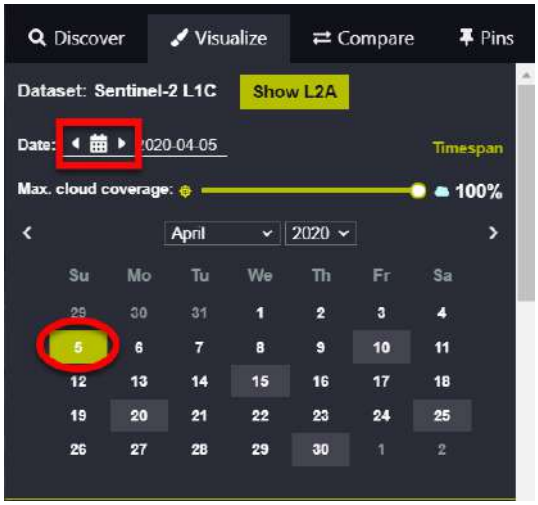
Determine the size of one of the largest areas of forest dieback caused by invasive pests.

Case 3

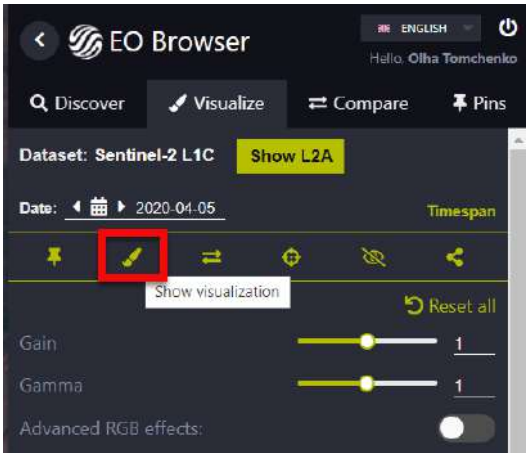
Sanitation cutting is a removal from the stand of single trees or groups of trees that are dead, dying off, very weakened, infested, diseased, or injured by natural disasters or man-made impacts. The sanitation cutting may be selective (a method where single trees or clumps with a margin of ≥ 5 m3 per hectare are removed) or clear-cutting (a method where all the trees are removed from areas of 0,1 hectares and more). Sanitation cutting also referred to as "sanitation and health-improving measures" in the silviculture literature, is a recommended effective measure to control pests and forest diseases. At the same time, according to L. V. Meshkova, Ph.D. in Agriculture, Head of Forest Protection Laboratory at the Research Institute of Forestry and Agroforestry of Ukraine, sanitation measures rarely lead to forest improvement. According to S. F. Nehrutskyi, DSc. in Biology, sanitation cutting as a method of combating Heterobasidion annosum infection is useless. This opinion is shared by O. M. Krasnytskyi, a forestry specialist, Ph.D. in Agriculture (from Wikipedia).

Task 3

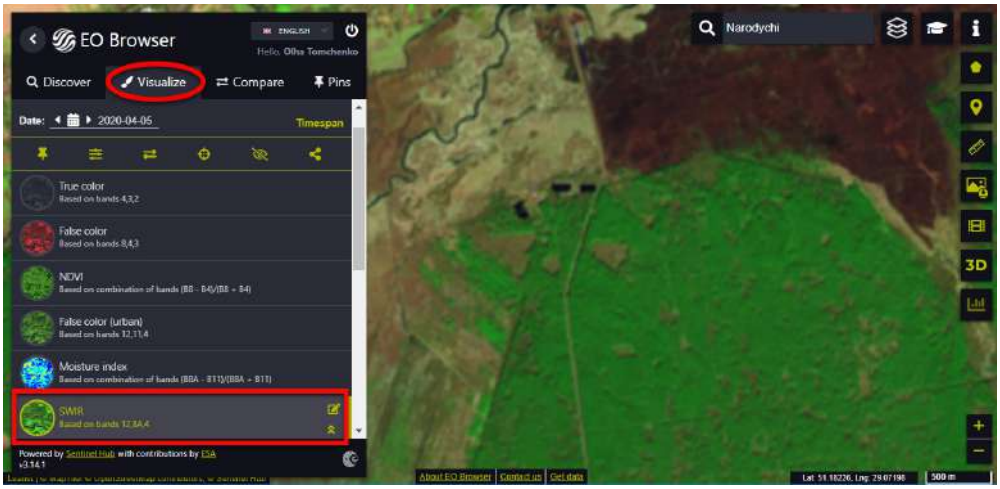
1. Check the Drevlians Nature Reserve for any sanitation cutting made to remove infested trees (use the area selected in the previous Task). First, change the date of the image in the left-hand pane to April 5, 2020.



2. Close the histogram adjustment box by clicking on the “brush” icon.



3. Select the visualization mode – SWIR (based on bands 12, 8A, 4).



4. Review the image of the Drevlians Nature Reserve. Identify the sites of felling that appear as light spots.

In this image, we may also notice the clumps of dead pines that have not been cut; they are shown in grey-lilac color.

5. We may also notice a large-scale wildfire and dark-brown burned-down areas of forest.

Check yourself

Identify by yourself a site of fire or forest cutting, or areas of trees' dieback within any forestland.	
Find a satellite image of the same area captured before the cutting.	

Assessing Water Bodies (Case Study: Evaluating Freshet Dynamics in the North of Kyiv and Chernihiv Oblasts)

Case

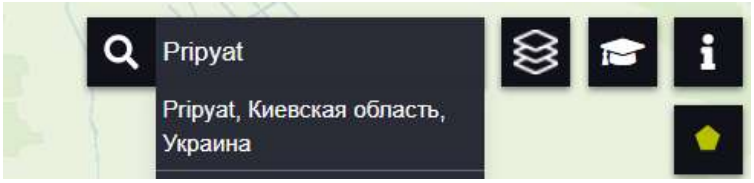
May 2013. Ukraine has a spring freshet peak; 9 oblasts are partially inundated. The worst situation is in Chernihiv Oblast: some villages suffer from the Desna River flooding. Channel 24 reports that according to Mykola Kulbida, Director of Ukrainian Hydrometeorological Center, the maximum water levels in the Desna River as it runs into the Kaniv Reservoir will be seen on May 15-20.

Task

Identify the river (Desna, Pripyat, or Dnipro) within the Kyiv Cistern area which was the starting point of the freshet; determine the dates of freshet start and peak; calculate the width of river channel overflow.

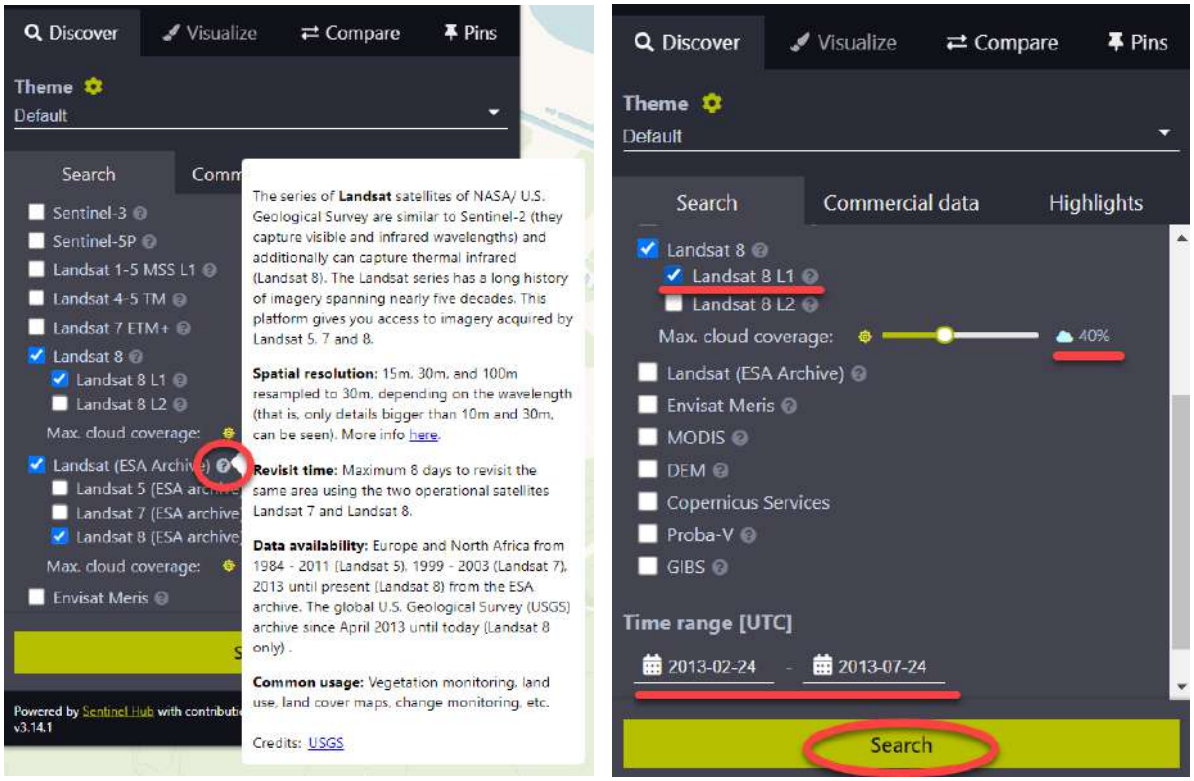
Instructions for self-guided work

1. Open *EO Browser* webpage (https://apps.sentinel-hub.com/eo-browser).
2. Log in on the website.
3. Enter *Pripyat* in the search field and click on the magnifying glass icon to zoom into the location on the map:

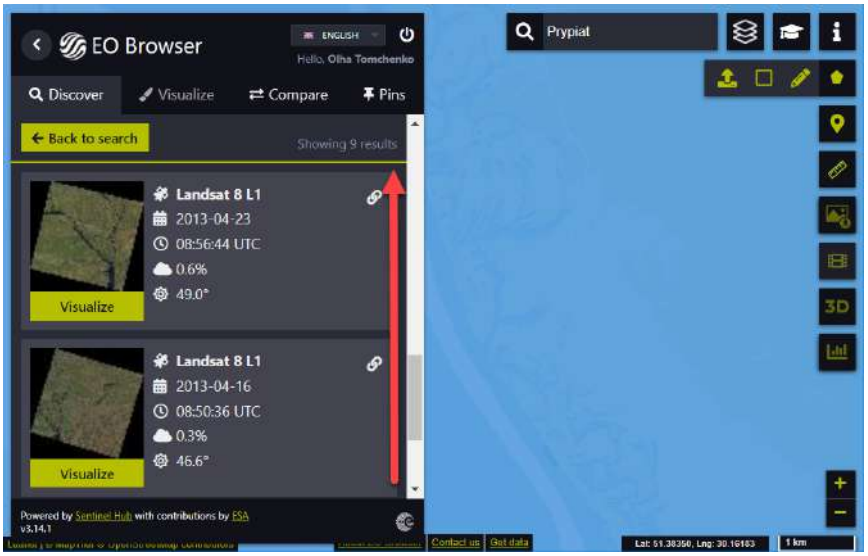


4. In the ***Search*** toolbar, select:

- ***Data sources*** *(satellite)* – Landsat 8 / Landsat 8 L1 (by clicking on the question icon ⓘ, you can read detailed information about the satellite: launch date and spatial resolution);
- ***Max. cloud coverage*** – 40%;
- ***Time range*** – February 24, 2013 – July 24, 2013;
- Click the ***Search*** button.



You will get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

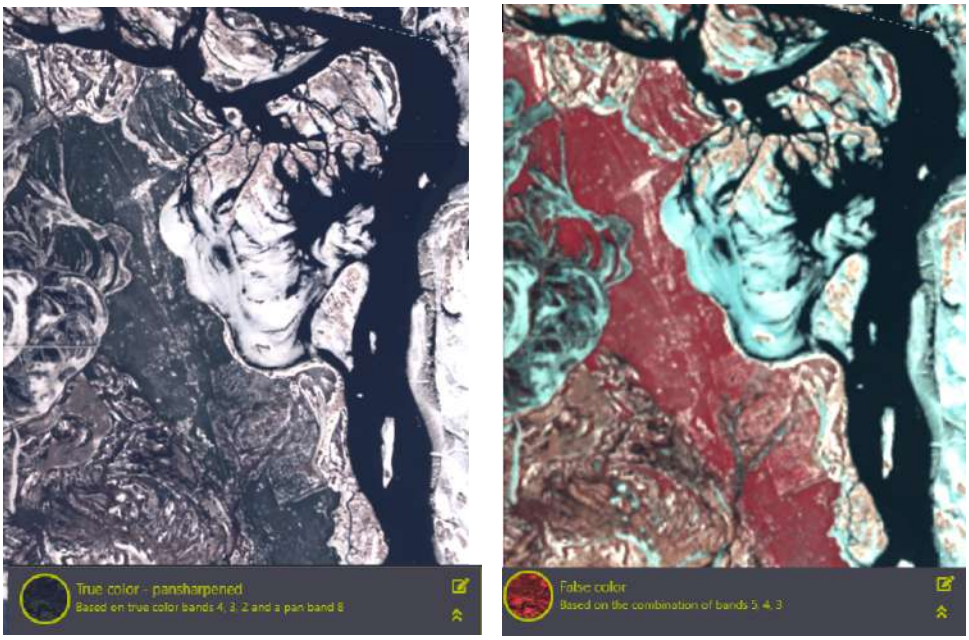


5. Review the images by scrolling up their list in a left-hand ***Discover*** tab (from the earliest to the most recent images). Find the first available image (09.04.2013) captured after the snowmelt start and click the ***Visualize*** button.

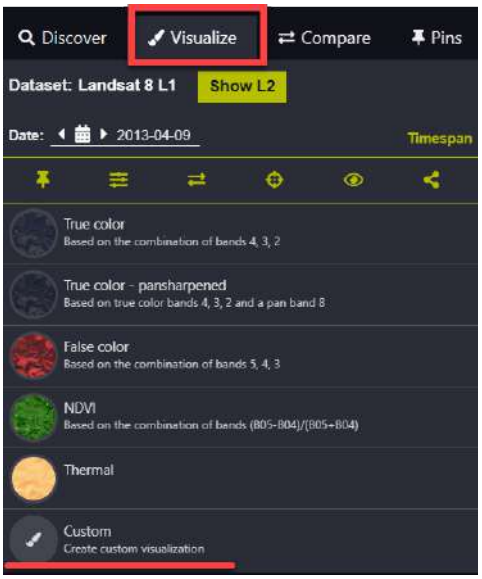
The selected image will be displayed in the map window, and the menu for image adjustment will open in the left-hand pane ***(Visualize)***.

6. Take a look at the image and identify the Pripyat, Dnipro, Desna, and Teteriv rivers and the state border of Ukraine.

By default, the image is displayed in the visible range, ***True color*** (i.e. it looks like a photo of the area taken from above and has a resolution of 30 m/pixel). Please note that this satellite provides imagery of higher resolution, 15 m/pixel ***(True color – pansharpened)***. Review the same area in the ***False color*** mode.

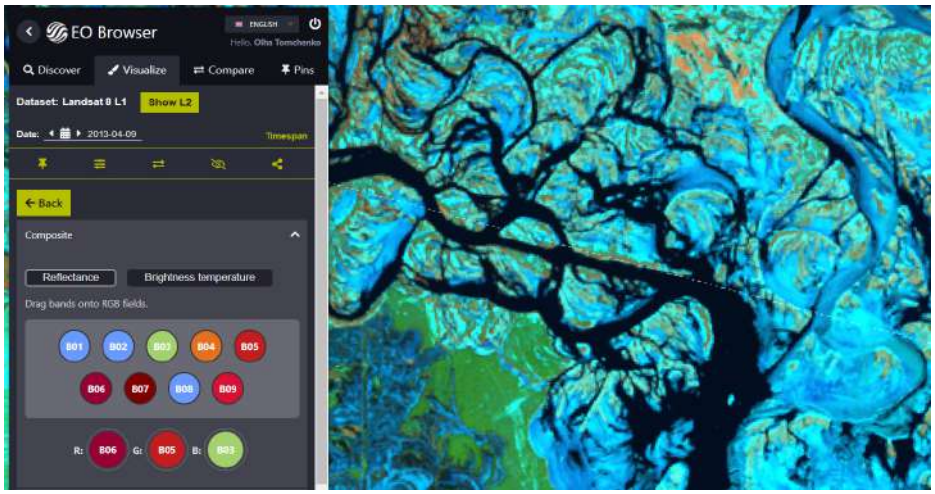


7. Click the ***Custom*** button in the left-hand pane of the menu to adjust visualization using other spectral bands. As a result, a window for selecting band combinations will open up.



By dragging the circles with specified spectral band numbers of Landsat-8 image to the bottom R:.. G:.. B:.. row, you can create a color picture. The color of the circle with band number denotes the respective spectral band (b01-b02 – blue, b03 – green, b04 – red, b05 – near-infrared, b06-b07-b09 – mid-wave infrared, b08 – panchromatic).

For more information on interpreting various Landsat 8 band combinations, see the *Common Sentinel-2A and Landsat Band Combinations* Section (Annex 1 and Annex 2).



Select the band combination to get an image with a clearly visible land-water boundary.

Specify the band combination you have used _____

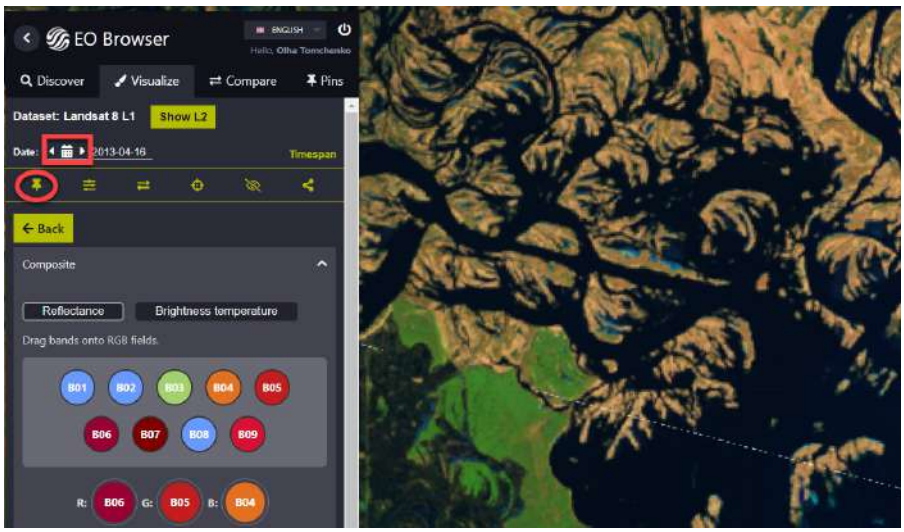
Check yourself

Write in the Table below the colors for these features as they appear in various band combinations:

forest			
water			
snow/ice			
agricultural land			

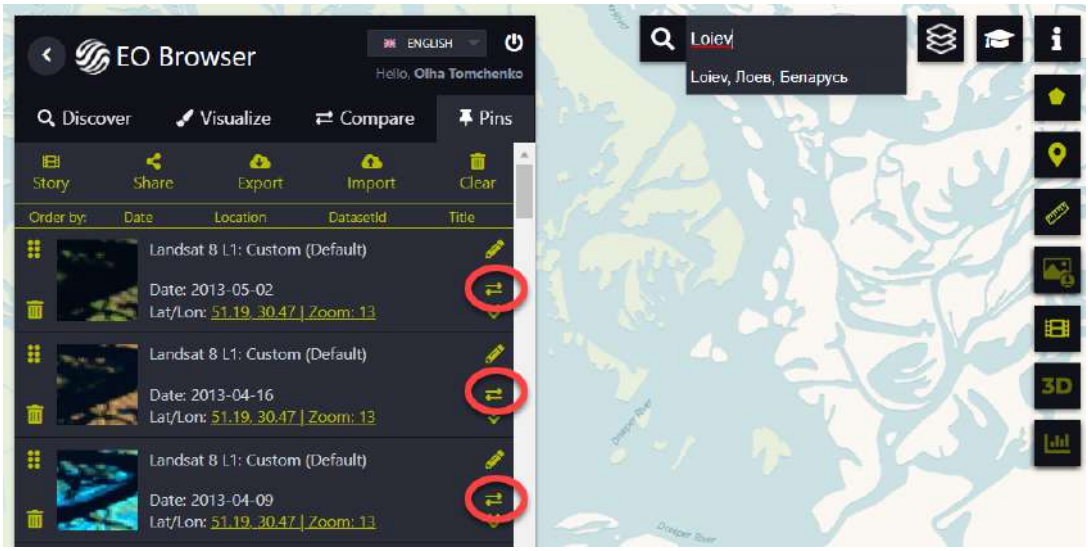
8. In the next step, we will review and compare the images taken at different times.

After selecting the most suitable band combination and an image representing the beginning of the snowmelt, zoom into the place where the Dnipro River first crosses the Ukraine-Belarus border (near the village of Loiev), and click ***Add to Pins*** to save the location and the image.

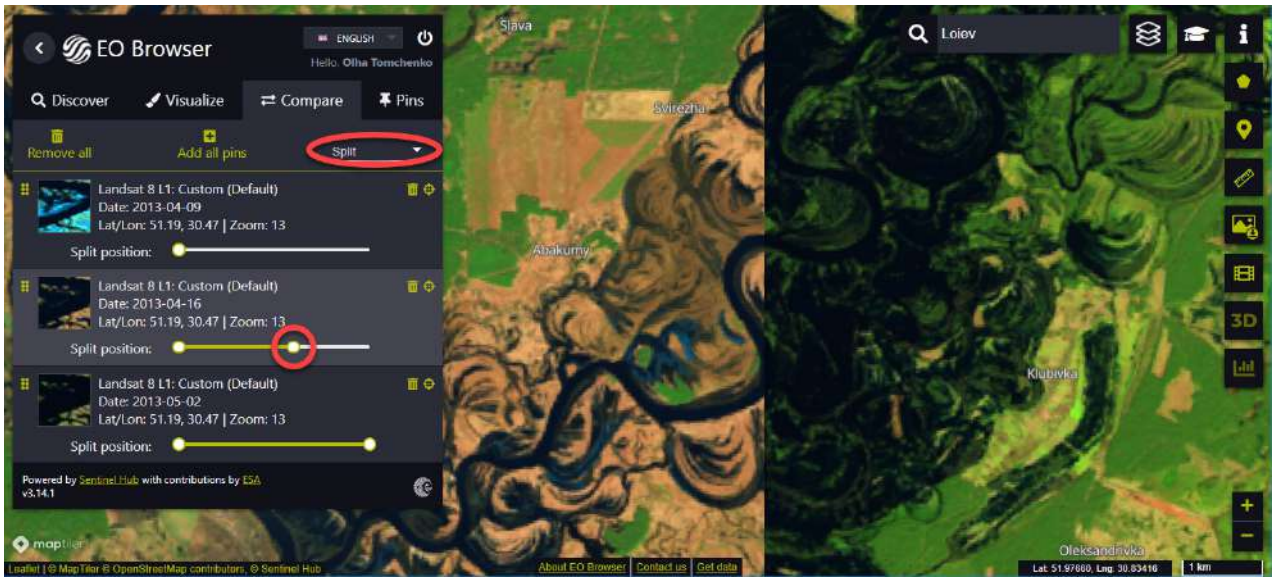


By scrolling through the dates of images in the ***Visualization*** mode, add one or two more images that differ the most from the first one in terms of water levels (click ***Pins*** again). Go to the ***Pins*** tab

and click the ***Add to Compare*** button. Using this procedure, determine the spring freshet start, peak, and end dates (illustrated by the Dnipro, Pripyat, Desna, or Teteriv River – at your discretion).

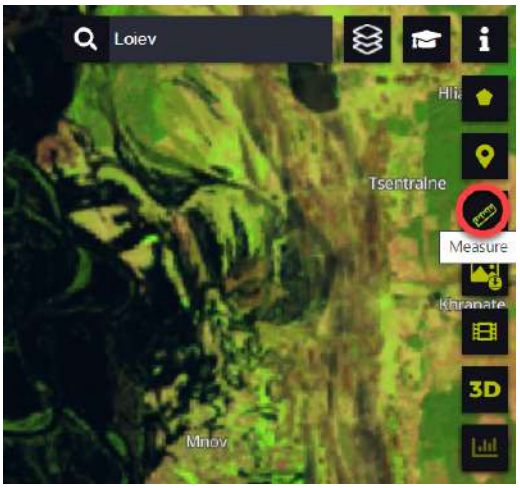


Compare the selected images in the ***Split*** or ***Opacity*** mode.

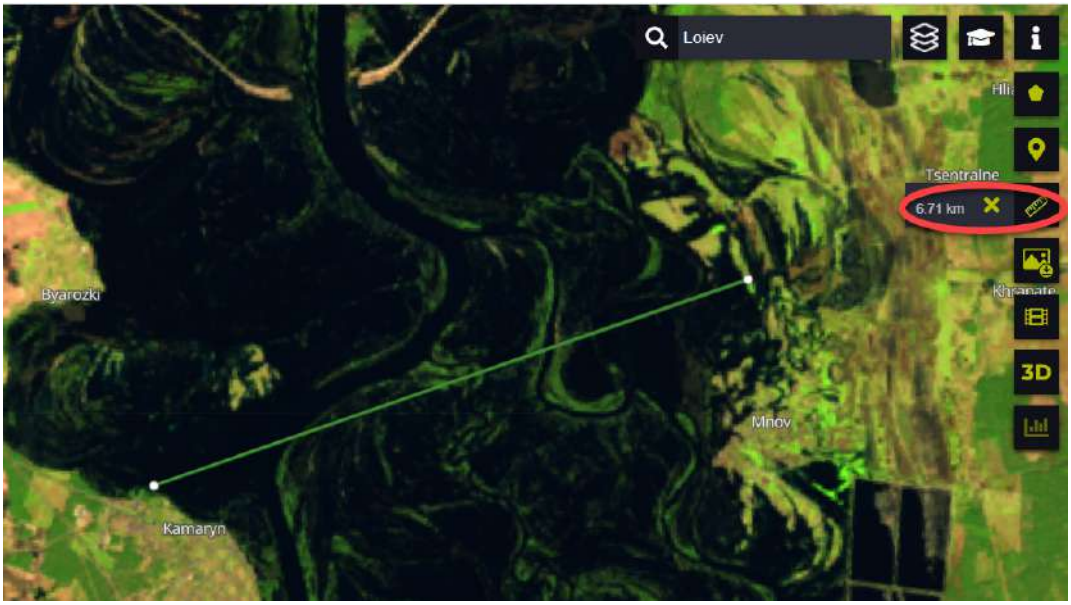


9. Measure the maximum width of the river channel overflow.

Select the ***Measure*** tool from the right-hand pane and measure the width of the river channel overflow.



The length of the selected area will display in the ***Measure*** pane. This is the width of the river channel overflow.



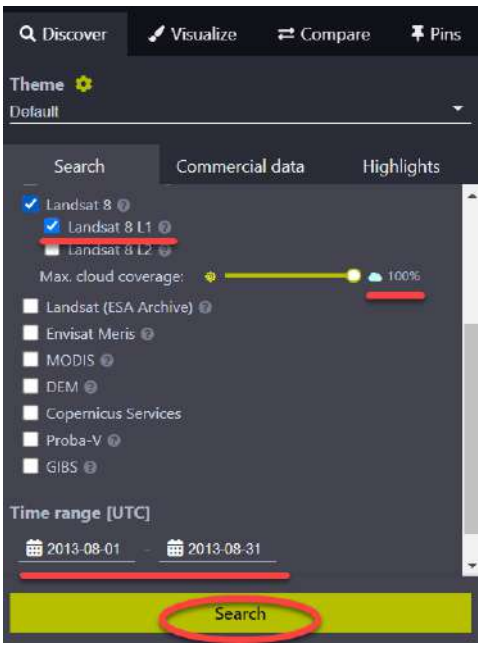
Check yourself

Specify the width of the Dnipro River channel overflow opposite Slavutych, Kyiv Oblast, Ukraine, as at the following dates*:

23.04.2013	
02.05.2013	
18.05.2013	
10.06.2013	

*select the date with the highest water level in the river

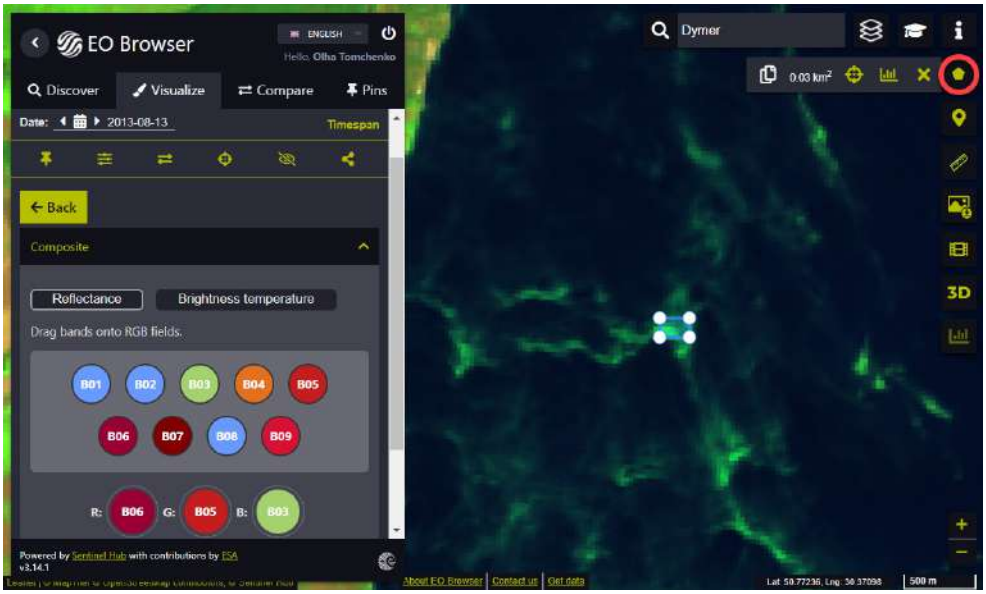
10. Return to the ***Visualization*** tab by clicking on the ***Back*** button select a space image for 13.08.2013 and test all visualization modes and indices available for this satellite.



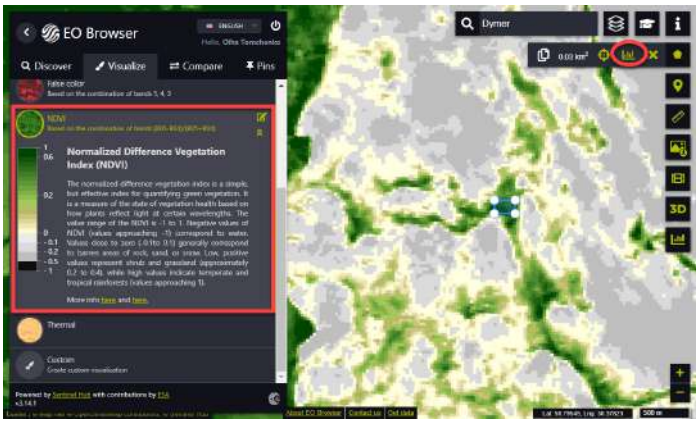
11. Analyze how an RGB image differs from the images made using the Thermal band or NDVI.

To assess the dynamics of the *water bloom*, we will apply NDVI (Vegetation Index) to the image of the Kyiv Cistern opposite Dymer settlement.

For this purpose, perform all the steps that have been described above (select the satellite (Landsat 8), date (13.08.2013), band combination (6, 5, 3) and zoom into the areas of algal blooms, which appear as abnormal green spots on the water surface).



Select one of the areas of algal bloom and build a vegetation mass change chart. For this purpose, digitize the selected area (using the *Pen tool*)  and click the ***Spatial Info / Feature into Service chart*** button. Now, we can select the period to be displayed on the chart (from one month to a year).



Assessing Agricultural Lands in Vinnytsia Oblast (Case Study: Evaluating Land-Use Change in Ladyzhyn District)

Case

The Myronivskyi Khliboproduct (MHP), Agro and Industrial Holding, is currently the leading producer of poultry meat in Ukraine and the largest company of the type in Eastern Europe. Activists from about ten local communities in Vinnytsia and Cherkasy Oblasts are bringing public attention to the issue of environmental degradation in the region caused by the activities of the Holding.

According to Ecoaction, the civil society organization, poultry farms are the second largest source of pollution after Ladyzhyn Thermal Power Station and chemical plant in Vinnytsia and Cherkasy oblasts. The facilities of Vinnytsia Poultry Farm (MHP subdivision) have a capacity of 1.5 million birds held at a time. In fact, poultry farms with a flock size of over 85 thousand broilers are regarded as sources of high environmental risks.

The MHP also produces cereals, sunflower oil, and meat products. The Holding sells its products under the following brands: Nasha Riaba, Lehko, Baschynskyi, and Qualiko, Vinnytski Kurchata (Vinnytsia chickens).

Task

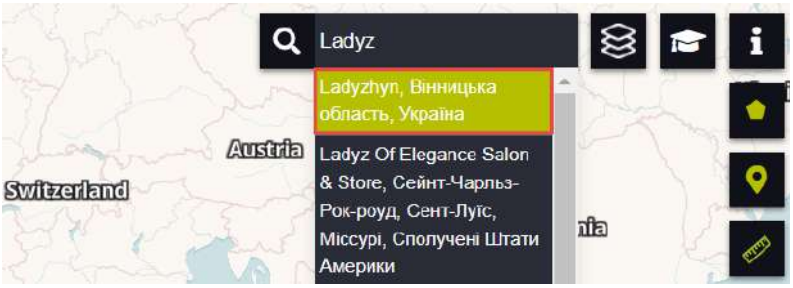
Analyze the agricultural lands in Ladyzhyn District in 2013 – 2019. Evaluate the capacity of the MHP by locating the poultry farms facilities. Learn how to calculate indices important in agriculture.

Instructions for self-guided work:

1. Open *EO Browser* webpage (https://apps.sentinel-hub.com/eo-browser).

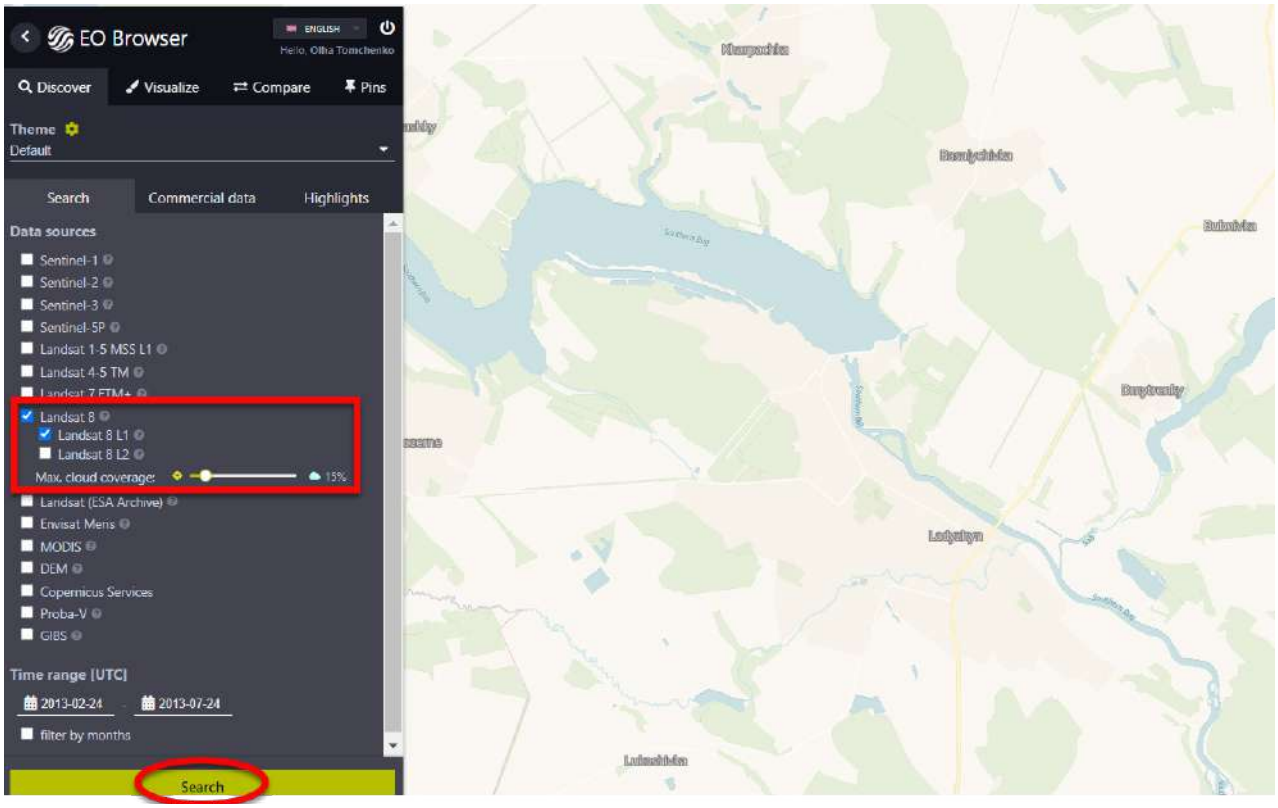
2. Log in on the website.

3. Enter *Ladyzhyn* in the search field and click on the magnifying glass icon to zoom to the location on the map:



4. In the settings toolbar, select:

- ***Data sources*** *(satellite)* – Landsat 8 (L1);
- ***Max. cloud coverage*** – 15%;
- ***Time range*** – February 24, 2013 – July 24, 2013;
- Click the ***Search*** button.



You will get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

Select the image captured on 02.05.2013 and display it in ***True color – pansharpened***.

Task

Identify the Ladyzhyn Thermal Power Plant on the image (clue: it is situated within Ladyzhyn town, on the bank of the Southern Buh River.) What features are useful for the identification of industrial facilities on an image?

_____

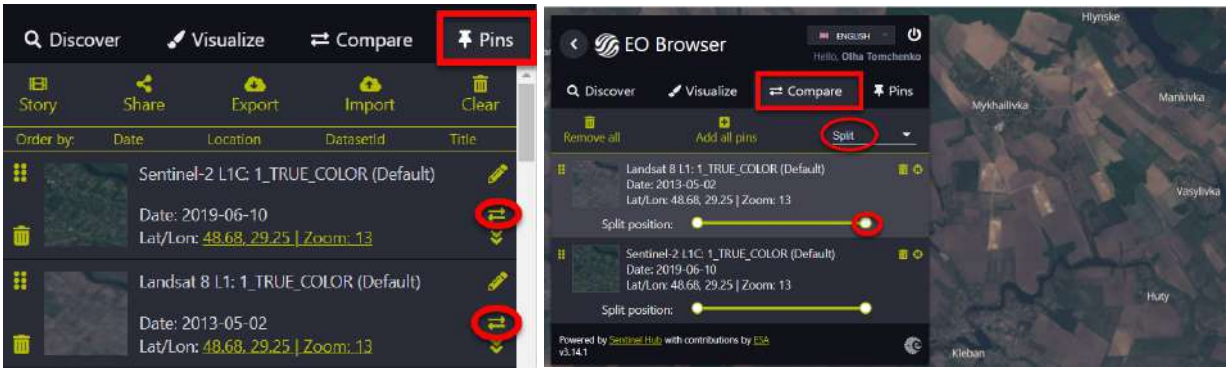
5. Using the ***Pins*** tool, save the image to your favorites.

6. Return to the ***Search*** tab and select the following:

- ***Satellite (Sentinel-2) (L1C));***
- ***Max. cloud coverage*** – 15%;
- ***Time range*** – February 24, 2019 – June 24, 2019;
- Click the ***Search*** button.

Select the image captured on 02.06.2019 from the list and save it in the ***Pins*** using the ***True color*** mode.

7. Compare two selected images in the ***Pins*** tab using the ***Opacity*** or ***Split*** mode.



Task

Has the appearance of the agricultural lands in Ladyzhyn District changed over 2013 – 2019? If yes, specify the changes?

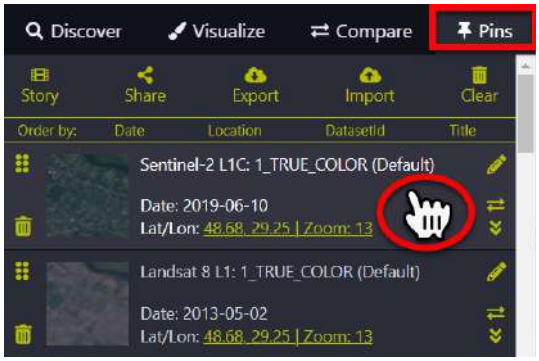
Calculate the number of poultry farms within *Ladyzhyn Reservoir – Haisyn – Kyrnasivka – Trostianets* territory (see the image below).

	2013 p.	2019 p.
Number of poultry farms		

Drone view of the poultry farm.

8. Finish comparing the images by clicking the ***Finish comparison*** button in the left-hand pane.

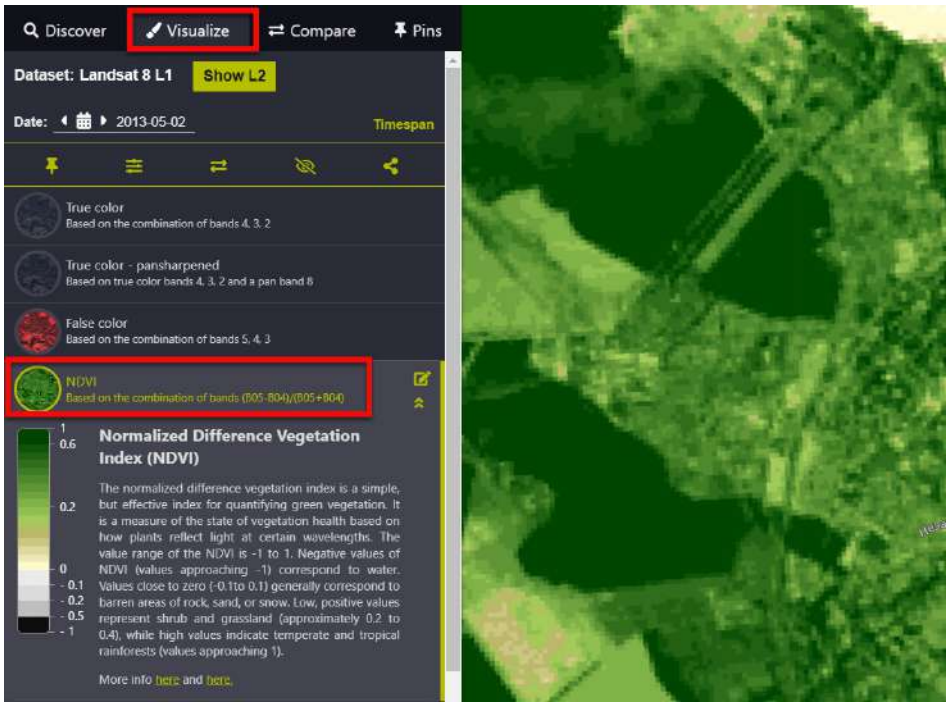
By selecting one of the images in the ***Pins*** tab, you will automatically switch to ***Visualize*** tab where you can test various indices.



The most popular in agronomy is the ***NDVI – Normalized Difference Vegetation Index***. Based on data on the vegetative activity of biomass, the index is used to assess the condition of crops at a particular time or over a certain period. During photosynthesis, green plants absorb most of the visible light spectrum and reflect near-infrared waves. In this way, the NDVI index is calculated – the difference between the values of the red and near-infrared spectrum divided by their sum. In characterizing vegetation density, NDVI indicates those areas of the field that require reseeding, application of plant protection products and fertilizers.

9. Select ***NDVI*** from the left-hand sidebar.

By clicking on the arrows near ***NDVI***, you can open the index scale (map legend), which varies from -1 to 1 (from black to dark green). Vegetation appears in the shades of green (the shade depends on the intensity of vegetation development: healthy vegetation with the highest biomass is dark green) and mostly ranges from 0.2 to 1.



Select any field and zoom in to it. Using the ***Draw area of interest*** tool  , from the right-hand sidebar, draw a polygon inside this field. Build a chart (click the  tool). By placing your mouse cursor over any point in the chart, you may see the minimum, maximum, and mean NDVI values within the polygon.

Task

Specify the mean NDVI value for the field at the beginning of May 2013 and compare it with the value as of early May 2019.

	2013 p.	2019 p.
Exact date (day, month)		
Mean NDVI value		

To speed up, you can use the same polygon and just go to the ***Pins*** tab, select a Sentinel image from the list and repeat from step 9. An important difference between the charts based on Landsat and Sentinel data is that Sentinel charts allow taking into account cloud coverage and reducing it by moving the slider at the top-right corner of the chart.

10. In the ***Visualization*** tab, compare the number of indices available for automatic calculation for Landsat and Sentinel imagery.

Check yourself

Why do you think the number of indices is different?

_____

Using Google, explain the difference between NDVI and NDWI.

_____

In addition to NDVI, what other indices are important for agriculture? Why

_____

Assessing Anthropogenic Landscape Changes Due to Amber Mining in Rivne Oblast

Case

According to the Center for Investigative Journalism, Syla Pravdy, "There is no need to investigate to prove that illegal amber mining is flourishing in Ukraine; it is enough to review the satellite data. Numerous whitish spots of pit craters appear on satellite images of forests and valleys of Ukrainian Polissia. Here and there in the forests located between Kukhitska Volia (a village in the Zarichne District of Rivne Oblast) and Lake Bile you come across "lunar landscapes".

For more information, visit https://sylapravdy.com/reportazh-iz-klondajku-na-karantyni/.

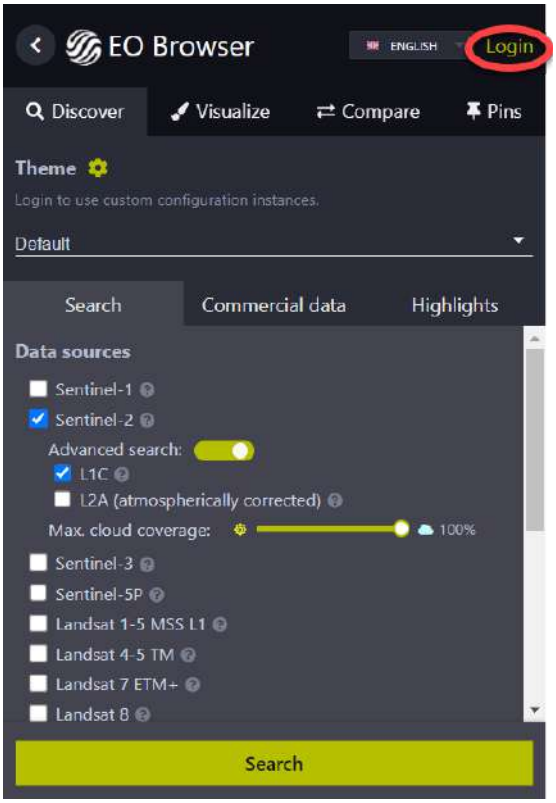
Task 1

Detect the sites of large-scale amber mining in Zarichne District of Rivne Oblast and select the best band combination for their identification.

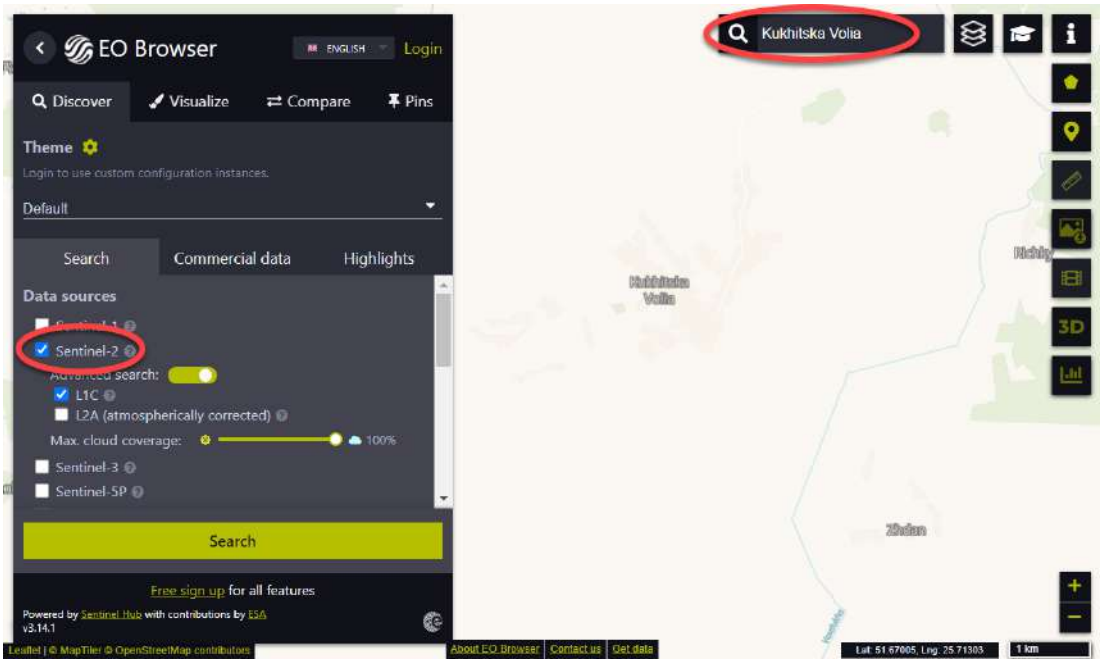
Instructions for self-guided work

1. Open *EO Browser* webpage (type *eo browser* in the Google search bar and click on the first link, *Sentinel-hub EO-Browser*, or go directly to https://apps.sentinel-hub.com/eo-browser).

2. Create an account and/or login on the website.



3. Enter *Kukhitska Volia* in the search field and click on the first line that is highlighted to zoom into the territory of Ukraine on the map.



4. In the Search tab, select:

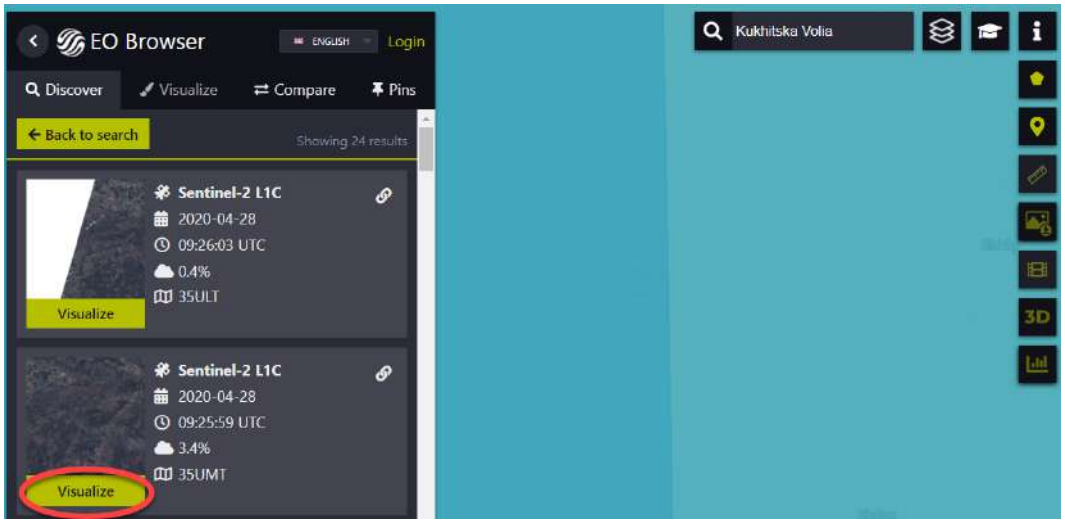
- ***Data sources*** (satellite) – Sentinel-2 (L1C), by clicking on the question icon to the right of the satellite name, you can read detailed information about the satellite;
- ***Time range*** – April 1, 2020 – April 30, 2020;

Important! To select a date, choose it from the calendar rather than type.

- Click the ***Search*** button.

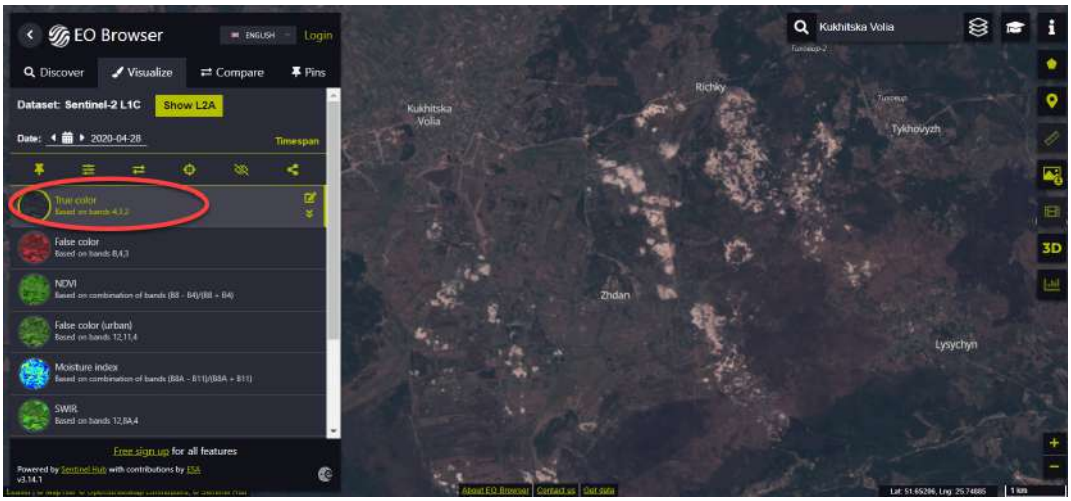
You will get a list of all images available in the catalog that match the search query, which may be viewed in the ***Results*** tab.

5. View the images by scrolling through the list in the left-hand sidebar, find the image taken on 28.04.2020 and click the ***Visualize*** button to display the image in the *EO Browser* window.



Under a closer examination, you will see white spots in the fields and woodlands – these spots indicate the landscape changes due to amber mining.

6. From the list, select the visualization mode that suits you best:



a – True Color (4, 3, 2);

b – False Color (8, 4, 3);

c – Short wave infrared composite (SWIR) (12, 8A, 4).

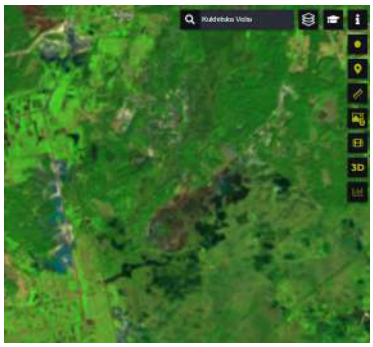
Task 2

Compare the dynamics of landscape changes due to amber mining in 2020, 2019, and 2016 within the territory between Kukhitska Volia and Tykhovyzh villages.

In the Search tab, select:

- ***Data sources*** *(satellite)* – Sentinel-2 (L1C);
- ***Time range*** – April 1 – April 30, 2020, 2019 and 2016.

One by one, find the images taken on 11.04.2020, 15.04.2019, and 18.04.2016. View each image by clicking the ***Visualize*** button and selecting the most suitable visualization mode. Now you can see how the area of amber mining increased over time.



2016 p.

2019 p.

2020 p.

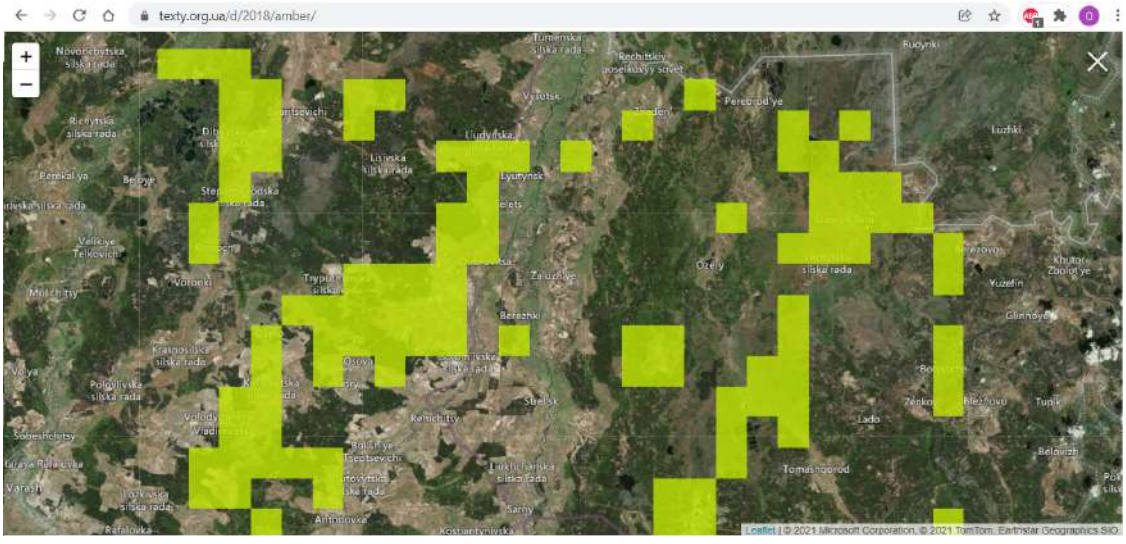
Check yourself

Calculate and write down in the table below the area of land destroyed by illegal amber mining between Kukhitska Volia and Tykhovyzh villages over three years:

Year	Area
2016	
2019	
2020	

Task 3

Using the interactive map of illegal amber mining in Polissia region developed within the framework of *Leprosy of the Land* project by a group of volunteers and a team of *Texty* website (https://texty.org.ua/d/2018/amber/), identify the largest areas of amber mining and check their current appearance (2020) in *EO Browser.*



The amber map covers three oblasts: Zhytomyr, Volyn and Rivne. The amber mining sites as of 2015 and 2016 were identified based on high-resolution satellite images provided by Google and Bing Maps. In general, the mining sites appear yellow on the map. By zooming in, you can view the satellite imagery of the selected location. Use the names of settlements near amber pits as references, search for interesting (in your opinion) territories in EO Browser and check these territories for changes.

Check yourself

Write down the districts and settlements in Rivne Oblast with the largest amber mining sites.

_____

Task 4

Create a thematic map of the areas that experienced anthropogenic landscape changes due to amber mining using *EO Browser* scripts.

In modern computer programming, a script is a sequence of commands that automates the execution of tasks that would otherwise be performed individually by a human operator, which is time-consuming. To write a script, special programming languages are used, scripting languages.

Below, we will discuss one of the custom scripts for Sentinel Hub that can be fed via the URL.

Pseudo Forest Canopy Density (FCD) – is a script for *EO Browser*'s Sentinel Hub, which classifies each pixel into one of the following categories:

- *High Forest*
- *Low Forest*
- *Grassland*
- *Bare land*
- *Water*
- *Unknown.*

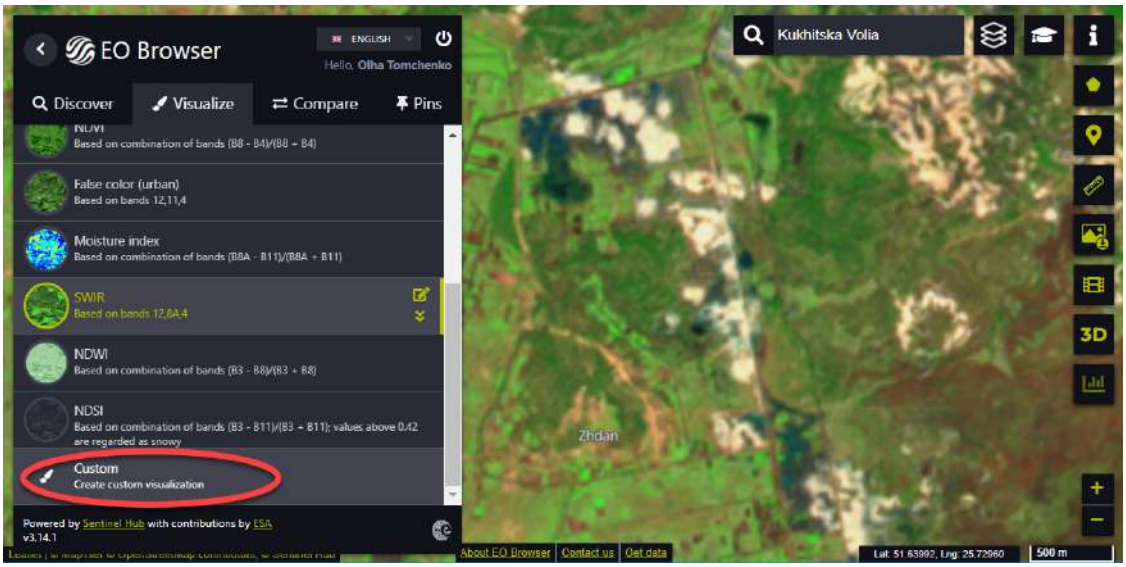
With this script, the Forest Canopy Density (FCD) is calculated using four different indices:

- Advanced vegetation index (AVI);
- Bare soil index (BI);

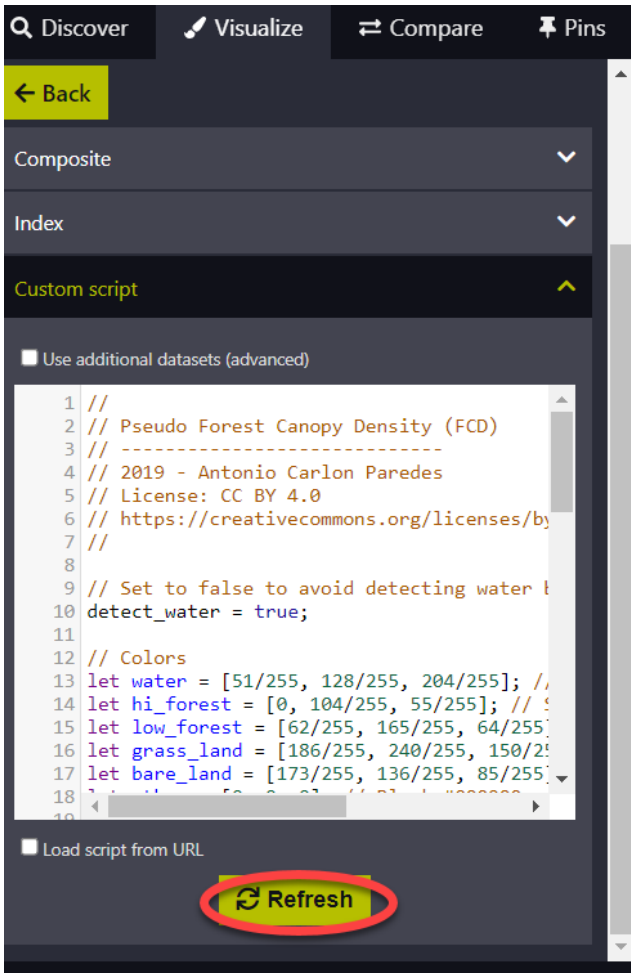
- Canopy shadow index (SI);
- Thermal index.

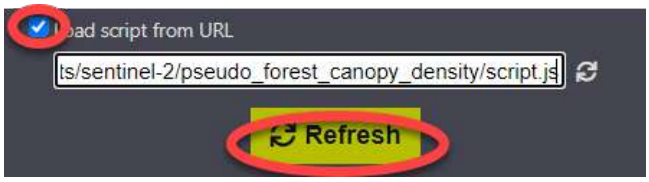
How to run a script?

First, select the image of your interest in the ***Discover*** tab and visualize it by clicking the ***Visualize*** button. Then, choose the ***Custom*** button from the left-hand pane.



In the script window, change the existing script with another one, in our case with ***Pseudo Forest Canopy Density***. Find the Pseudo Forest Canopy Density script by searching in Google or specify to load the script from the link – URL.

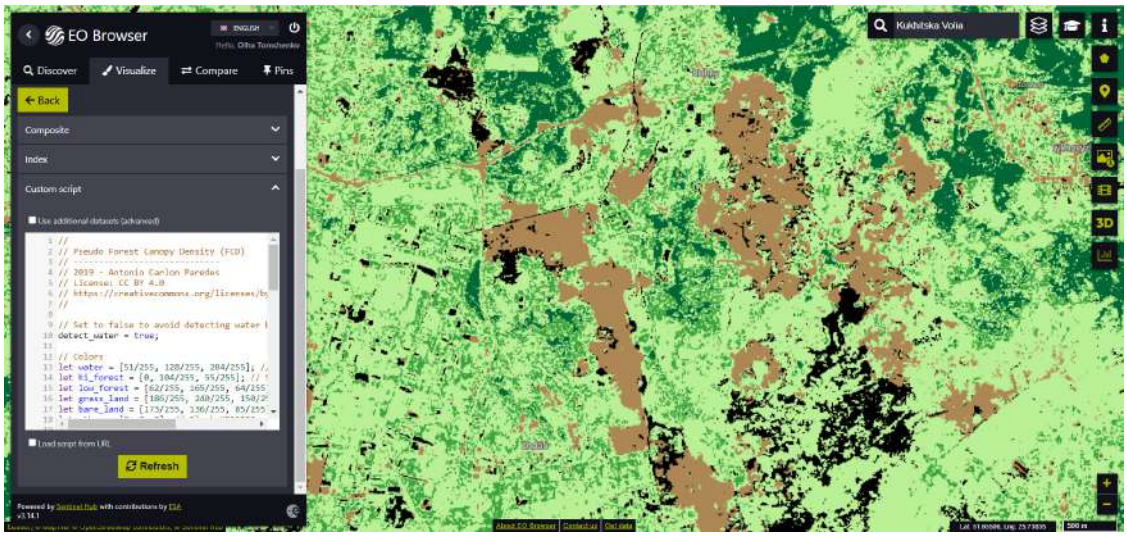




To do this, copy the script code for forest canopy density at https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel-2/pseudo_forest_canopy_density/script.js, or from this document, and paste the code in the script window and click ***Refresh***.

```
// Pseudo Forest Canopy Density (FCD)
// ----------------------------
// 2019 - Antonio Carlon Paredes
// License: CC BY 4.0
// https://creativecommons.org/licenses/by/4.0/
//


// Set to false to avoid detecting water bodies
detect_water = true;


// Colors
let water = [51/255, 128/255, 204/255]; // Blue #3380cc
let hi_forest = [0, 104/255, 55/255]; // Strong green #006837
let low_forest = [62/255, 165/255, 64/255]; // Medium green
#3ea540
let grass_land = [186/255, 240/255, 150/255]; // Light green
#baf096
let bare_land = [173/255, 136/255, 85/255]; // Brown #ad8855
let other = [0, 0, 0]; // Black #000000


// COEFICIENTS: These coeficients are orientative
// and some tweak may be needed depending on the
// location and case of study


// NDWI water limit
let ndwi_hi = 0.2;


// Bare soil index (BI), soil limit
let bi_hi = 2;


// NDVI high and low limits
let ndvi_lo = 0.20; // 0.20 for L1C (suggested value)
    // 0.25 for L2A (suggested value)
let ndvi_hi = 0.40; // 0.40 for L1C (suggested value)
    // 0.45 for L2A (suggested value)


// Shadow index (SI) high and low limits
let si_lo = 0.90; // 0.90 for L1C (suggested value)
    // 0.92 for L2A (suggested value)
let si_hi = 0.93; // 0.93 for L1C (suggested value)
    // 0.95 for L2A (suggested value)




if (detect_water) {
            ndwi = (B03 - B08) / (B03 + B08);
            if (ndwi > ndwi_hi)
             return water;
}


let ndvi = (B08 - B04) / (B08 + B04);
let bi_1 = (B08 + B03 + B04) / (B08 + B03 - B04);
let si = Math.pow((1 - B03) * (1 - B04), 1/2);


if (ndvi > ndvi_hi && bi_1 < bi_hi && si > si_hi)
 return hi_forest;
else if (ndvi_hi > ndvi > ndvi_lo && bi_1 < bi_hi && si_hi > si
> si_lo)
 return low_forest;
else if (ndvi > ndvi_lo)
 return grass_land;
else if (ndvi < ndvi_lo && bi_1 > bi_hi && si_lo > si)
 return bare_land;
else
 return other;
```

If everything is done correctly, you will get a new map based on a satellite image, in which *Bare land* appears brown and represents areas of illegal amber mining.



For more information about scripts for Sentinel Hub, visit: https://custom-scripts.sentinel-hub.com/.

Check yourself

What are the threats posed to nature by illegal amber mining?	
Is there legal amber mining in Ukraine?	

Assessing Urban Landscape Changes (Case Study: Evaluating Urban Growth of Kyiv)

Case

Protecting nature near megacities is not an easy task. For several years now, Ecopark Osokorky, the public organization, has been trying to prevent the development of floodplain meadows in Kyiv. Currently, the city has two adjacent landscape reserves in this area: "Lake Tyagle" (officially established in November 2019) and "Osokorkivsky Meadows" (established in April 2019). It is planned that these reserves and other sites will be combined into a regional landscape park (RLP).

To watch the video of the territory, go to https://cutt.ly/ZuLbIXE.

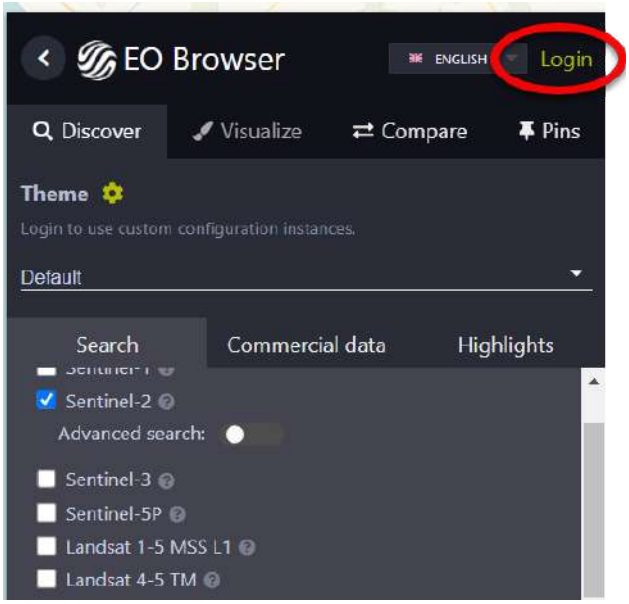
Task 1

Monitor the construction of the Osokorky neighborhood – compare the appearance of the territory in 1984 and 2020.

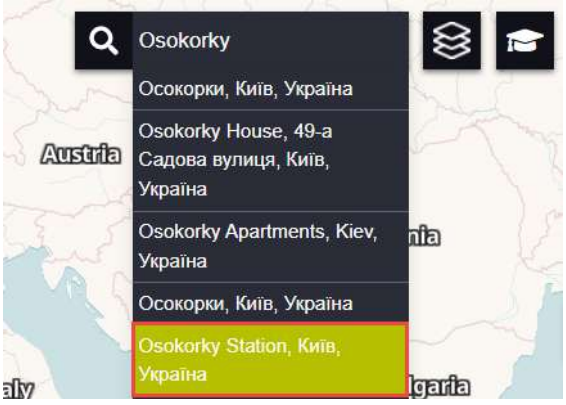
Instructions for self-guided work

1. Open *EO Browser* webpage (type *eo browser* in the Google search bar and click on the first link, *Sentinel-hub EO-Browser*, or go directly to https://apps.sentinel-hub.com/eo-browser).

2. Create an account and/or login on the website.



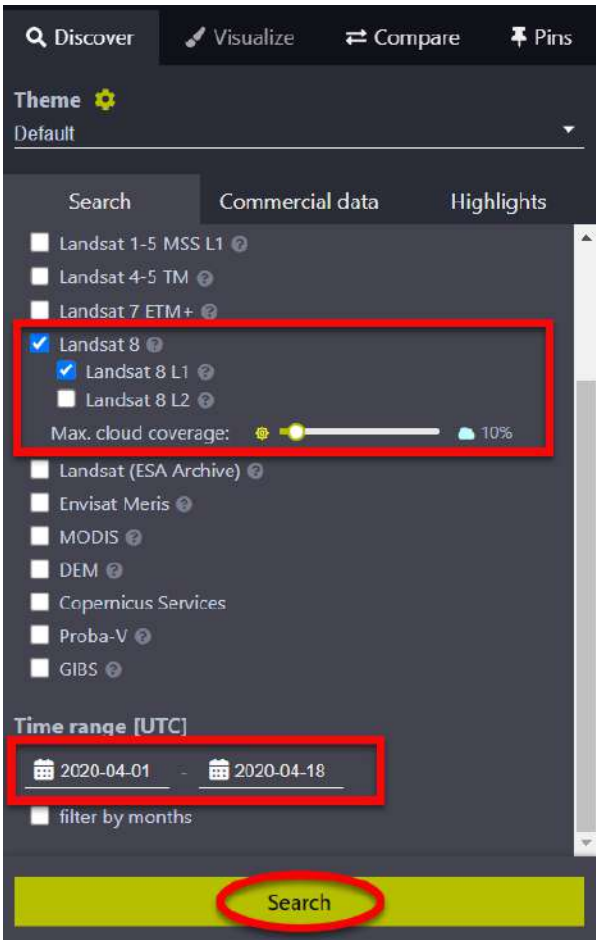
3. Enter *Osokorky* in the search field and click on the first highlighted line to zoom into the territory of Ukraine on the map:



4. In the ***Search*** toolbar, select:

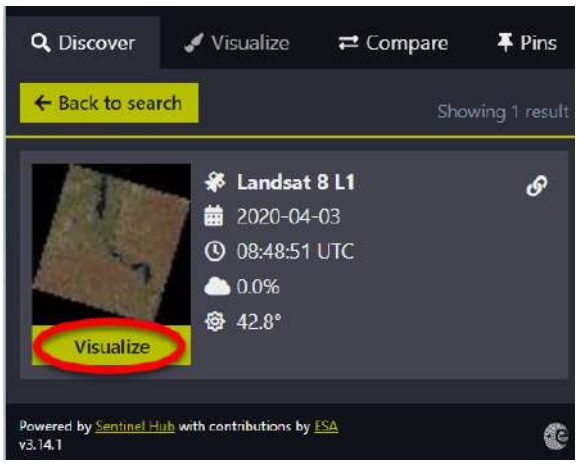
- ***Data sources*** *(Satellite)* – Landsat 8 (Landsat 8 L1);
- ***Max. cloud coverage*** – 10%;
- ***Time range*** – 01.04.2020 – 18.04.2020;
- Click the ***Search*** button.

Important! To select a date, choose it from the calendar rather than type.



You will get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

5. Select the image captured on 03.04.2020 from the list and click the ***Visualize*** button to display the image in the *EO Browser* window.

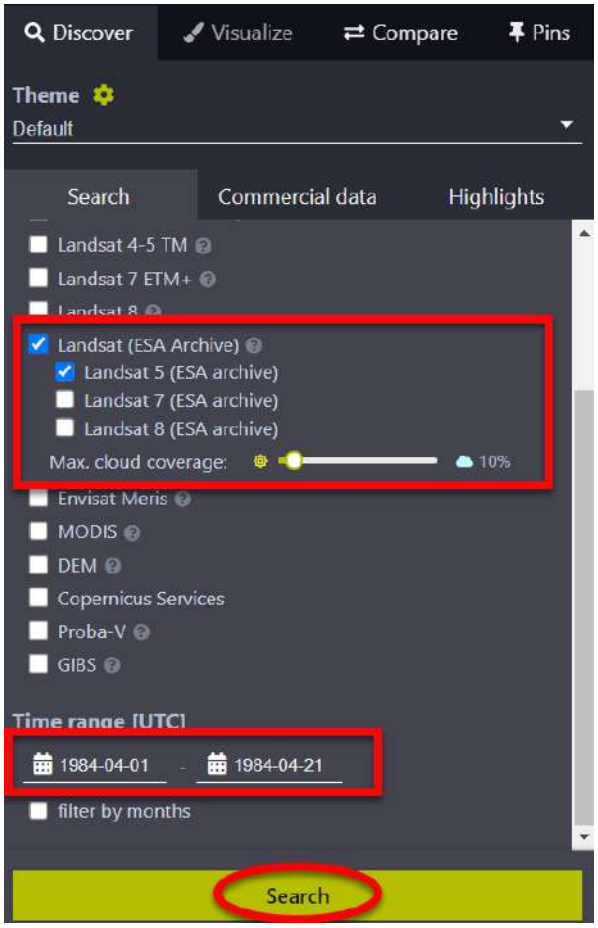


6. Switch to the ***True color – pansharpened*** visualization mode. It will allow you to get a clearer image since you are using a 15-m resolution panchromatic band 8.

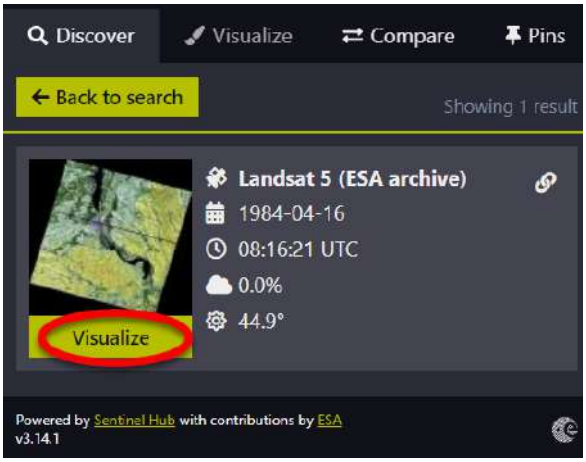
7. Visually evaluate the scale of construction in the given territory and save the image to the favorites by clicking the icon.

8. Return to the ***Search*** tab and download the ***Landsat 5*** image captured on June 6, 1984, by selecting the following search parameters:

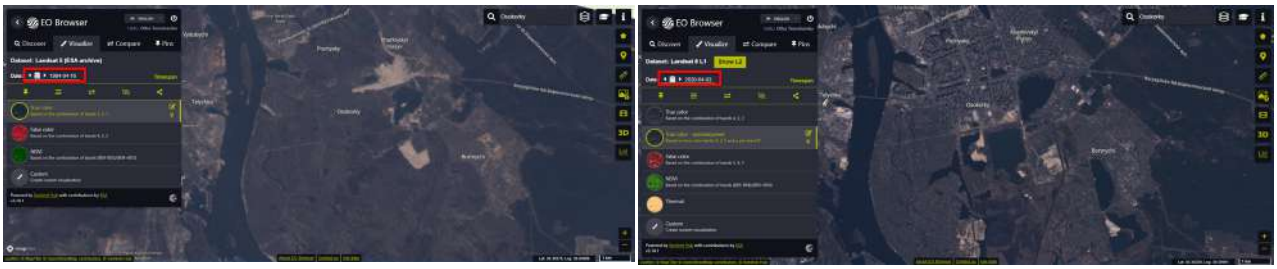
- ***Data sources*** *(Satellite)* – Landsat (ESA archive) - Landsat 5;
- ***Max. cloud coverage*** – 10%;
- ***Time range*** – 01.04.1984 – 21.04.1984;
- Click the ***Search*** button.



9. Visualize the image taken on April 16, 1984, and save it to the favorites by clicking the icon in the ***Pins*** tab.



10. Click the ***Compare*** button under the *Pins* tab and select the ***Split*** mode. By moving the slider near the upper image, compare the images of the Osokorky neighborhood in 1984 and 2020.



1984 2020

We recommend you to study other districts of Kyiv using the abovementioned procedure and see with your own eyes how Ukraine's capital has changed over time.

Check yourself

Analyze the satellite images of Kyiv captured in 1984 and 2000 and specify which neighborhoods have been constructed during that time.	

Task 2

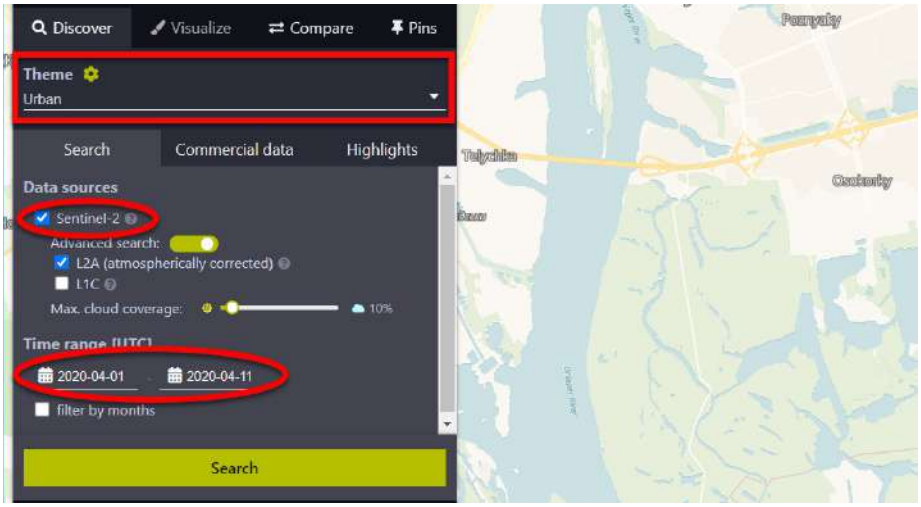
Classify the ***Sentinel-2A*** image captured on April 7, 2020, in the *Education* mode using the automatic script, ***Urban Classified Script***.

1. Switch to the *Education* mode by clicking the icon in the upper-right corner of the screen and selecting ***Education***. An abridged version of the ***Search*** tab that comprises a new ***Theme*** section will appear. Depending on the theme you choose, the program will automatically select the appropriate satellites.

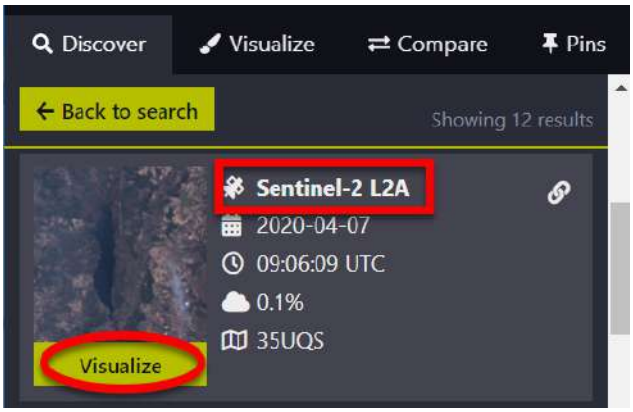
2. Select the ***Urban*** theme. For this theme, there are only Sentinel-2A images available. Enter Kyiv in the search field or zoom out the Osokorky neighborhood using the navigation buttons to display the whole city on the map.

3. In the ***Search*** tab, select the following:

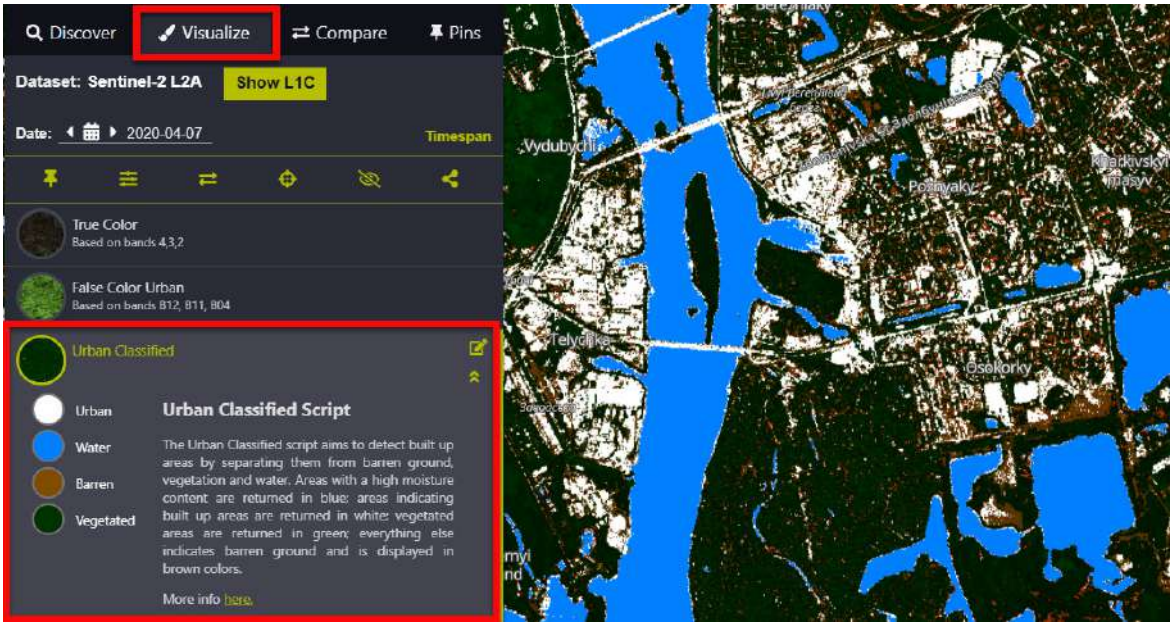
- ***Data sources*** *(Satellite)* – Sentinel-2 (L2A);
- ***Max. cloud coverage*** – 10%;
- ***Time range*** – 01.04.2020 – 11.04.2020;
- Click the ***Search*** button.



4. In the Discover tab, select and visualize the image taken on April 7, 2020.



5. The image will automatically open in the ***Visualize*** tab in a ***True color*** mode. Select ***Urban Classified*** from the list of combinations.



You will get a four-color image. The ***Urban Classified*** combination aims at identifying built-up areas, separating them from barren soil, vegetated areas, and water. Areas with NDWI values greater than 0.3 have a high moisture content and are colored blue; areas with B11 values greater than 0.8 and NDVI values lower than 0.1 are considered to be built-up and appear white; NDVI values greater than 0.2 indicate vegetated areas and are colored green; all other pixels are considered to be barren soil and appear brown.

As a result, we have made a map of the built-up and green areas within the location under study, in our case, Kyiv. This algorithm is certainly not 100% correct: due to the automatic classification, some built-up areas can be classified as barren soil, etc. The result depends on the specific area and the image, but this visualization is important for image interpretation and can be useful for research.

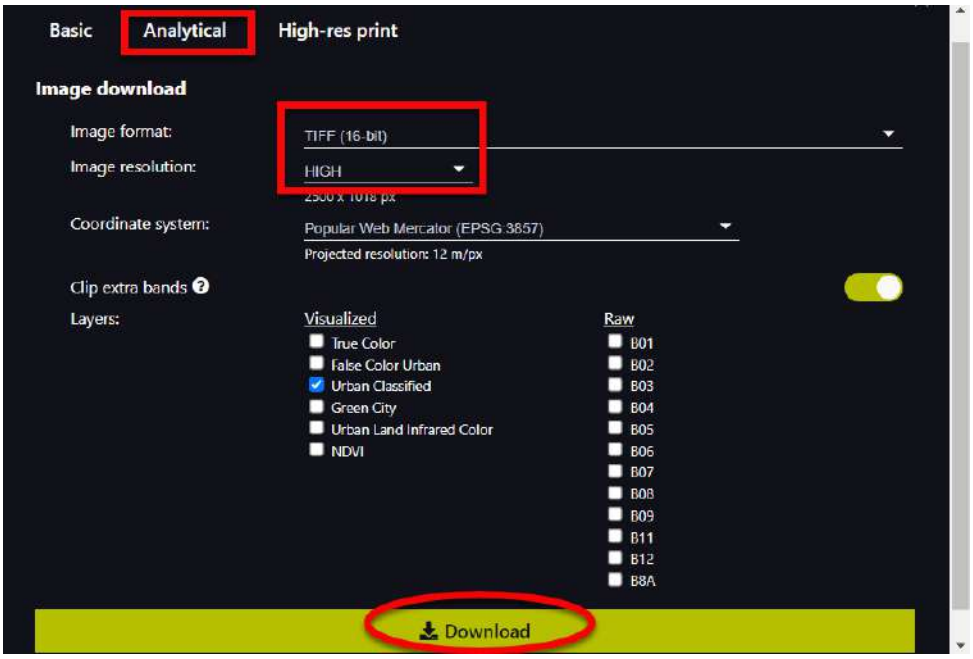
The ***Urban Classified*** visualization for Sentinel-2A images is available as a script that may be used in the custom mode in EO Browser. To find out more about the script and copy it, go to https://custom-scripts.sentinel-hub.com/sentinel-2/urban_classified/.

If you want to know more about scripts and test them, visit the special library that includes scripts suitable for various satellites and purposes – https://custom-scripts.sentinel-hub.com/.

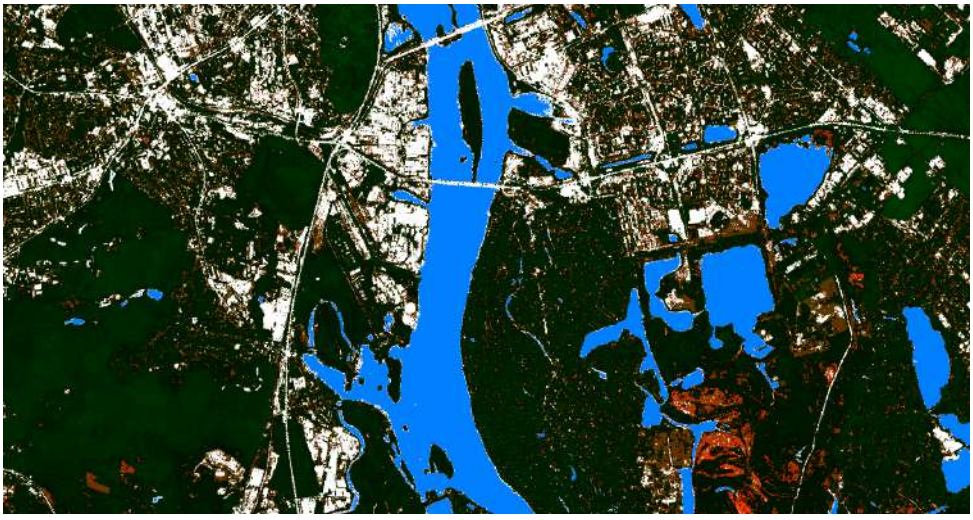
6. Save the resulting map as a TIFF image with georeferencing. This will allow you to open the image in any GIS application with automatic projection.

First, click the button in the upper-right pane and select ***Roads***, ***Borders***.

Using the navigation buttons , adjust the map to display the territory of interest on the resulting map and click the button (***Download image***) in the right-hand sidebar. Switch to the Analytical tab in the window that shows up and select ***Image format*** – TIFF (16-bit), ***Image resolution*** – HIGH; leave all other settings unchanged and click the ***Download*** button.



The image will be saved to your downloads folder. The resulting map will look similar to the map shown below.



Check yourself

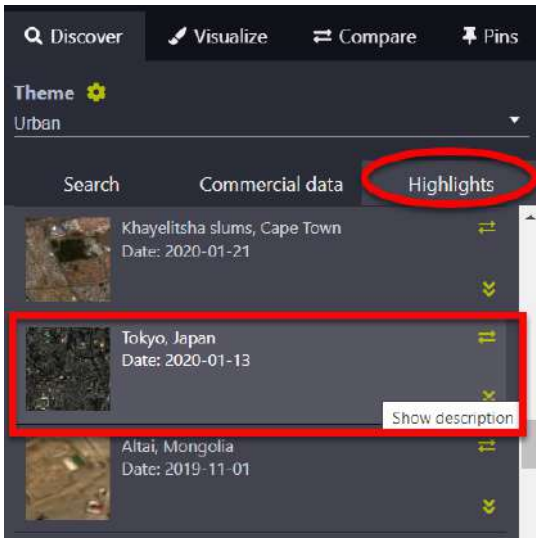
Analyze the resulting image and specify on which bank of Kyiv there are more green areas: left or right.	

Task 3

In the *Education* mode, evaluate the vegetated areas in any city of the world using the list of images in the ***Pins*** tab.

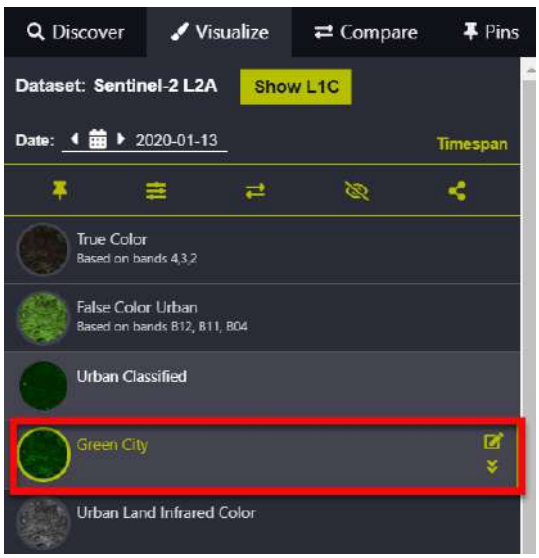
1. One of the features of the *EO Browser's Education* mode is the library of thematic images available in the ***Pins*** tab. Therefore, when you have switched to the *Education* mode and selected ***Theme – Urban*** in the search pane, go to the ***Pins*** tab. You will get a list of available images of different cities worldwide in various band combinations. Select any city from the list and display its image in *EO Browser* by clicking on the image thumbnail with the left mouse button.

As an example, we will select the image of Tokyo.



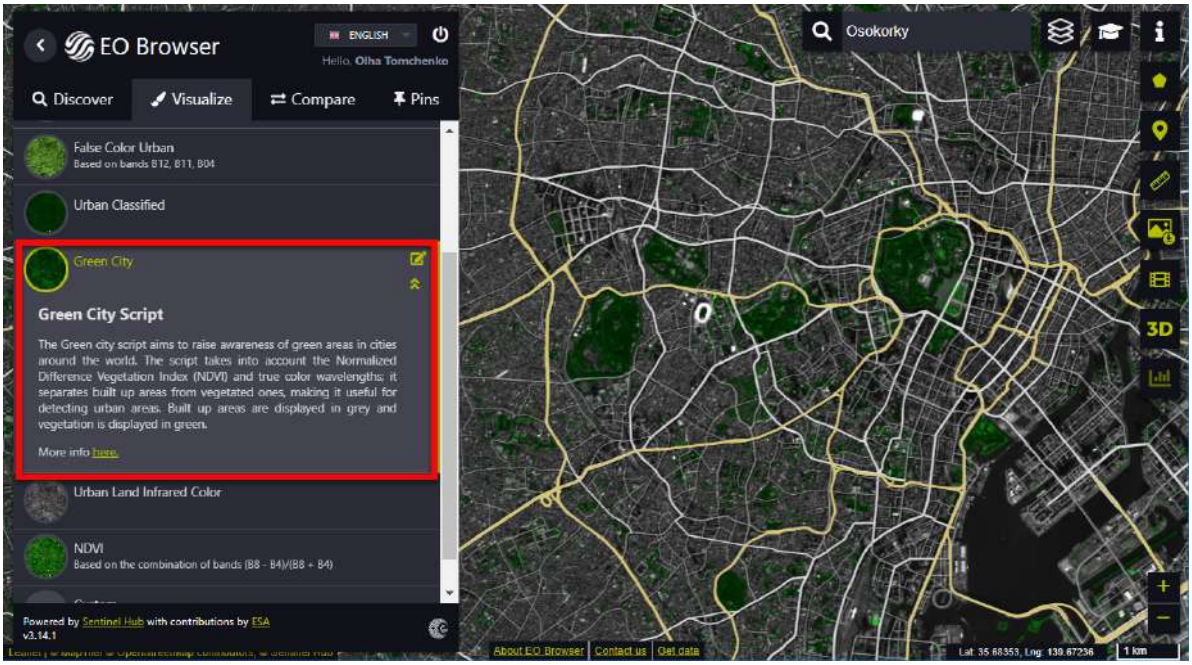
2. The selected image is displayed in the ***Visualize*** tab in the band combination that was used to save the image in the library (please note, it will not always be a *True color* mode).

To analyze the vegetated areas in the city and their spatial location, select the ***Green City*** combination. This combination takes into account NDVI and *True color* bands and sets boundaries to separate built-up areas from vegetated ones. The buildings are colored grey and the vegetation is green. Visualize the selected image in this band combination and try to analyze whether the greenery is equally distributed in the city and is enough for the comfortable living of its residents.



Green City is available as a script at https://custom-scripts.sentinel-hub.com/sentinel-2/green_city/ or may be used in the customary mode of *EO Browser.*

3. The image of Tokyo in the ***Green City*** combination.



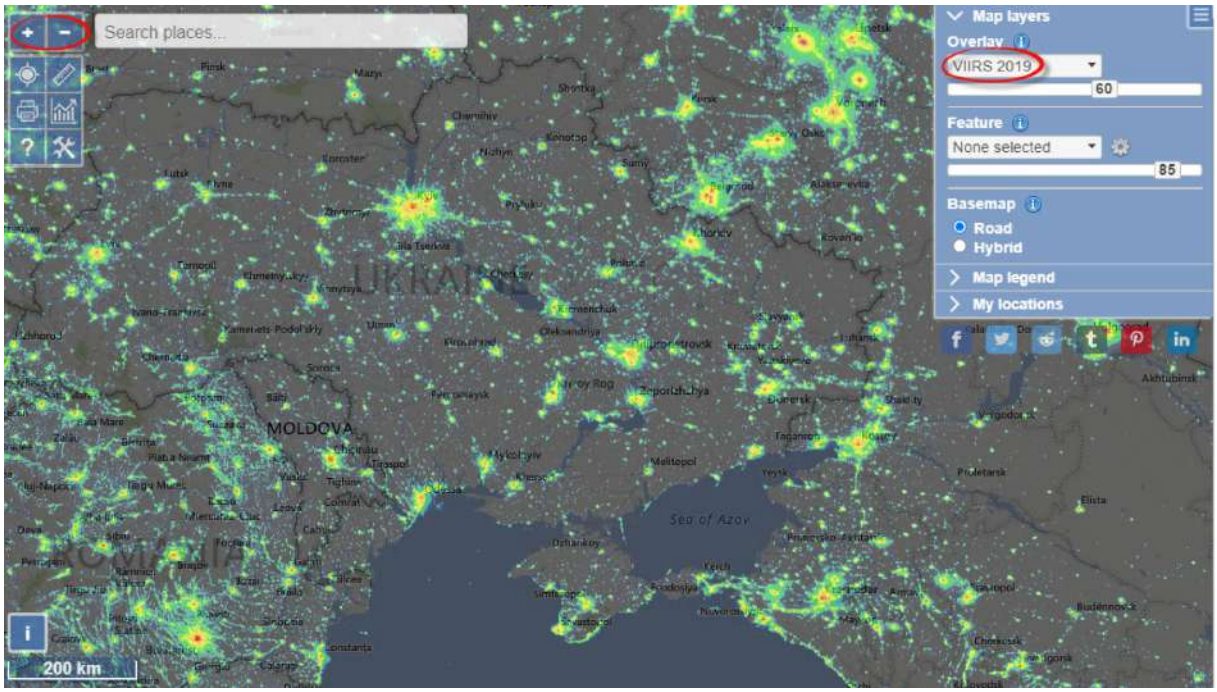
Check yourself

Specify the city you have selected for the analysis of vegetated areas.	
How would you characterize the amount and distribution of vegetated areas in this city?	

Light pollution washes out starlight in the night sky to urban onlookers and disrupts ecosystems as any other pollution. Achievements in lighting technology that provide energy savings and brighter light have actually made the situation worse. Due to excessive artificial light, the Milky Way is not visible to one-third of the humanity.

Light Pollution Map is an online platform where the light pollution of the world since 2012 may be analyzed. Using these maps, a level of light pollution in different cities may be determined.

Visit the platform at www.lightpollutionmap.info/. Select **VIIRS 2019** from the right-hand sidebar to display the map of 2019. Using the navigation buttons in the left-hand corner of your screen, zoom into the territory of Ukraine.



Check yourself

Using the map, analyze what city in Ukraine had the highest light pollution in 2019.	
Analyze the light intensity in the eastern regions of Ukraine (select the cities independently) in 2012-2019. What changes can be observed? What is causing such changes?	

Google Earth Pro Virtual Globe

Case

In this Section, we will discuss another Internet resource that has an intuitive interface and enables exploring our planet from space without leaving home. It is a virtual globe from Google, which allows users to view 3D-models of Earth, Mars, and Moon with superimposed high-resolution aerial photography and satellite images, as well as various data layers to obtain various real-time geoinformation.

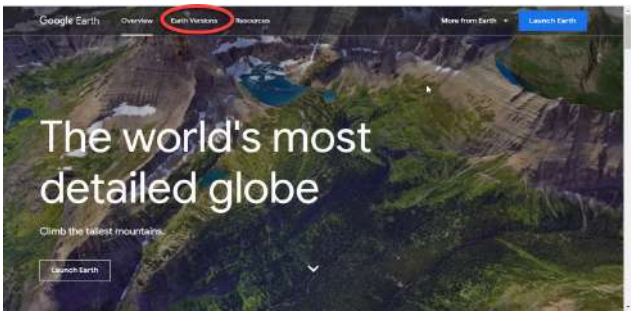
Currently, there are two simplified versions of Google Earth available: a web version for exploring 3D locations in the browser, and a version for mobile devices, which enables browsing the globe with a swipe of your finger on your phone or tablet. However, an extended Google Earth Pro desktop version is the most convenient for research, which allows users to import and export GIS data, and go back in time with historical imagery.

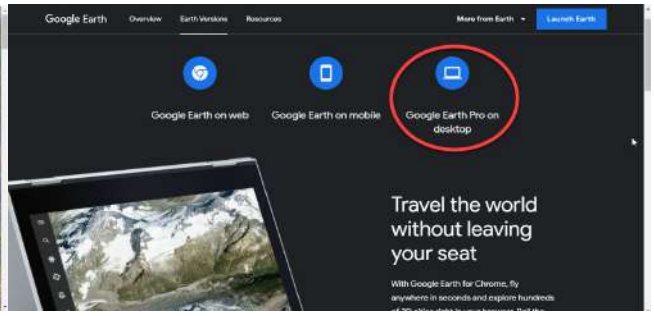
Task 1

Study the interface of the application, calculate the distance from your residential area to the capital of Ukraine and build the elevation profile.

1. Download and install an extended version of the application on your computer.

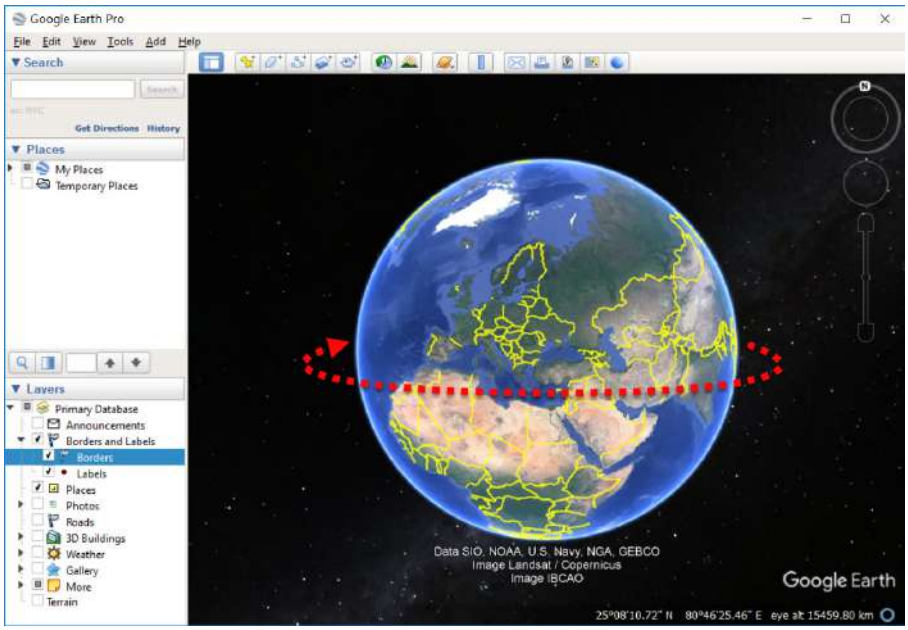
Go to the official *Google Earth* website https://www.google.com.ua/earth/ and click the ***Earth Versions*** tab on the homepage to select the required version of the application, namely – ***Google Earth Pro on desktop***.





Following installation on your PC, a *Google Earth Pro* icon will appear on your desktop. Now you can start exploring our planet.

2. For a start, we recommend you experiment independently. Try to set a rotation speed of the planet using your mouse – simply push it in one direction or another while holding down the left mouse button. You will see that the planet, contrary to all the laws of physics, can rotate in any direction at any speed you set.



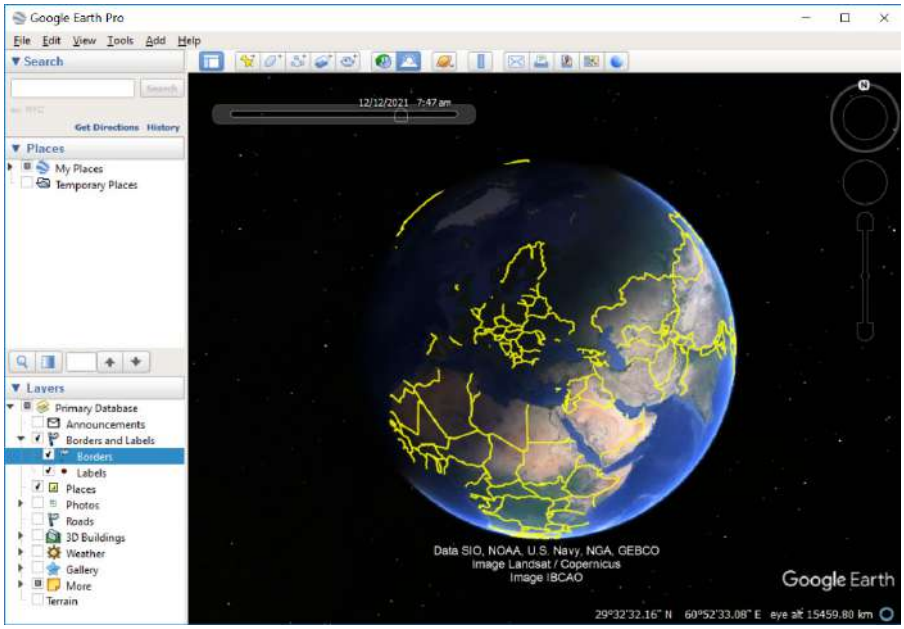
3. Let's have a closer look at the application's toolbar.

As you see, the toolbar is divided by the developers into several sections according to the functions. Some tools are used to add placemarks, create tours, make virtual trips, record and save trips for playback. Using other tools, you can create animations, visually illustrate and explain changing seasons, the revolution of Earth around the Sun, and the day and night cycle. There are also tools for measuring the exact distance between geographical features, viewing celestial bodies in a virtual planetarium, saving and sharing other screen images via email or printer, or viewing specific features with Google Maps service.

	***Hide/Show Sidebar*** toggles on and off the visibility of the sidebar, which contains the search field, history of your trips, your places, and layers available for overlaying.
	***Add Placemark*** enables creating a new placemark on the surface of the planet. You can forthwith enter the information about the selected location in the dialog box that opens.
	***Add Polygon*** allows you to enclose a certain territory into a polygon. The polygon's size may be adjusted with the mouse buttons. A new polygon may be saved to the *My places / Places* pane.
	***Add Path*** enables drawing a path between geographic points and saving it to *My places*.
	***Add Image Overlay*** enables setting the overlay image for the location or territory. The created map that contains a link may be saved to *My places*.
	***Record a Tour*** enables recording your virtual tour and saving it to *My places* for future playbacks.
	***Show historical imagery. Use the time slider to move between acquisition dates***, or shortly a time slider, provides a dynamic image, i.e. illustrating changes over time.
	***Show sunlight across the landscape. Use the time slider to set the time of day.*** It is better to use a time slider to see the changes over time. Without a time slider, you may view the day and night cycle at various locations by simply rotating Earth with your mouse.
	***Switch between Earth, Sky, and other planets*** enables switching between the view modes. Currently, there are Earth, Sky, Moon, Mars view modes available.

	Show ruler enables measuring distances and many more.
	Email enables sending emails with screenshots without opening a mailing service.
	Print enables printing a screenshot, last search results, or files from the selected folder under *My places*.
	Save image enables saving the created thematic map or satellite image using various resolutions.
	View in Google Maps enables exploring a certain location in Google Maps without leaving the Google Earth application.

4. Let's review simple visual effects now.



Have you noticed that the virtual globe shown above has dark and light parts?

Check yourself

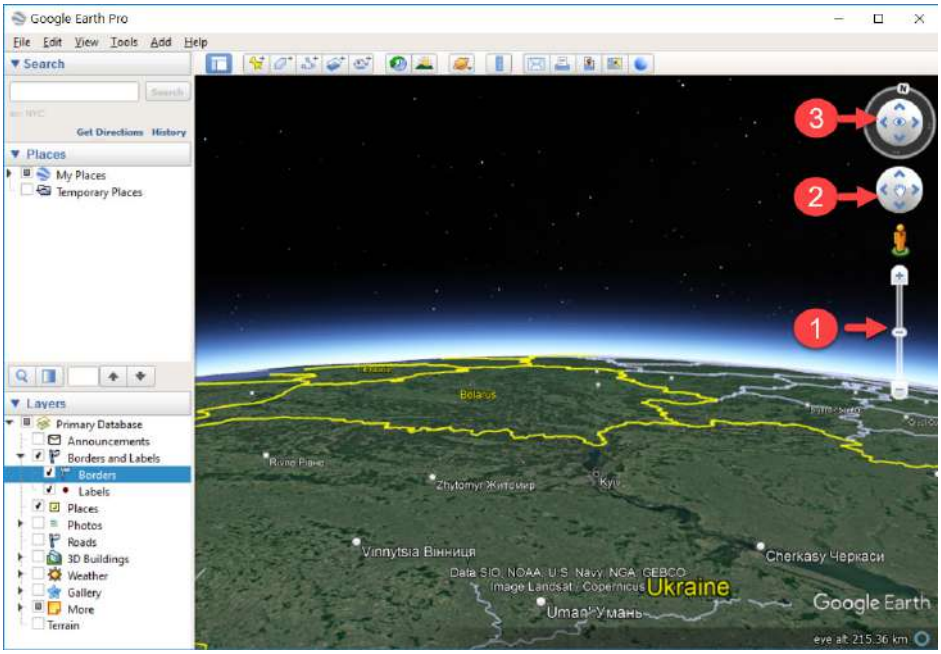
Why do you think our planet is displayed this way? Draw an analogy: why the day changes at night?

_____

Therefore, Google Earth enables real-time monitoring changes between day and night. Select the ***Show sunlight across the landscape*** button from the toolbar.

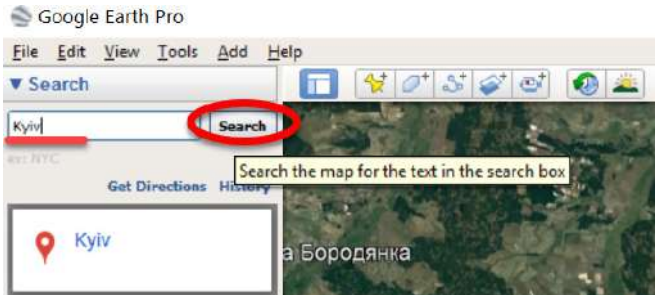
A time slider will appear in the upper left corner of your screen. As you move the slider back and forth, it shows you where the sun is during the day. You may also view any phenomenon as a short animation .

5. Using the navigation controls. To change the scale, first, get closer or move away from the center of your view by dragging the zoom slider (1) in the top right corner of the 3D viewer. To move around, you may use your mouse scroll wheel or the navigation joystick (2).



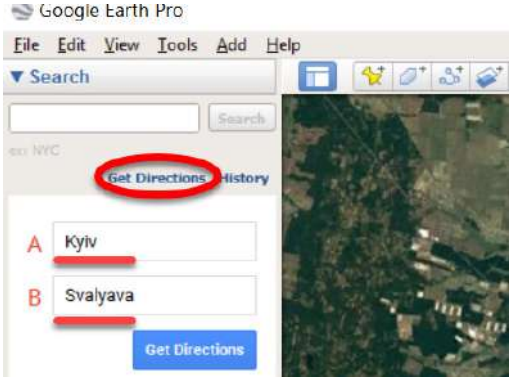
To tilt the view, use the navigation joystick (3) in the top right corner of the 3D viewer. It allows changing the downward angle of your view.

6. Using the ***Search*** panel. Enter a zip code, country, city, etc. in the search field in the top right corner of your screen. The map will automatically switch to the location of your interest.

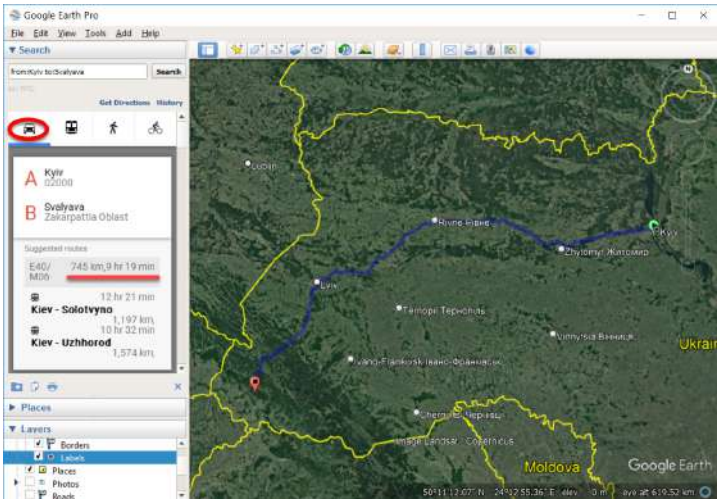


7. Measuring distance from your location to the capital of Ukraine and viewing the elevation profile.

Enter the starting and ending points (Kyiv – Svalyava) in the respective fields in the upper right-hand sidebar and click the ***Get Directions*** link. A blue line representing the route between two points will appear on the map.



Select the travel mode and you will see the travel time and distance in kilometers.



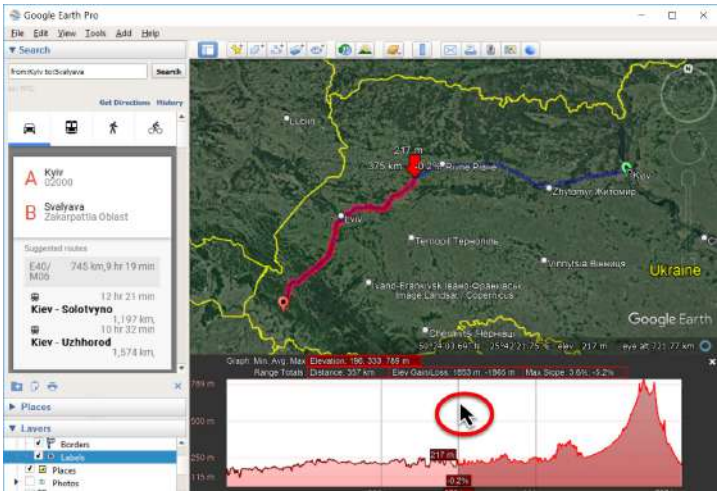
Check yourself

Compare the travel options and specify below the estimated time and distance in kilometers for a trip by different transportation methods:

by car	
by public transit	
by foot	

8. Click on the route line with your right mouse button and the ***Show Elevation Prof*** window opens. By hovering the cursor over the profile, you can get an online image of the corresponding point with displayed elevation and distance values. Depending on the position of the cursor, an active vertical line appears on the terrain profile.

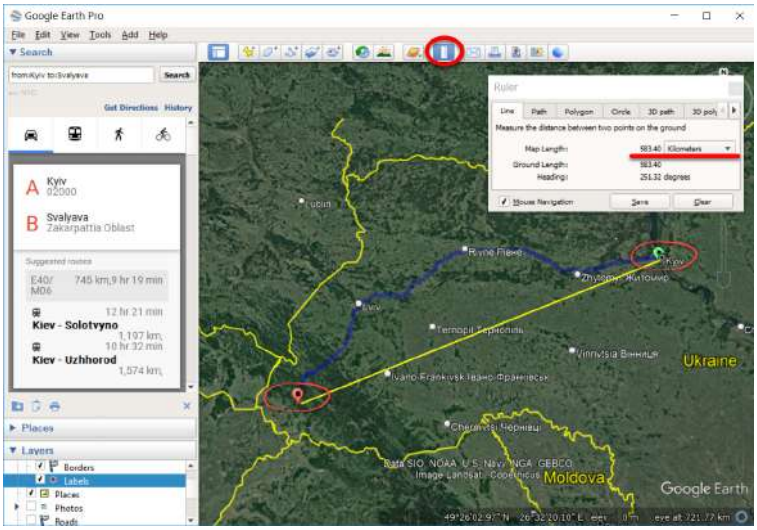
To display the elevation profile, drag the corresponding slider. You can select any part of the route by holding down the left mouse button.



9. Next step is measuring the distance between two locations: Kyiv and Svalyava. Using the Ruler tool, draw a path between P-1 point (Kyiv) and P-2 point (Svalyava): click a starting and ending points for your measurement.

The map length (584.37 kilometers), and additional values, such as heading (65.93 degrees), etc. will show up in the *Ruler* window.

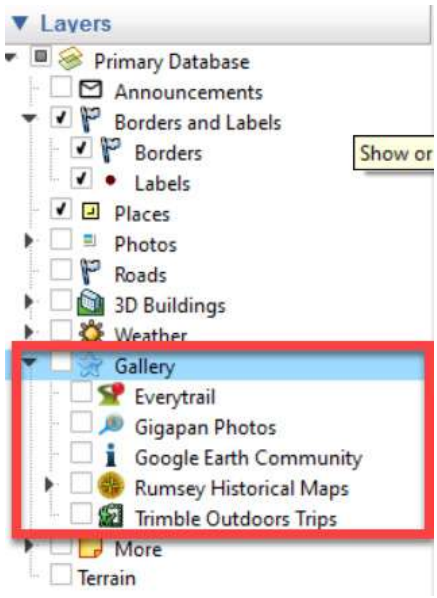
Please note, the more precise you specify the starting and ending points, the more exact the distance values you get.



Note: As you move your mouse over the location, its latitude and longitude coordinates will be displayed at the bottom of the screen as well as the elevation above sea level.

10. Review the list of available thematic layers (sidebar). It is rather long and you can choose by yourself what to display on the Earth's surface. All layers are structured and grouped into categories. Currently, there are 8 main categories: Borders and Labels, Photos, 3D Buildings, Ocean, Weather, Gallery, Global Awareness, and More. You can expand a category and turn individual sub-categories on and off. Some categories have several levels of sub-categories. It is enough to click on an arrow symbol next to a category name and a full list of features will display. As you know, the list of layers is updated and expanded regularly.

Try out each of the layers individually and determine their relevance and practicability. Below is a detailed description of the ***Gallery*** category.



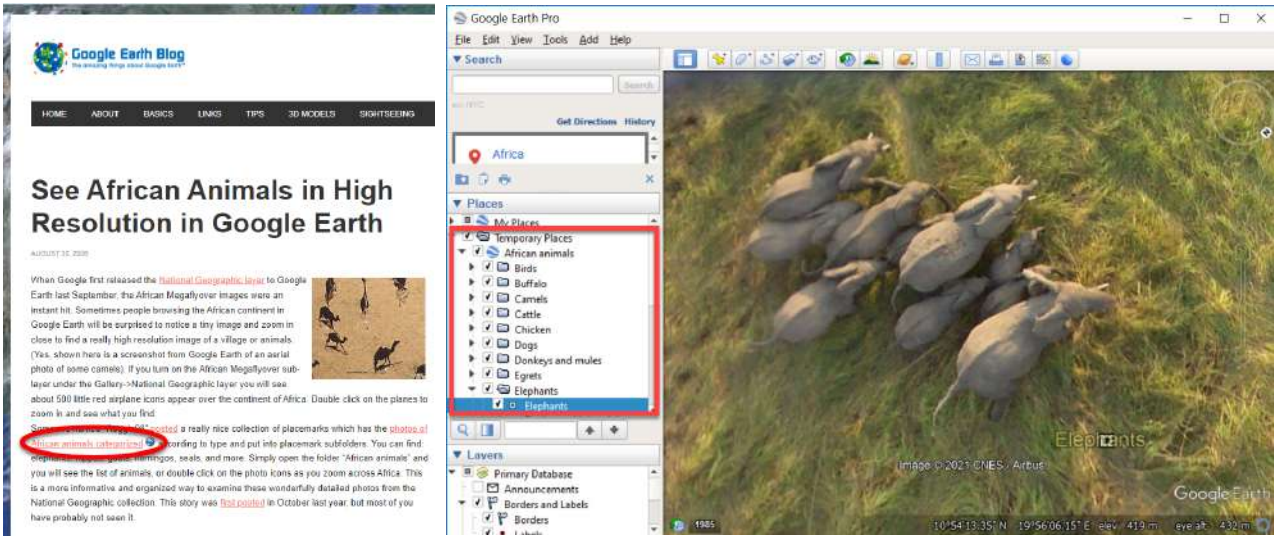
Task 2

Review the thematic layers available in *Google Earth*.

The ***Gallery*** layer contains information about a feature from different sources – published on the Internet by mass media or uploaded by other users. Its sub-categories are, namely:

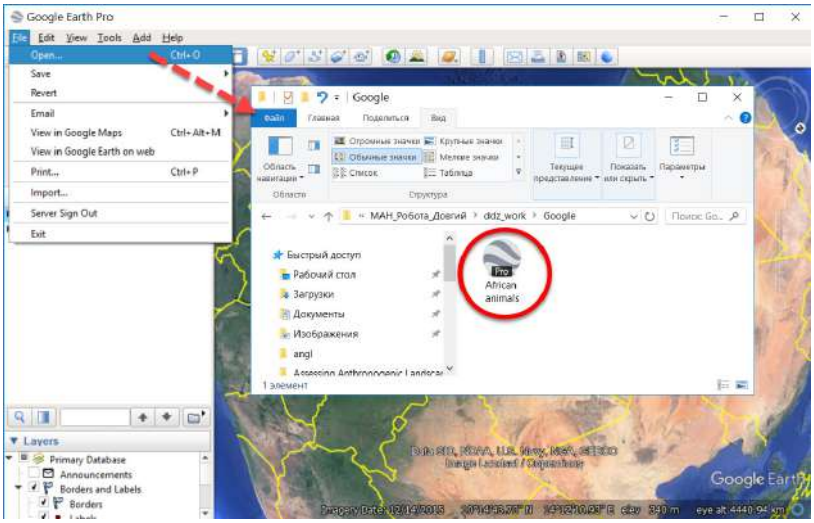
- *Everytrail* showcases trip data, geotagged photos, and trails;
- *Gigapan Photos;*
- *Google Earth Community;*
- *Rumsey Historical Maps;*
- *Trimble Outdoors Trips.*

We propose you make a virtual plane trip over Africa now. You can find elephants, hippos, goats, flamingos, seals, and more. For your convenience, below is a link to a separate KMZ-file posted on *Google Earth Blog*, which contains a collection of interesting aerial photographs taken over Africa and categorized according to the type.



First, go to https://www.gearthblog.com/blog/archives/2006/08/see_african_ani.html and click the underlined text, *photos of African animals categorized*. A file 57185.kmz will automatically download to your PC. If the link to the sites is not active, download the file from Google Drive, https://drive.google.com/drive/folders/1lZJTOQXVCGPILuseyQGEeXF27kd_9emS.

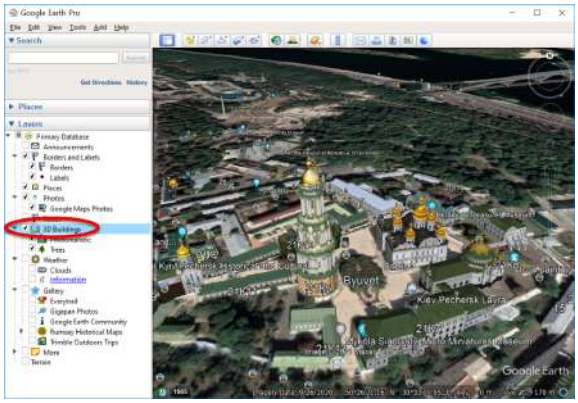
After downloading, you need to upload this file to *Google Earth*. This may be done in two ways: double-click on the file name in your PC's folder or add it via the *Google Earth* menu – ***File – Open***.

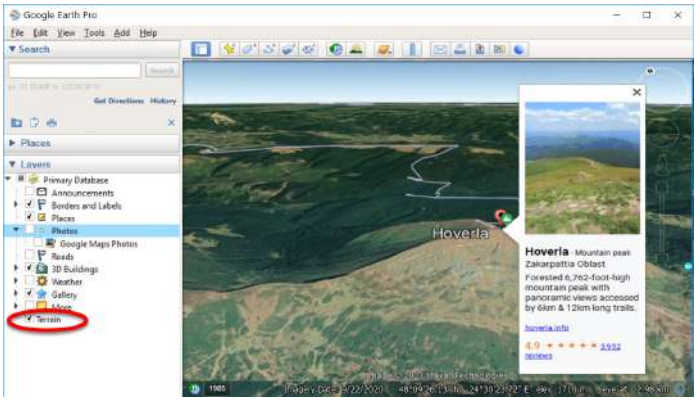


A new thematic layer, *African animals*, will appear in your ***Temporary Places*** folder, which contains different categories of animals. To zoom into any aerial image, double-click on the category of interest.

3D Buildings

A great way to virtually study the location you're traveling to is to explore the map based on the uploaded and geotagged photos taken by other travelers. To do this, turn on the *Google Maps Photos* (ordinary photos) and *3D Building*. As you select an icon and click on an image, you will get a view of the landscape at the point where the photo was taken. After viewing the location, select *Exit photo* and you will return to the previous view mode. For a better display of the terrain, especially in the mountains, we recommend activating the ***Terrain*** layer, the last one on the list.

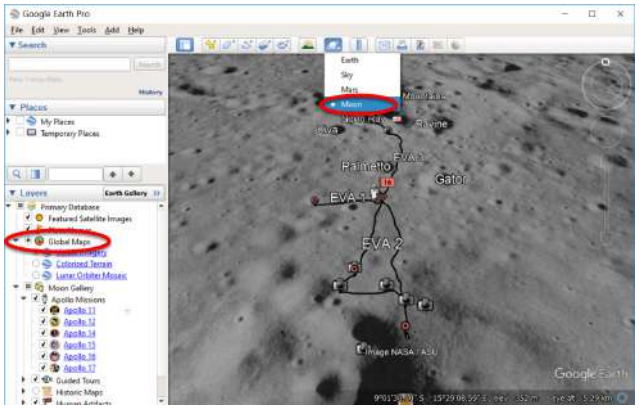


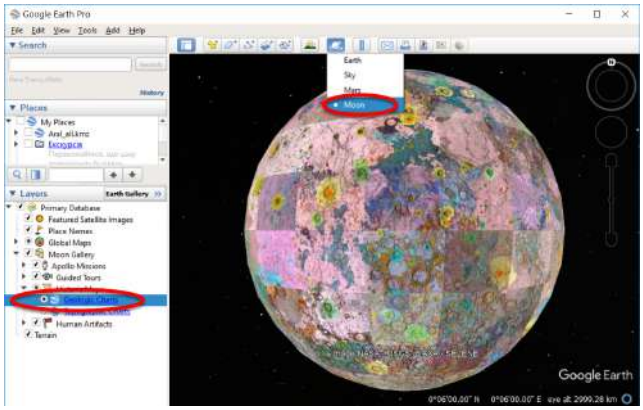


The Moon and its Terrain

Despite the name of the service, you can find other planets on *Google Earth*. Click on the planet icon  in the top menu and select the celestial body you want to study. In addition to Earth, there are also Mars and Moon available. As you select the ***Sky*** option, you can get access to detailed star maps. Note that when switching between Earth, Mars, Moon, and Sky choices, the thematic layers change accordingly. Let's view outer space, namely use ***Google Moon***.

Google Moon contains several tours, including one about the Apollo missions, which showcase maps (historical, geological, etc.), videos, and Street View-style panoramas, all provided by NASA.





Creating Thematic Maps in Google Earth Pro (Case Study: Shrinking Aral Sea)

Case

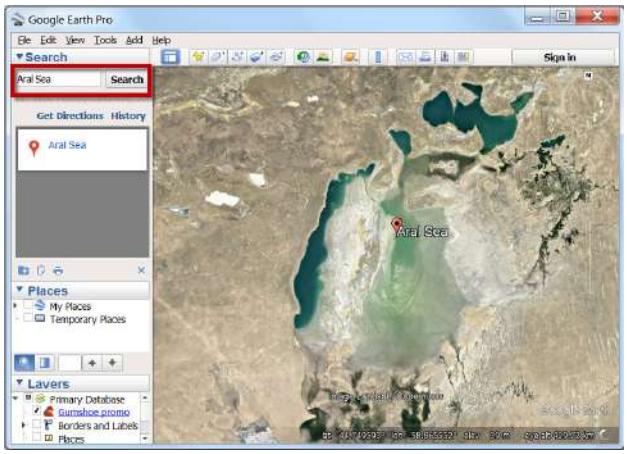
The Aral Sea was the fourth-largest lake in the world in the mid-20th century (area – 50 thousand square kilometers; depth – 68 meters). Currently, however, the seabed has nearly completely dried out, leaving only sandy salt deposits, which look like a large salt desert. Located in the heart of the Central Asian deserts, at 53 m above the World Ocean level, the Aral Sea was a giant reservoir – about 60 cubic kilometers evaporated from it into the atmosphere. Today, drying up is considered one of the largest environmental catastrophes of our time, which has negatively affected the local climate and natural ecosystems of the Aral Sea basin, in particular, contributed to the formation of dust storms.

Task

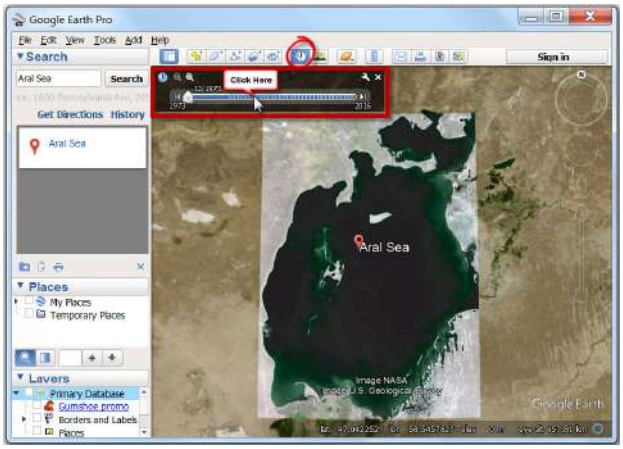
Create a map illustrating the drying up of the Aral Sea, digitize the shoreline of the Aral lake as of 1973, 2000, and 2020, and compare the surface area changes.

1. Launch *Google Earth Pro* on your PC.

2. Find the *Aral Sea*: enter the name of the location (*Aral Sea*) in the search field.



3. To view a map of the Aral Sea over time, use the ***Show historical imagery*** tool. This tool allows you to see the changes in the location on satellite images over time.



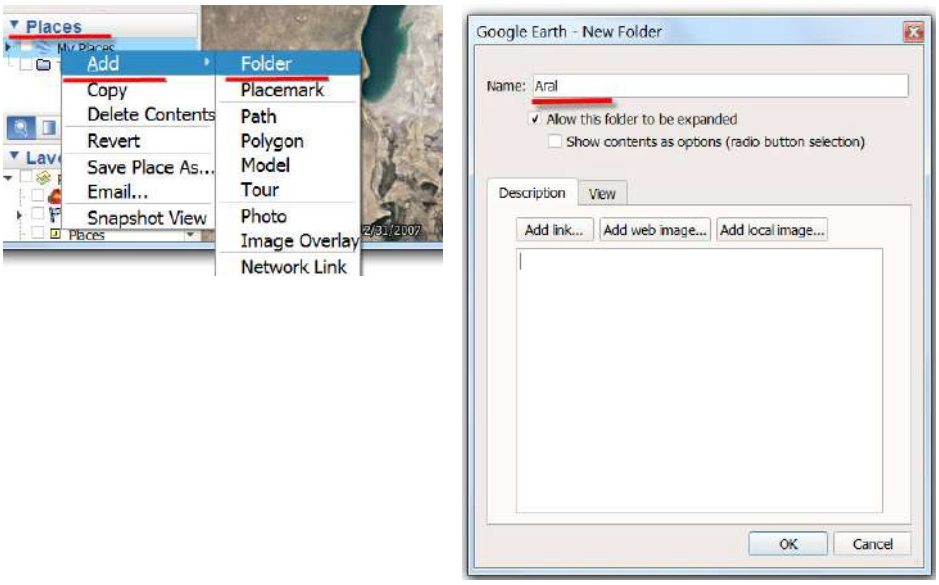
Using the *time slider*, you can view the satellite images captured at different times and see the appearance of the lake in different periods. First, find the earliest available image of the location – it was captured in 1973.

4. Now let's start thematic mapping.

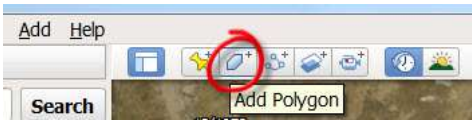
With the program's mapping tools, you can draw your own routes, polygons, add features, overlay various images, and many more. It is possible to specify individual color, size, style, and signature for each element, and easily create schematic maps for different areas.

4.1. First, you need to create a new folder.

Go to the ***Places*** tab, right-click on ***My Places***, and select ***Folder*** from the context menu. Give a name to a new folder, *Aral*.

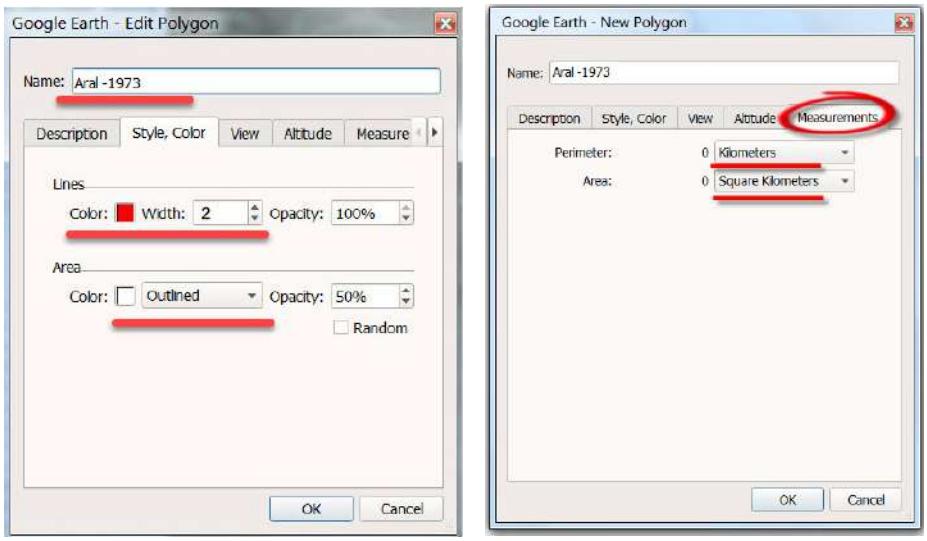


4.2. The next step is to draw a new polygon and calculate its area. To select the contour of the feature (in our case – the boundaries of the Aral Sea as of 1973), use the ***Add Polygon*** tool.



To do this, first, click the  ***Add Polygon*** icon in the toolbar. Then, enter the ***Name*** of a new feature (in our case *Aral* – 1973) in the ***New Polygon*** window that opens automatically, and change the color and line width (optionally) in the ***Style*** tab. For example, choose red color and width 2. To help capture and digitize the area, change from ***Filled*** (just the fill) to ***Outlined*** (just the boundary line) mode.

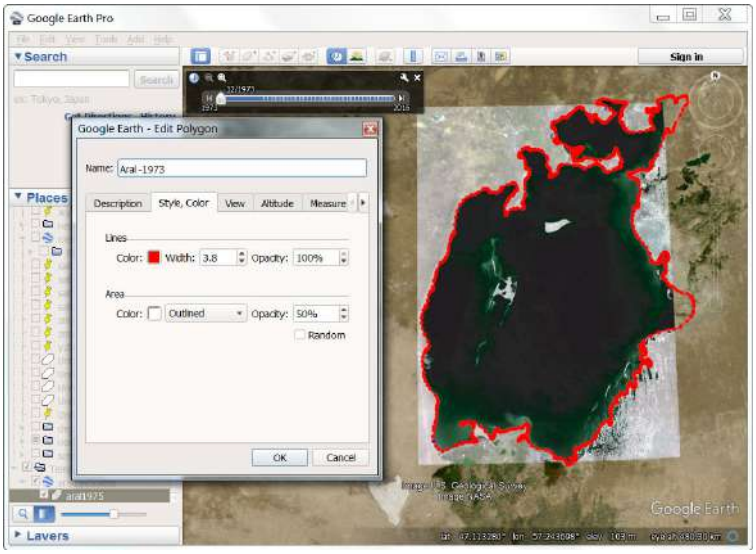
Next, specify ***Area – Square Kilometers*** under the ***Measurements*** tab.

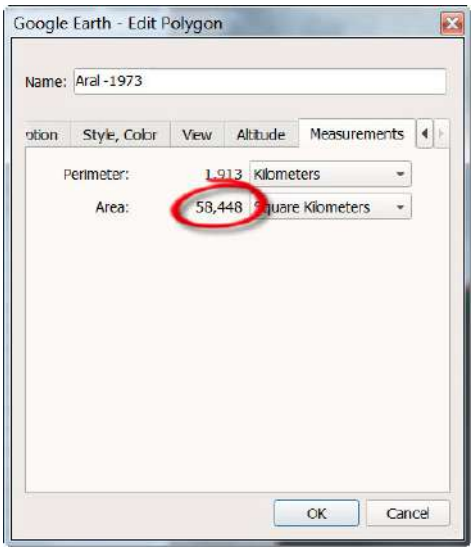


Now, you can go to a map and start manual digitization, i.e. drawing the polygon to enclose the Aral Sea. Don't close the ***New Polygon*** dialog box!

Finally, save the changes by clicking the ***Ok*** button. To continue editing the same feature, left-click on the created polygon ***Aral – 1973*** → ***Properties***. The ***Edit Polygon*** window will open again, and you can continue the digitizing process.

Digitization Features: for step-by-step digitization, place a *vertex* and immediately press the left mouse button after each *vertex* placement, or perform digitization in the ***Trace*** mode by holding down the left mouse button and moving the cursor smoothly across the screen.



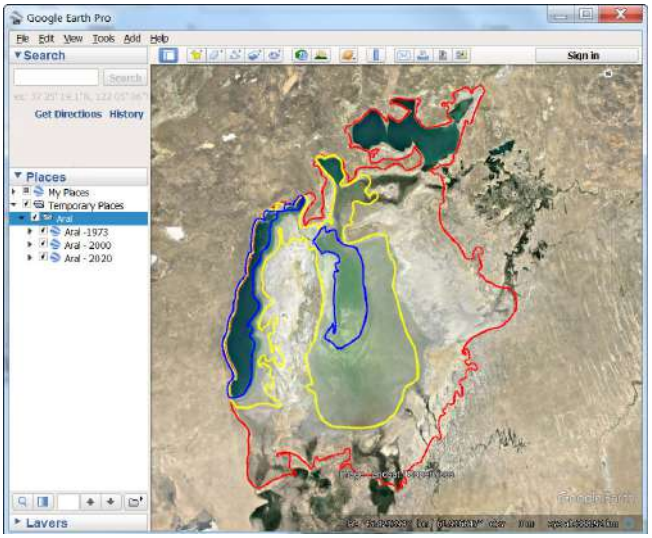


Draw the polygon around the lake as accurately as possible to obtain the correct area values for three periods (1973, 2000, 2020).

The stages of work are as follows:

- choose the year from the timeline (the earliest – 1973, transitional – 2000, most recent – 2020);
- create a new layer for each year;
- зchange the properties of its display (shoreline color);
- digitize the shoreline of the lake for each year.

As a result, you will get three different shorelines of the Aral Sea displayed on the map.



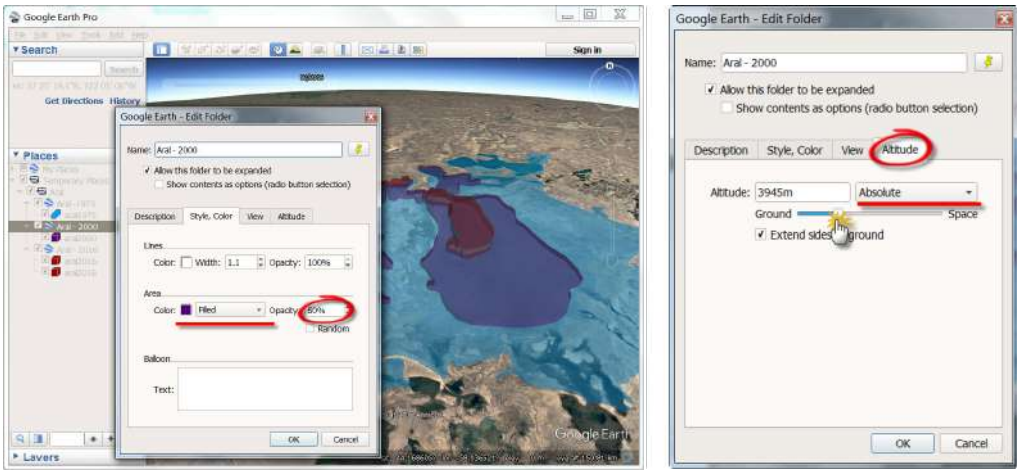
Check yourself

Write in the table below the surface area of the Aral Sea in the following years:

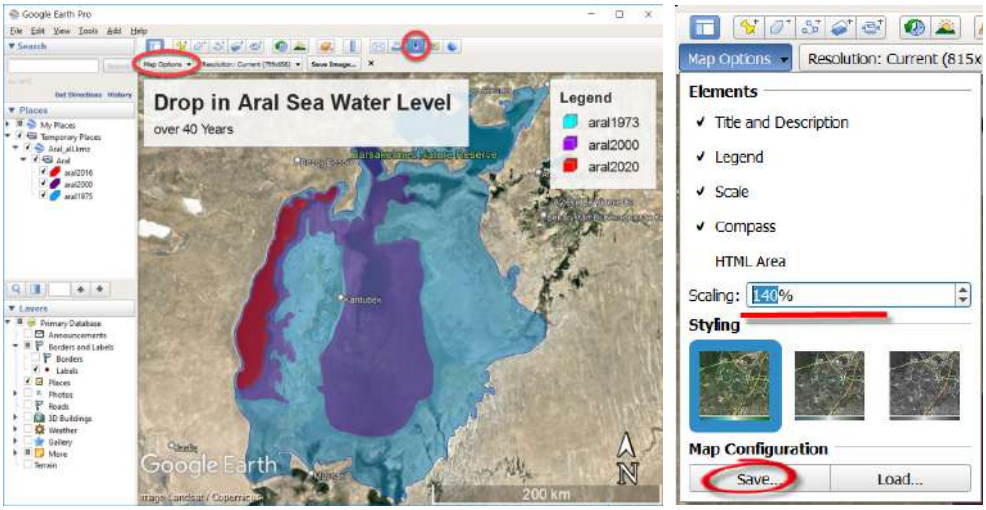
1973	
2000	
2020	

5. Finally, you need to choose the colors to represent each year, create a legend and save a map of the Aral Sea changes.

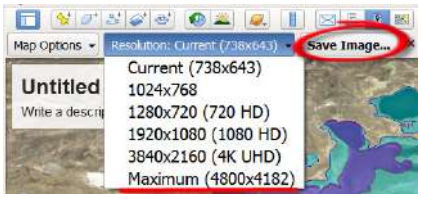
5.1. You can change the color of each year in the ***Edit Polygon*** window. To do this, left-click on the vector name and select ***Properties*** → choose the desired color in the ***Style*** tab. For example, select the ***Filled*** mode, 50% opacity, and apply polygon display with elevation above Earth's surface by adjusting the absolute elevation above the sea level with the slider in the ***Altitude*** tab.



5.2. To save the map, use the *Save image* tool. Enter the map name, for example *Drop in Aral Sea Water Level over 40 Years*, and description in the Untitled Map field. Then choose the appropriate legend scaling and map display styling in the ***Map options*** window.



Finally, save the map as a high-resolution image to your PC.



Identification of Landfill Sites (Case Study: Waste Dumps in Kyiv-Sviatoshyn District of Kyiv Oblast)

Case

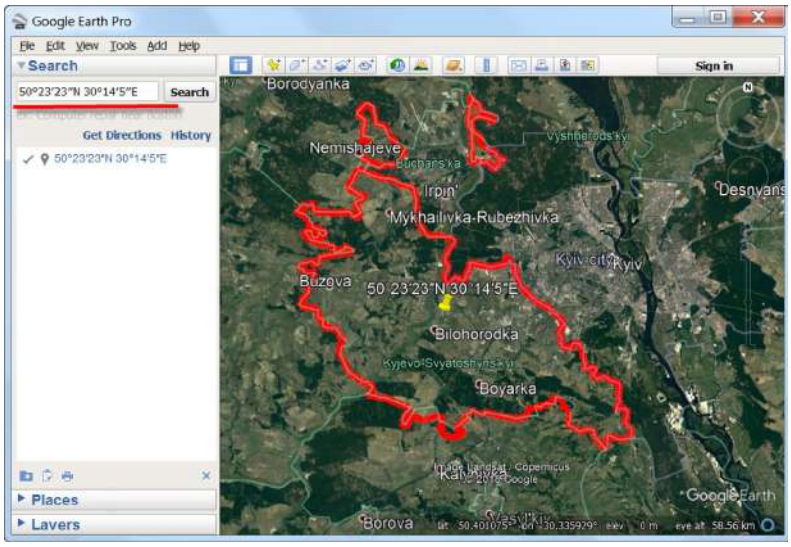
Some 40 years ago, plastic packaging was rarely used in Ukraine. In recent decades, the situation has changed drastically. Nearly all products are bought in stores, and most of them have several layers of packaging made of synthetic polymers. Changes in consumption patterns have led to an unprecedented increase in the volumes of household waste and the number of illegal dumps. They used to emerge only near cities and industrial facilities in the past. Currently, each of the 60,000 settlements in Ukraine has from one to dozens of landfills nearby, and almost all of them are illegal due to location in unauthorized areas: within tree belts, plantations, gullies, ravines, quarries, etc.

In 2016, the Ministry of Environment of Ukraine launched an interactive Ecomap of landfills (https://ecomapa.gov.ua/), where residents of all regions can report the location of waste dumps.

Task

Identify and mark on the map all landfills within the Kyiv-Sviatoshyn District of Kyiv Oblast.

1. Find Kyiv-Sviatoshyn District of Kyiv Oblast by entering the coordinates in the search field: 50°23'23"N 30°14'5"E, or simply navigate the map – Kyiv-Sviatoshyn District is adjacent to the western boundary of Kyiv.



2. Identify all landfills within this area that are visible in satellite images.

Tip: Below, you can view the appearance of different landfills on the satellite images.

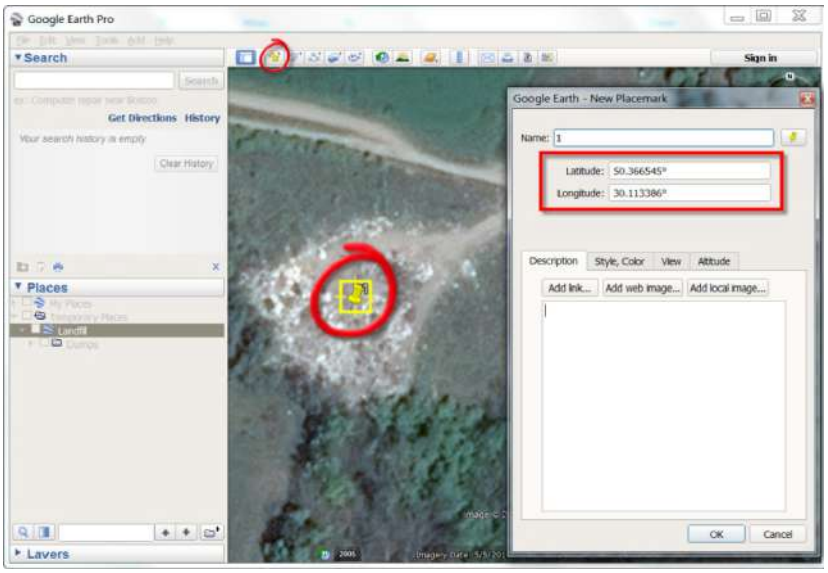
Large authorized municipal solid waste landfill

Illegal waste dumping sites in forestland near a village

3. Add placemarks for the landfills.

As already described above, first, you need to create a new folder, *Landfill*: go to the ***My Places*** tab in *Google Earth*, and add a new folder by right-clicking the ***My Places*** tab => ***Add*** => ***Folder***.

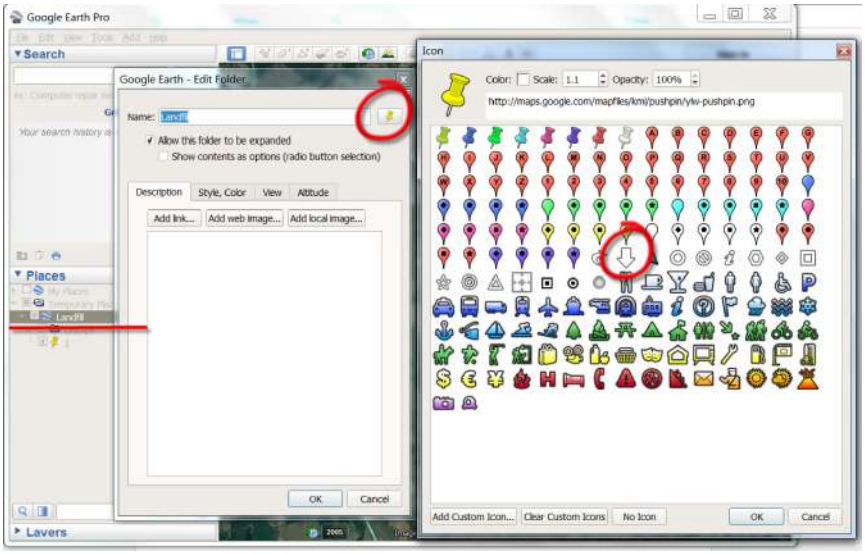
Using the ***Add Placemark*** tool, mark all identified landfills on the map.



Please note that the coordinates of the location you mark are displayed in the ***New Placemark*** window. You can copy and paste these coordinates into any report or other statistical document.

4. . Now you need to select the symbol to display landfills in the legend. Left-click on the *Landfill* folder → ***Properties***. A new dialog box, ***Edit Folder***, opens up. Click the icon and select the type and color for a new symbol.

If possible, create folders for two types of landfills and choose two types of symbols to represent *authorized* and *illegal* dumping sites, respectively.



Thus, you get a map of landfills that can be processed and saved as described above.

Check yourself

Specify below the settlements near the three largest landfills in Kyiv-Sviatoshyn District of Kyiv Oblast.

Ravine and Gully Landforms (Case Study: The Area Near the Samara Riverbed, Novomoskovsk District of Dnipropetrovsk Oblast)

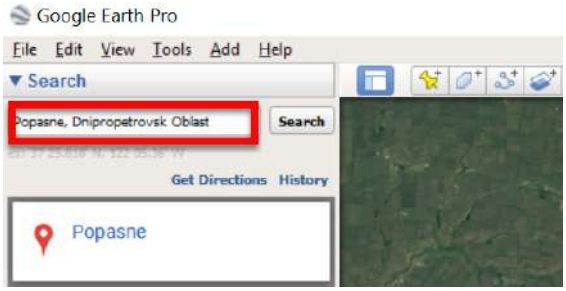
The ravine and gully systems – one of the landscape types found in Ukraine that belongs to erosive and ravine landforms and is typical for the Donets Ridge, branches of the Central Russian Upland, and the whole Dnieper Lowland. Characteristic features are asymmetry of river valleys with high right banks and low left floodplains, as well as hills replete with gullies and ravines. Predominates the natural vegetation of the forest-steppe area (Wikipedia).

Task 1

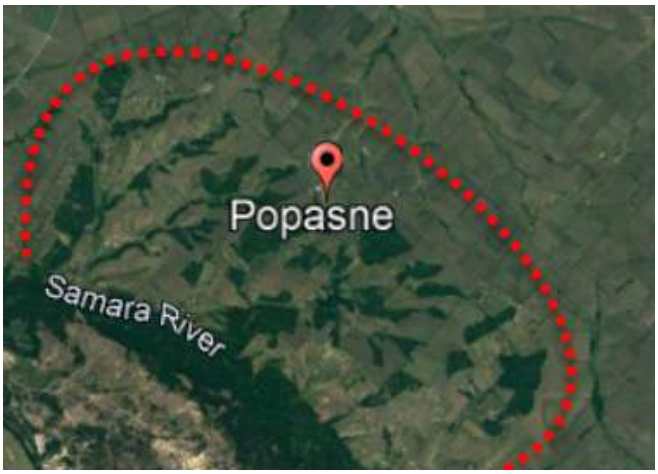
Identify signs of erosional processes on high-resolution images in *Google Earth* using both satellite imagery and geotagged photos of the location (explore agricultural lands between the settlements).

Instructions for self-guided work

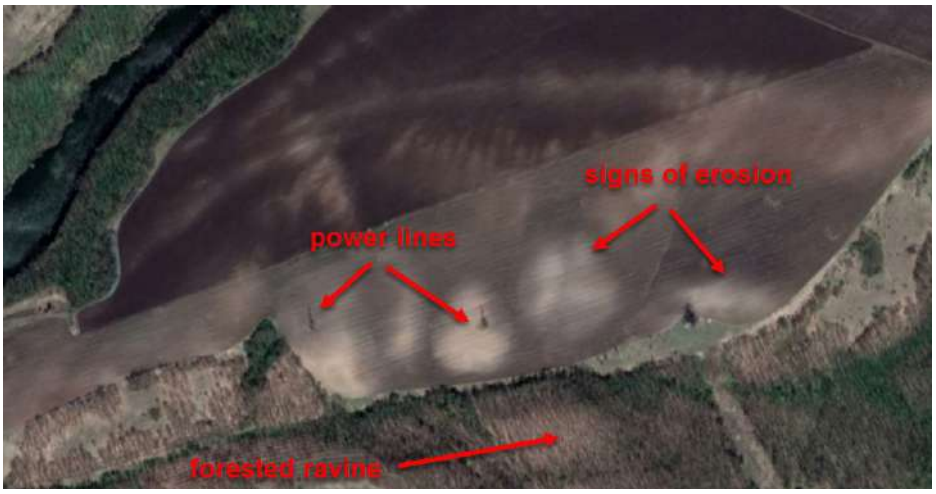
1. Open *Google Earth Pro*.
2. Enter *Popasne, Dnipropetrovsk Oblast* in the search field.



3. Zoom into the settlement and ravines on the map. Carefully examine the territory under study and identify the riverbed and ravine systems.

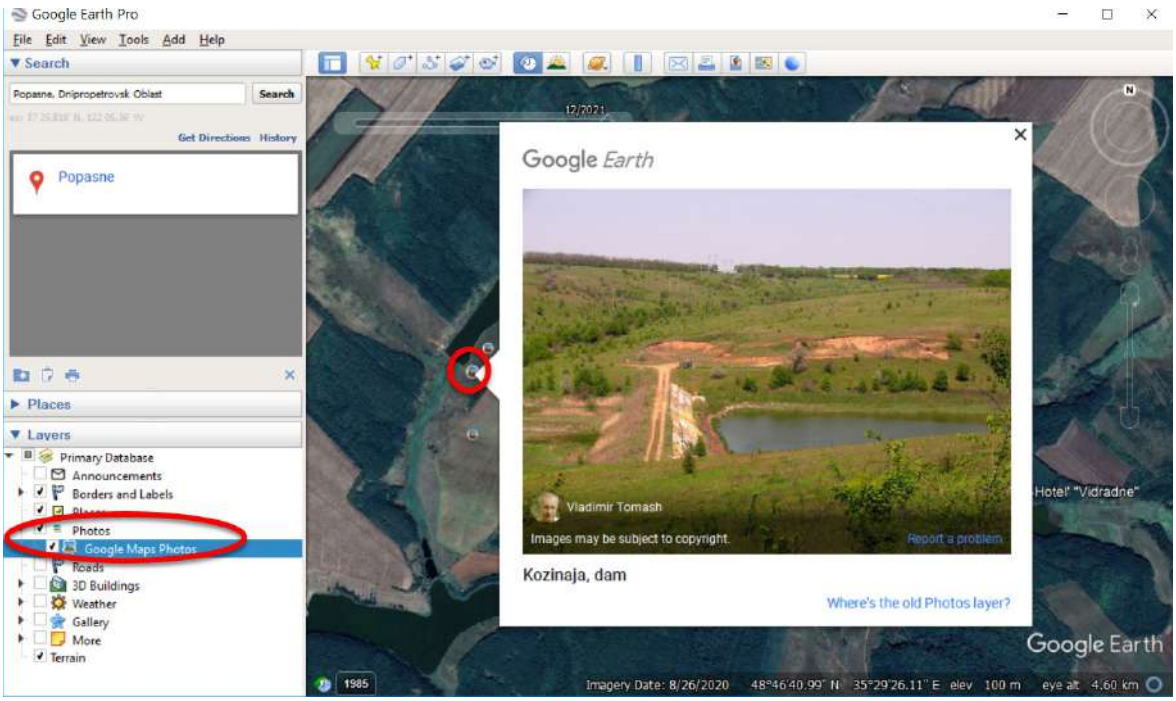


The satellite imagery in Google Earth mostly has 1 m or higher spatial resolution, which allows detecting small objects on the map, e.g. even power lines or erosional processes in the fields.



4. With geotagged photos posted by the Internet users and automatically added to the map in *Google Earth*, you can see how a particular feature appears in the image (keep in mind that the geotags may slightly offset, so it is important to compare features in the image and photo). By clicking on the circular photo icons, view what the terrain looks like from the ground perspective.

If the photo icons do not appear in the image, make sure the ***Photos*** layer is turned on in the left sidebar of your screen.



5. The date of the image is displayed at the bottom of your screen. This image was captured on April 20, 2019.

Important! If the imagery date is not displayed at the bottom of your screen, zoom to the location of your interest again.

Check yourself

Find Ivano-Mykhailivka village on the map and specify the date of the image available for this location in *Google Earth*.	

6. Save this location. Do not close the application: you may need to return to it during the performance of the following tasks and compare different satellite images of the area under study. The next step is to search for the same ravines on the Sentinel-2 satellite image in *EO Browser*.

Check yourself

Specify the causes for ravine and gully systems formation.	

Task 2

Find the most recent Sentinel-2 satellite image of the location under study available in the *EO Browser* archive and compare the appearance of the ravine and gully system on the geotagged photo, high-resolution satellite image (1 m), and Sentinel-2 satellite image (10 m).

Instructions for self-guided work

1. Satellite images available in *EO Browser* have a lower spatial resolution than images in *Google Earth*, for example, the spatial resolution of Sentinel-2 is 10 m, and that of Landsat is 15-30 m but the frequency of image acquisition is much higher. With *EO Browser* you can access both the most recent images and the earliest ones. In the next two tasks, we will search for two such images.

2. Open *EO Browser* website (enter *eo browser* in the Google search bar and click on the first link, *Sentinel-hub EO-Browser*, or go directly to https://apps.sentinel-hub.com/eo-browser.)

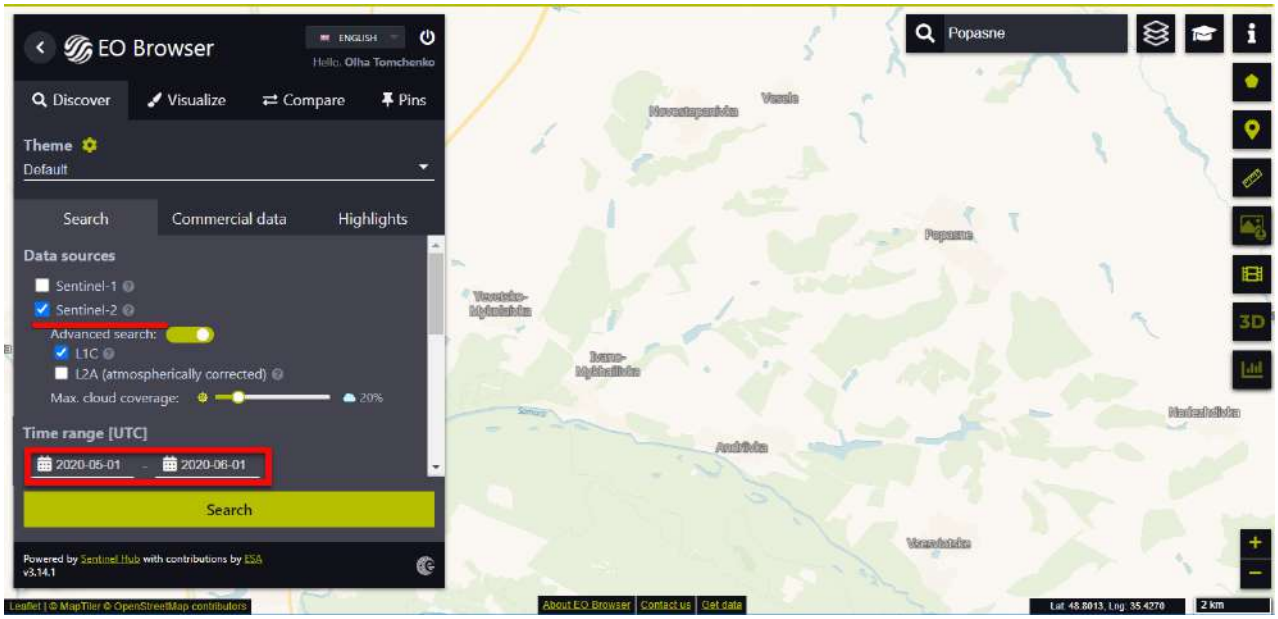
3. Create an account and/or login on the website.

4. Enter *Popasne, Dnipropetrovsk Oblast*, in the search field and click on the first highlighted line to zoom into the territory of Ukraine on the map.

5. In the settings pane, select:

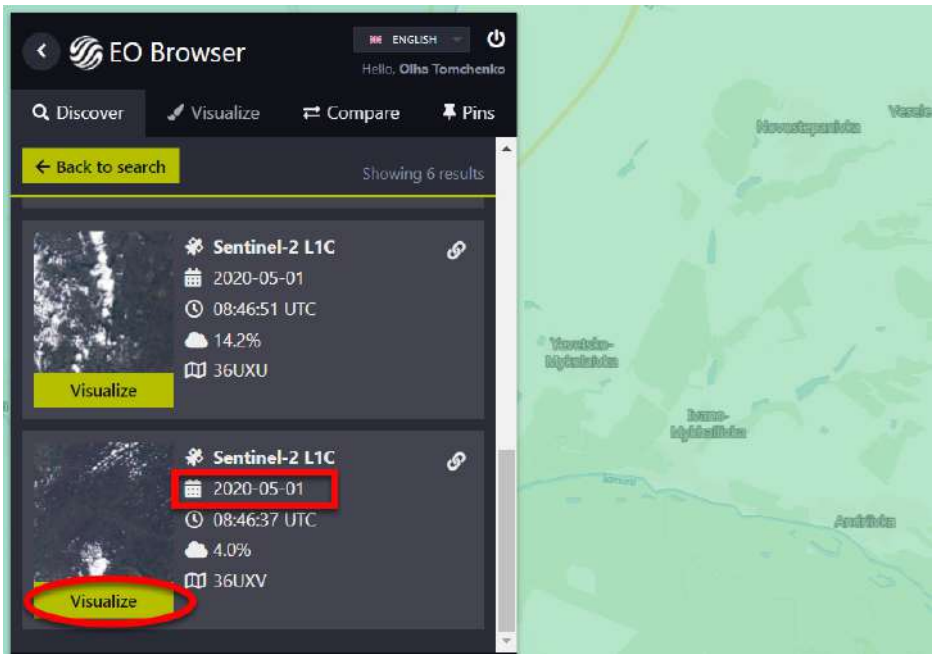
- ***Data sources*** *(Satellite)* – Sentinel-2 (L1C) (by clicking on the question icon to the right of the satellite name, you can read detailed information about the satellite);
- ***Max. cloud coverage*** – 20%;
- ***Time range*** – May 1, 2020 – June 1, 2020;
- Click the ***Search*** button.

Important! To select a date, choose it from the calendar rather than type.

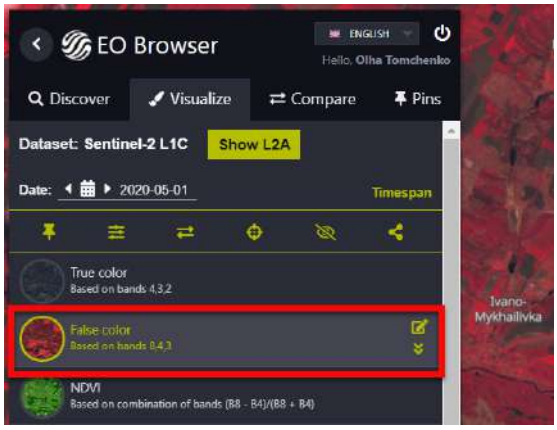


Once you heat the ***Search*** button, you get a list of all images available in the catalog that match the search query, which may be viewed in the ***Discover*** tab.

6. View the images by scrolling through the list in the ***Discover*** tab that pops up automatically in the left sidebar, find the image taken on 01.05.2020, and click the ***Visualize*** button to display the image in the *EO Browser* window.

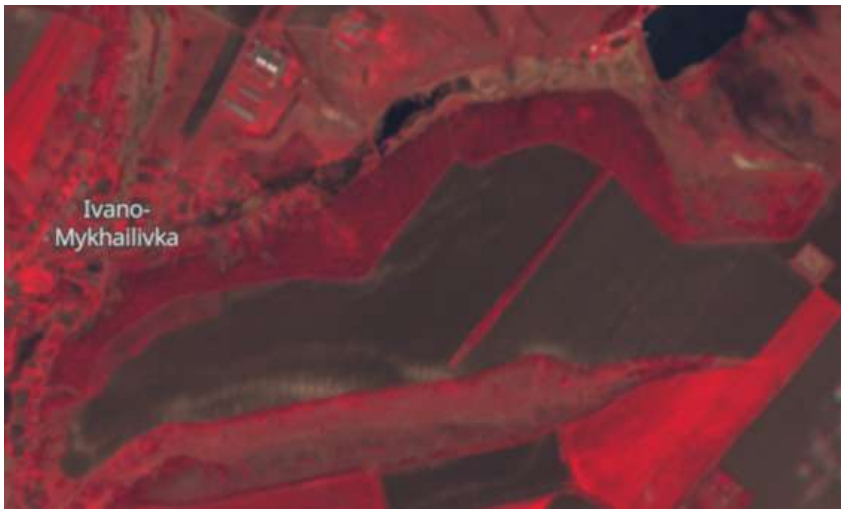


7. Select the visualization mode – ***False color***, which uses an infrared band to synthesize a color image. With this combination of bands, the forest and vegetation appear in shades of red: the denser the vegetation, the brighter the color. This band combination allows you to see the difference between the coniferous (shown dark-red) and deciduous forests (appear light red), as well as fields with different types of crops.



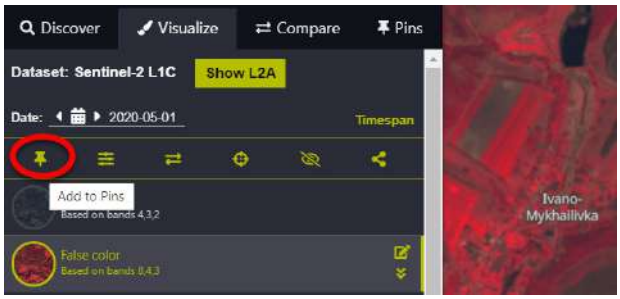
8. Take a closer look at the image and compare the appearance of ravines on this image and satellite imagery provided by *Google Earth*; identify the place where the photo of the location that you opened in Task 1 was taken.

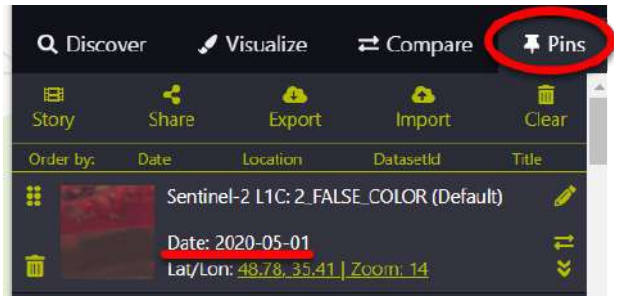
9. Identify the signs of erosion in the fields near the ravines and save the image (make a screenshot – this will be the Task 2 result) from *Google Earth* and the same field with signs of erosion from *EO Browser.*



It should be a bit easier to interpret Sentinel-2 satellite images now.

10. Save the image to your favorites by clicking the *pin* icon on the left sidebar in the upper corner of the image; the image should appear in the ***Pins*** tab.





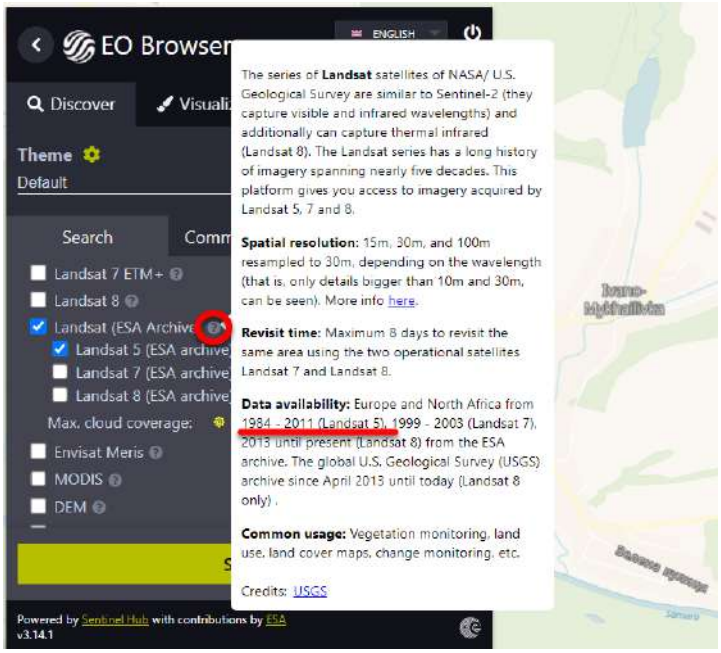
Task 3

Find the earliest satellite image of the location available in the *EO Browser* archive. Check how the location has changed over 35 years, and identify erosional ravines.

Instructions for self-guided work

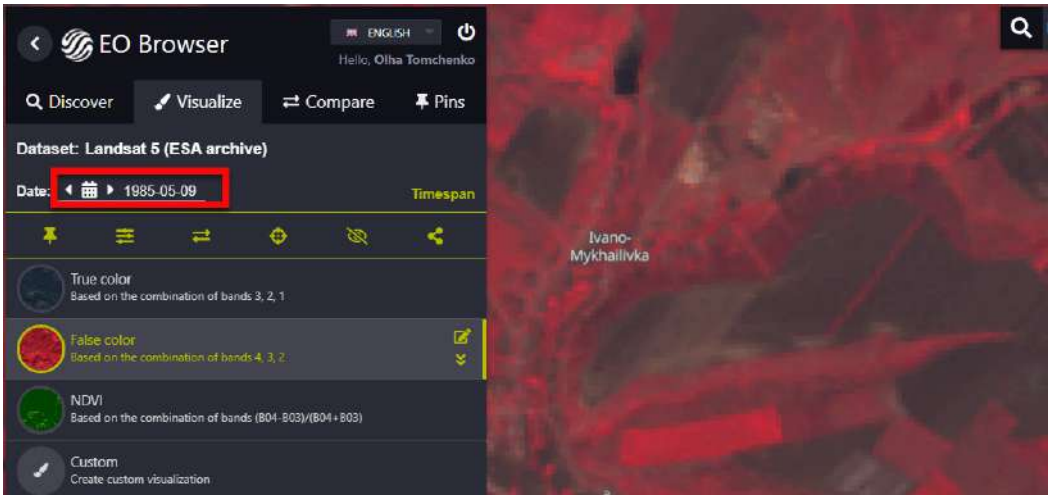
1. Now, let's go back 35 years and see what these ravines looked like at that time, and check them for noticeable signs of ravine erosion.

2. Return to the search menu on the left sidebar, uncheck the Sentinel-2 images so that the program excludes them from the search, and check the box near Landsat. Select Landsat 5 in the tab that pops up: of 8 Landsat mission satellites, Landsat 5 only operated in the 1980s (to find out more about satellite operation time, click the question mark next to the image name), and specify the time range: 01.01.1984 – 01.01.1990.



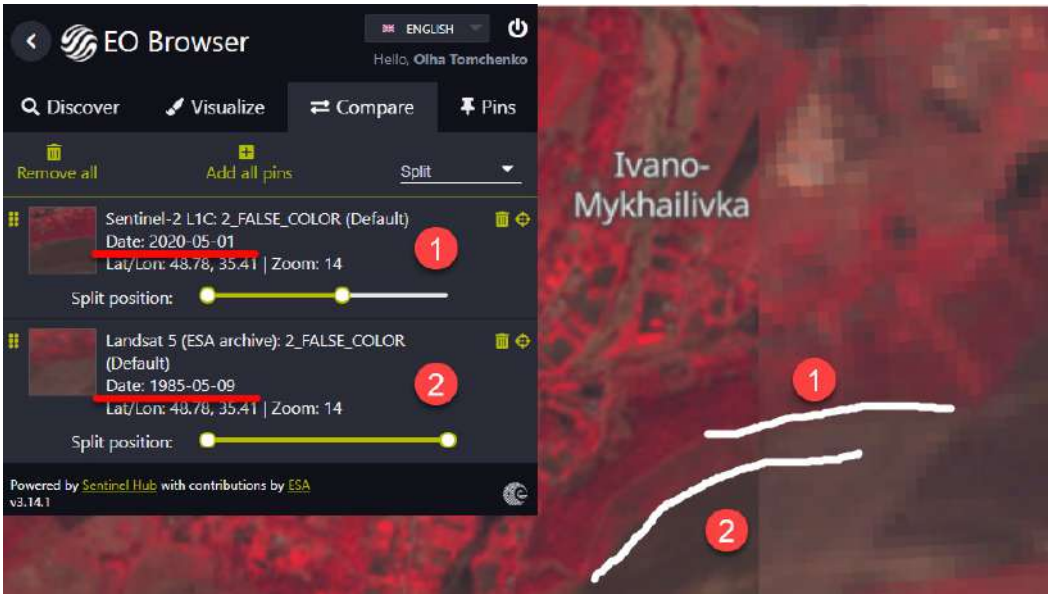
In the ***Results*** tab, select and visualize an image captured on May 9, 1985; turn on the ***False color*** visualization mode

3. Find the field with the signs of erosion, which image was saved in Task 2, and save its screenshot.

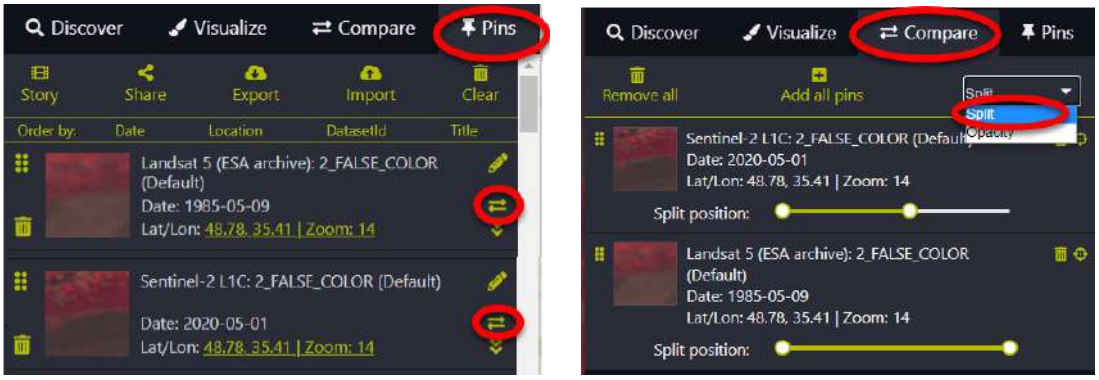


4. One may notice that the erosional processes were present in the field as early as 1984. The yields of erosive land plots are always lower compared to the rest of the field. Such areas require more fertilizers and expediency should be considered. It may even be more cost-effective to exclude this part of the field from cultivation, not to mention the environmental factor: reducing the fertilizers and pesticides' use will reduce the environmental load.

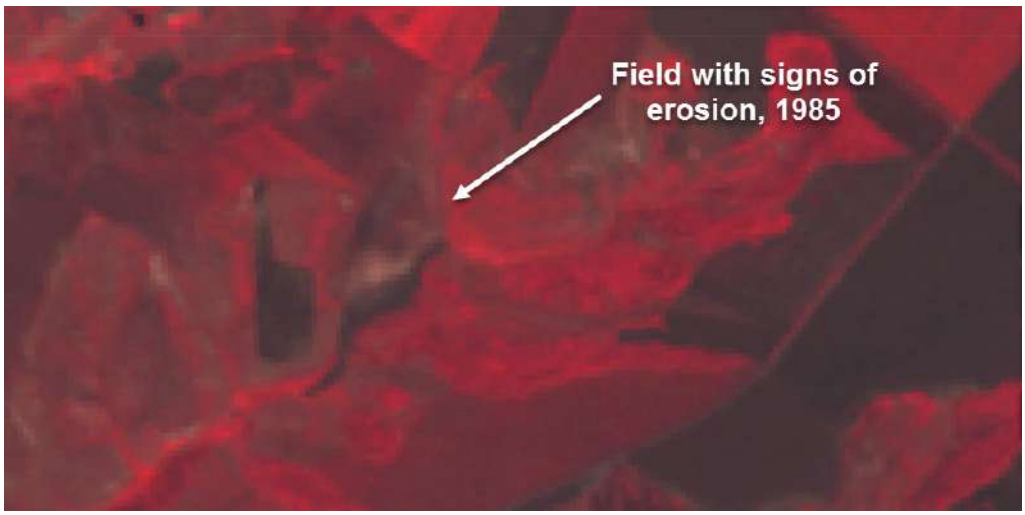
Interestingly: contemporary images show that a part of the field on its north side, which was under cultivation in 1984, has been excluded from the total sown area later.

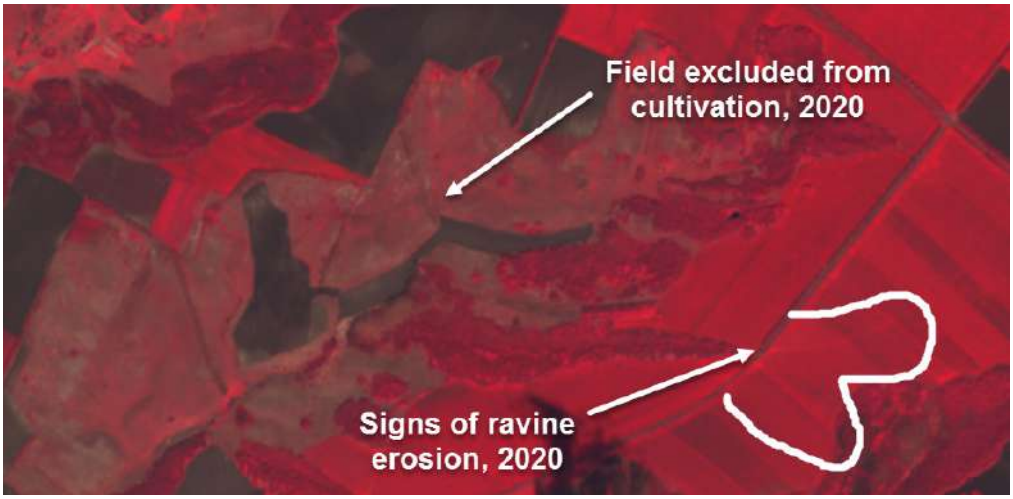


5. Go to the ***Pins*** tab to compare the images captured in 1984 and 2020. To do this, select ***Compare*** under the ***Pins*** tab and turn the ***Split*** mode on. You can show and hide the image by dragging the slider next to the upper image.



6. Compare the images and identify the location that has changed; pay special attention to the edges of ravines; save Sentinel-2 and Landsat 5 images of the location with changes.





In general, this area of ravines was forested, and large-scale changes will not be visible here. You can also try to search for non-forested ravines in another part of Ukraine and explore their development.

Check yourself

Find a location that has changed; pay special attention to the edges of ravines; save two images of the location with changes – Sentinel-2 and Landsat 5, and briefly describe the changes.

_____

Check yourself

Find ravines in another region of Ukraine on the Sentinel-2 satellite image and write the name of the place.	

Monitoring Atmospheric Air Quality (Case Study: Evaluating Changes of Atmospheric Composition Using Sentinel-5P Data)

Case

Smog is one of the most dangerous types of air pollution. In addition to smoke, fog, dust, etc., it also contains nitrogen dioxide. Some cities are exposed to such air pollution quite often. In particular, according to the State Emergency Service of Ukraine, the level of nitrogen dioxide pollution in Kyiv was 5 to 6 times higher than average daily limits in Skliarenko St., Obolonskyi Avenue, Bessarabska, and Demiivska Squares on June 12-13, 2019, as reported by the monitoring stations of the Central Geophysical Observatory named after Borys Sreznevsky. In early autumn 2019, Kyiv suffered from smog again.

Task 1

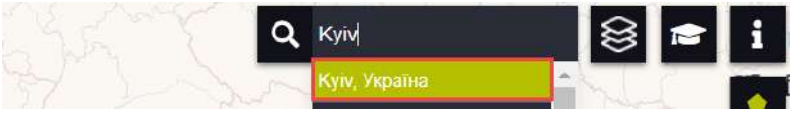
Define a city in Ukraine and a city in Europe that had the worst air pollution during the last month.

Instructions for self-guided work:

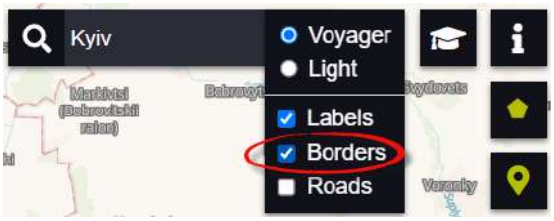
1. Open *EO Browser* website: https://apps.sentinel-hub.com/eo-browser.

2. Log in on the website.

3. Enter *Kyiv* in the search field and select the first highlighted line in the list to zoom into the territory of Ukraine.



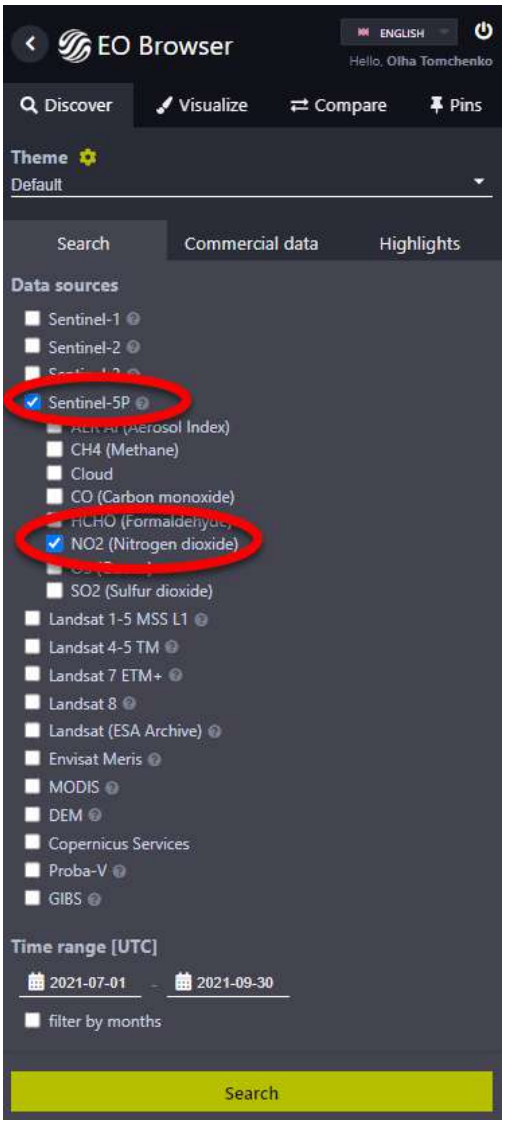
4. Turn the borders display on by clicking the  symbol and checking the ***Borders*** box.



The borders of oblasts will display on the map.

5. In the settings toolbar, select:

- ***Data sources*** *(Satellite)* – Sentinel-5P (please note that Sentinel-2/L1C is selected by default so you need to uncheck it to get the Sentinel-5P images displayed in the search list) and NO_2 (pollutant);



Sentinel-5 is the first mission within the Copernicus program aimed at providing information on air quality. Tropomi (TROPOspheric Monitoring Instrument) is a spectrometer measuring ultraviolet (UV), visible (VIS), near-infrared (NIR), and short-wave infrared (SWIR) light for monitoring amounts of ozone, methane, formaldehyde, aerosols, carbon monoxide, NO_2, and SO_2 in the atmosphere.

- by clicking the icon next to the Sentinel-5P name, you can see information on the revisit time of the satellite.

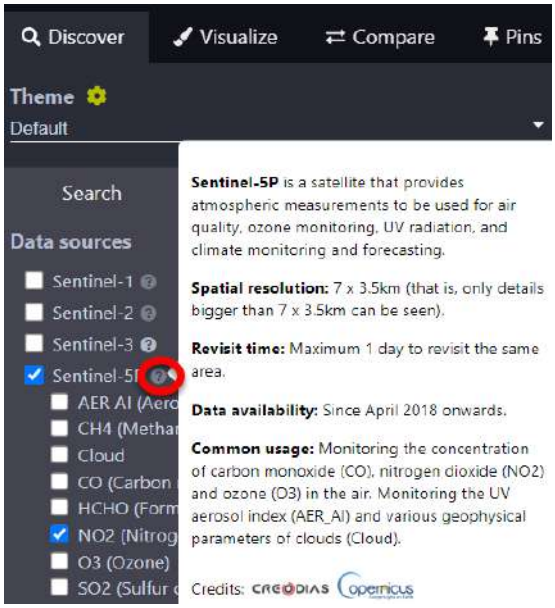
Check yourself

Write down the revisit time of the Sentinel-5P satellite (time interval between two image acquisitions of the same location).

_____

What does the satellite revisit time depend on?

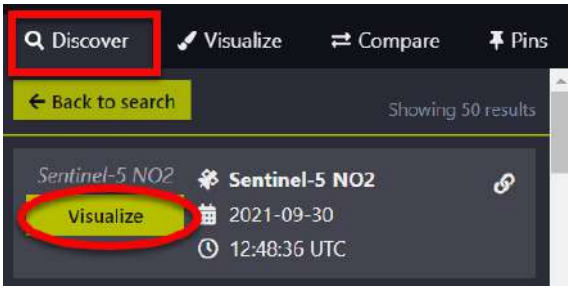
_____



- ***Time range*** – by default, the last month is set; if it is the case, leave unchanged, or change the dates to search for the images captured during last month: click the calendar icon and select the required date from the calendar;
- Click the Search button.

You will get a list of all images available for the specified time range. The satellite coverage projections will also display on the map.

6. Select the first image from the list and display it on the map by clicking the ***Visualize*** button.



You will get a color image of NO_2 concentrations map, although a fragmented one.

Check yourself

Why do you think the image is fragmented?

_____

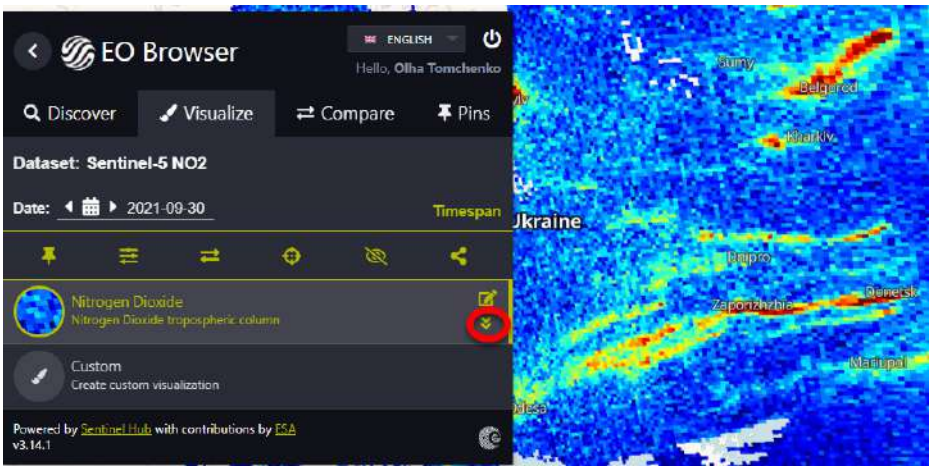
7. To see what color on the map represents higher concentrations of the substance, open the NO2 map legend by clicking on the arrow next to the image name.

Check yourself

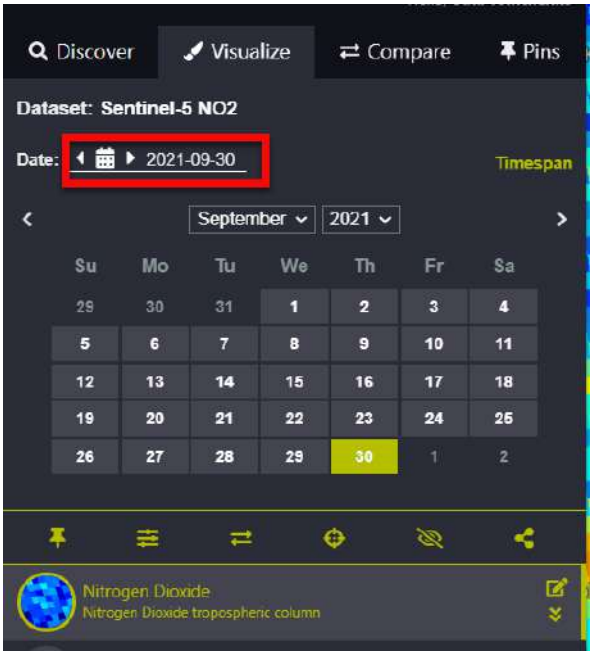
Write down the colors representing the highest and the lowest NO_2 concentrations.

_____

What units of measurement have been used?



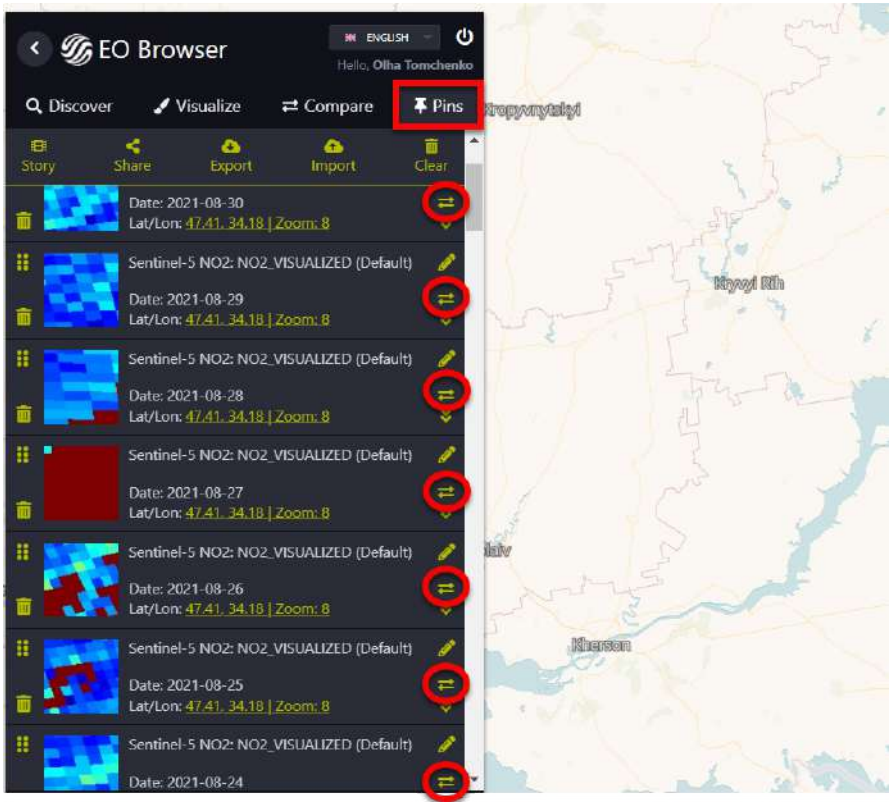
8. Scroll through the calendar to review the images captured before the specified date by clicking the arrow icon.



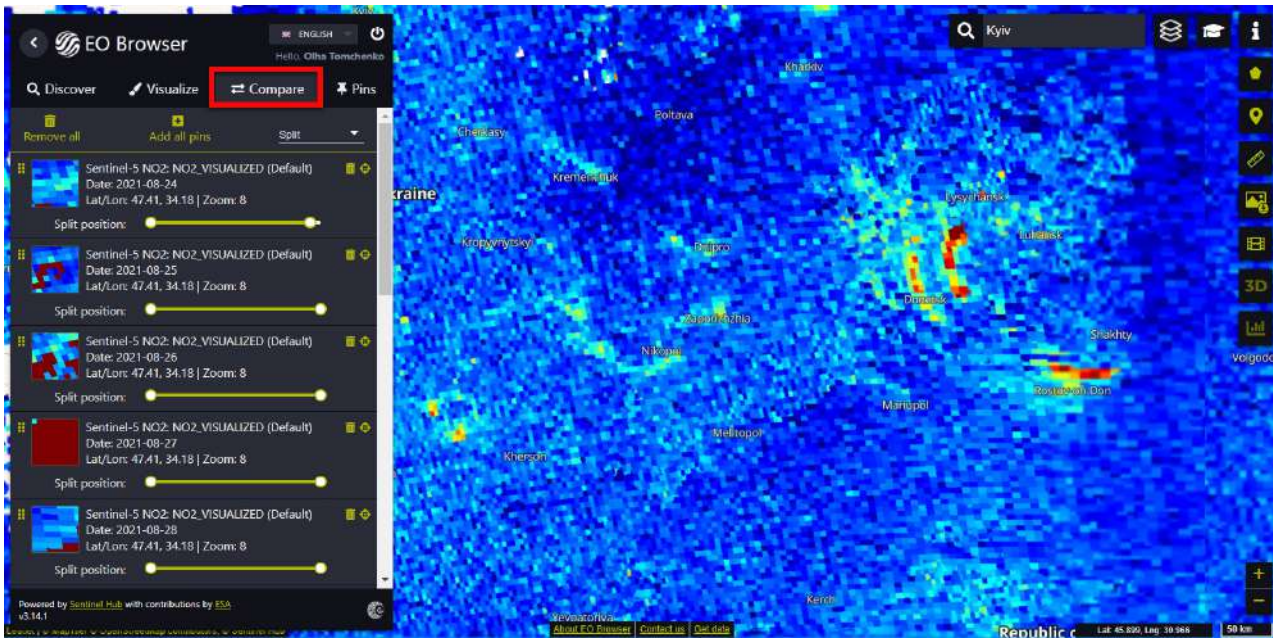
9. *EO Browser* has no special tools for creating a mosaic (composite of two or more satellites). However, it is possible to overlay images and see the data for a location collected over previous days if information for the given date is missing. To do this, return to the ***Discover*** tab to display a list of images by clicking the ***Visualize*** button, and add images one-by-one to the list of favorites by clicking the ***Pins*** tool next to the name of each image.

Each time you click the *pin* icon, the menu will automatically switch to the ***Pins*** tab that contains a list of selected images, and it is necessary to go back to the ***Visualize*** tab each time to add the next image. Thus, you need to add 10 images to the list of favorites (pinned).

10. Visualize a series of images simultaneously by clicking the ***Compare*** button. In previous tasks, we have already used this tool, in particular, to compare two images of the river during the spring freshet and low water periods. In this case, the ***Compare*** tool can help you overlay and display all the selected images at the same time.



11. If there are still many locations on the map of Ukraine's territory, for which the images are missing (it depends on the level of cloud coverage at the time the satellite images were taken), you need to return to the ***Discover*** tab and add more images to the list of selected ones.



12. Analyze the result by identifying the cities in Ukraine and Europe, which have the highest NO_2 concentrations.

Check yourself

Write below three Ukrainian cities that have the highest NO_2 pollution levels.

_____

Write below three European cities that have the highest NO_2 pollution levels.

_____

13. Similarly, analyze the distribution of other pollutants: SO_2, CO_2, etc.

Check yourself

What chemical compound has been analyzed?

_____

Write below three Ukrainian cities that have the highest levels of this chemical compound.

_____

Write below three European cities that have the highest levels of this chemical compound.

_____

Exploring Volcanic Activity (Case Study: The Eruption of Hawaii's Kilauea Volcano)

Case

Kilauea is one of the most active volcanoes on Earth. An eruption at Kilauea summit jolted the area with the force of a 5.5 magnitude earthquake and sent an ash and fume plume 8 kilometers into the sky, CNN reported referring to the Hawaii County Civil Defense Agency.

According to US Geological Survey, the earthquake occurred on Sunday (03.06.2018) afternoon local time. However, the quake did not cause a tsunami threat.

The eruption lasted for more than a month, during which time lava covered more than 8 hundred hectares of land on the island. As a result, clouds of hazardous gases were formed on the coast, and the air was filled with hydrochloric acid and sulfuric acid. To watch the video, go to: www.youtube.com/watch?v=uEmX6fBsD3I.

Task

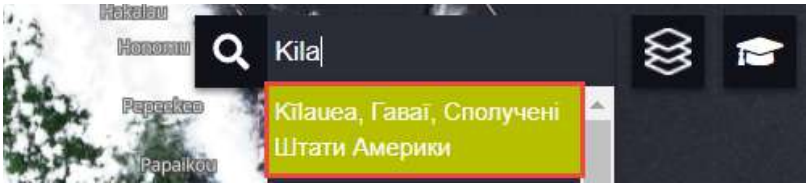
Identify the place of volcanic eruption and lava flow path. Determine whether carbon dioxide was released into the atmosphere during the eruption. What area of air was polluted with carbon dioxide?

Instructions for self-guided work:

1. Open the *EO Browser* website at https://apps.sentinel-hub.com/eo-browser.

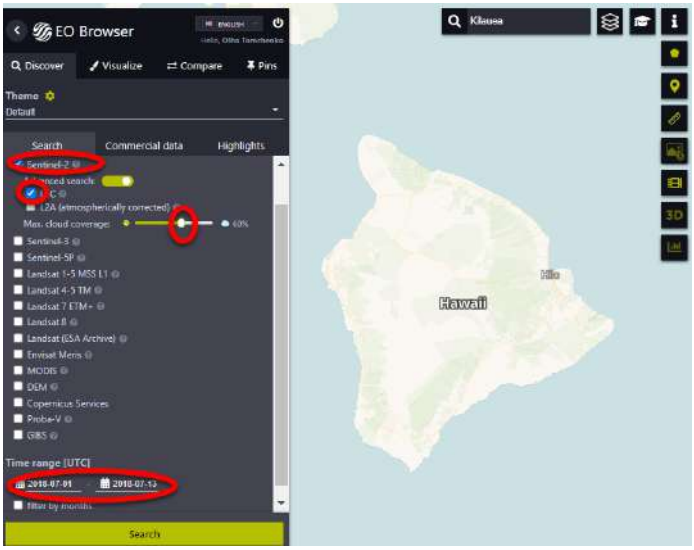
2. Log in on the website.

3. Enter *Kilauea* (a Hawaii volcano) in the search field and click the magnifying glass icon to zoom into the location:



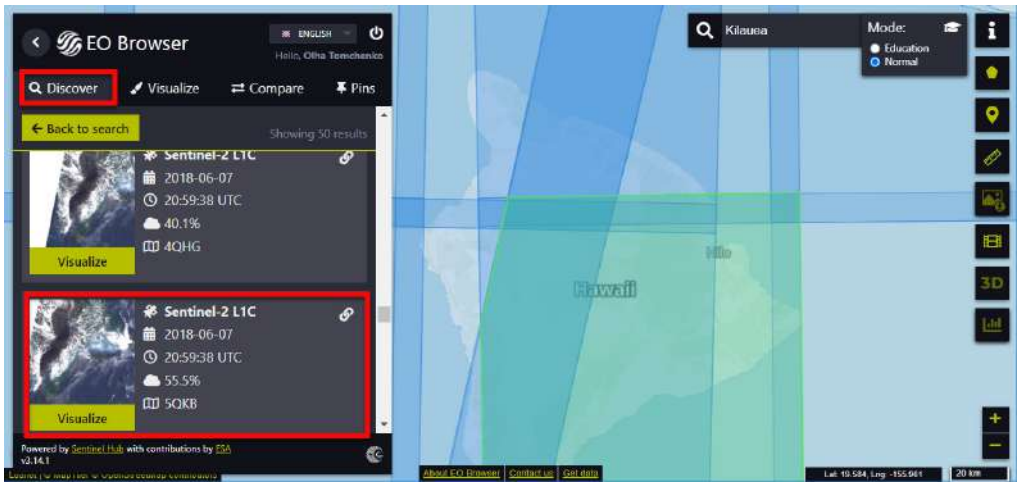
4. In the settings toolbar, select:

- ***Data sources*** *(Satellite)* – Sentinel-2 / L1C;
- ***Max. cloud coverage*** – 60%;
- ***Time range*** – June 1, 2018 – June 13, 2018;
- Click the ***Search*** button.

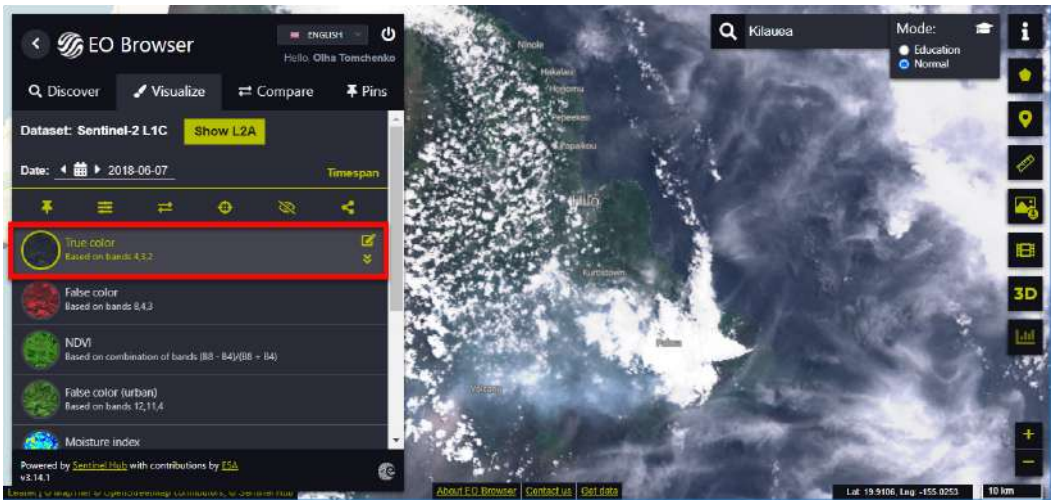


As a result, a list of all images available in the catalog that match the established criteria will be displayed.

5. View the images by scrolling through the list in the left sidebar, find the image captured on June 7, 2018, and click the ***Visualize*** button.



The selected image will show up in the *EO Browser* window and a ***Visualize*** menu will open in the left pane where you can adjust the image display.



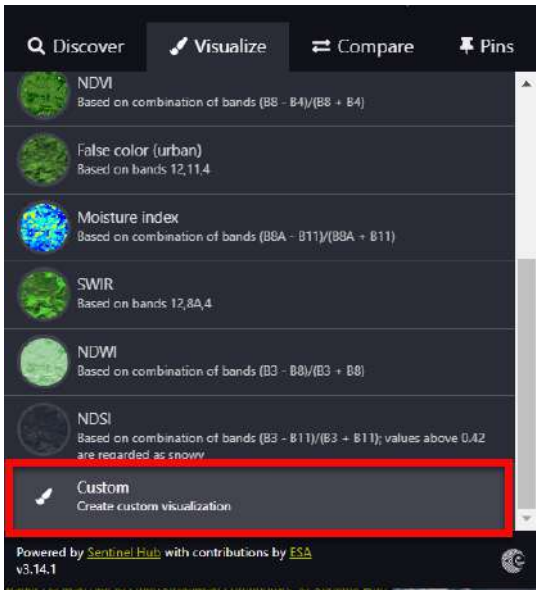
By default, the image is displayed in a ***True color*** mode, which means that it looks like a photo of the location taken from above.

Check yourself

Look at images of this location taken at different times and think how clouds and volcanic fumes can be distinguished?

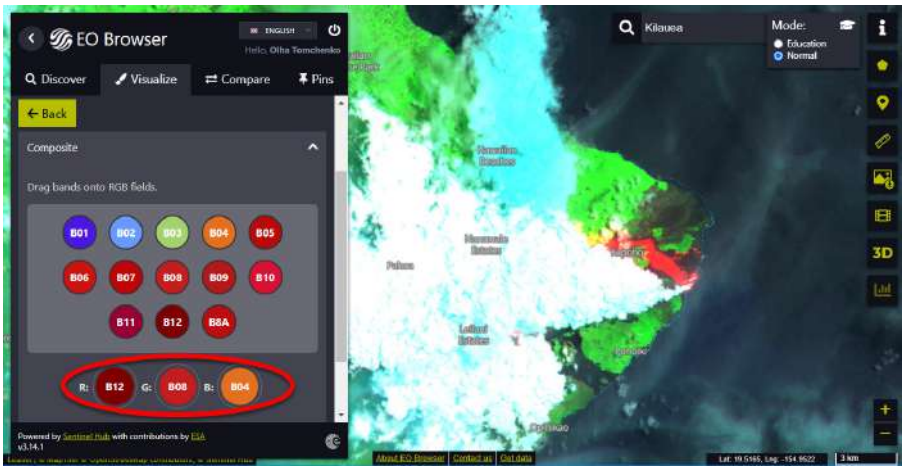
_____

6. Click the ***Custom*** button in the left sidebar to adjust the visualization using other spectral bands.



With the band combination B12, B11, and B4, you will detect lava flows.

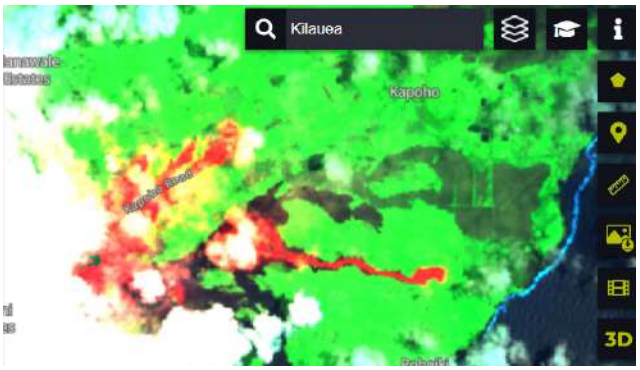
Using another combination of bands, B12, B8, and B4, you can explore volcanic activity.



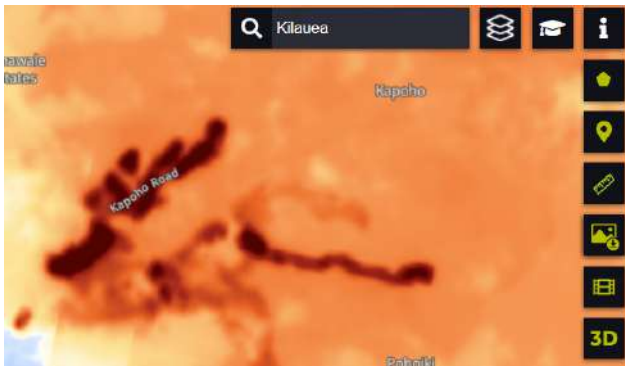
Go back to the ***Visualize*** tab by clicking the ***Back*** button, and test different visualization modes and indexes one by one.

7. Analyze the temperature changes above the volcano using Landsat images. To do this, select the Landsat 8 image captured on May 30, 2018, from the list and detect lava flows using the combination of bands: 7, 5, and 3. Compare the appearance of the volcano in ***True color*** and ***Thermal*** modes.

Select a small section of lava flow using a pencil and review the temperature graph for the location



combination of bands: 7, 5, and 3



thermal mode

Check yourself

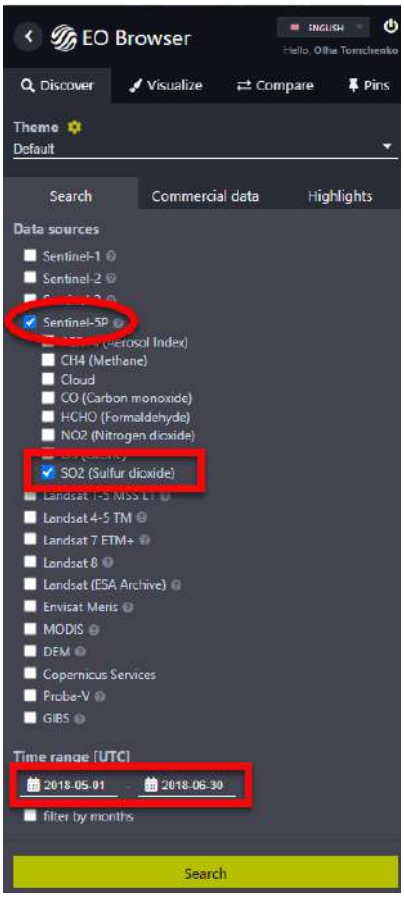
Determine the area of a lava flow on the Landsat image using the ***Thermal*** mode.

---

8. View the same location on the *Sentinel-5P (Sentinel-5 Precursor)* images.

Set the time range (May 1, 2018 – June 30, 2018) to display SO_2 on the Sentinel-5P image.

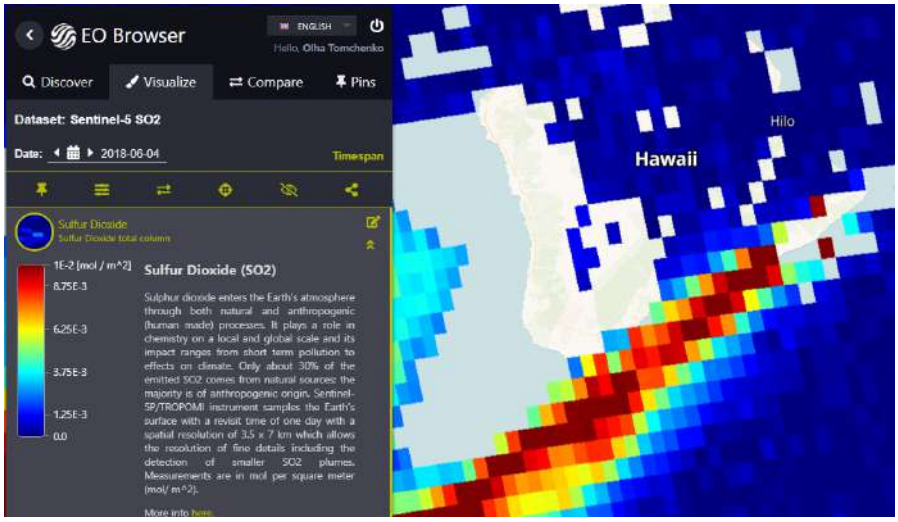
Sulfur dioxide (SO_2) is a hazardous (Category 3), colorless gas with a strong, irritating, and pungent odor. It turns into smoke in the air and is heavier than air. At –10.1°C, it is condensed to a colorless liquid, which is heavier than water. It is highly soluble in water (sulfuric acid is formed), as well as in alcohols, ether, benzene. Sulfur dioxide is not flammable, explosive.



Using the animation tool, ***Create timelapse animation***, determine the dominant direction of SO_2-containing air masses movement.

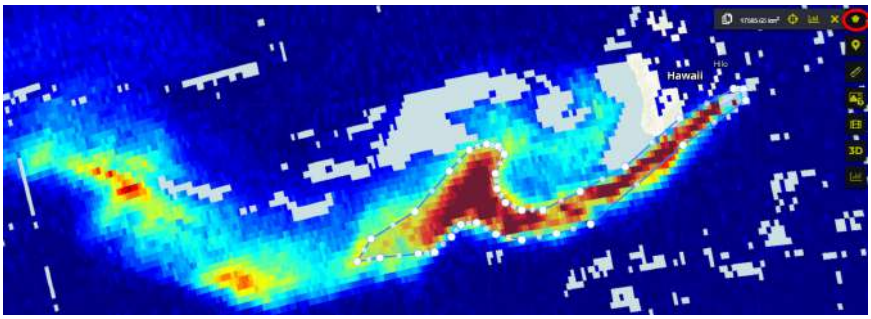
Select the SO_2 display for the Sentinel-5P image captured on June 4, 2018.

Look at the SO_2 air pollution graph.

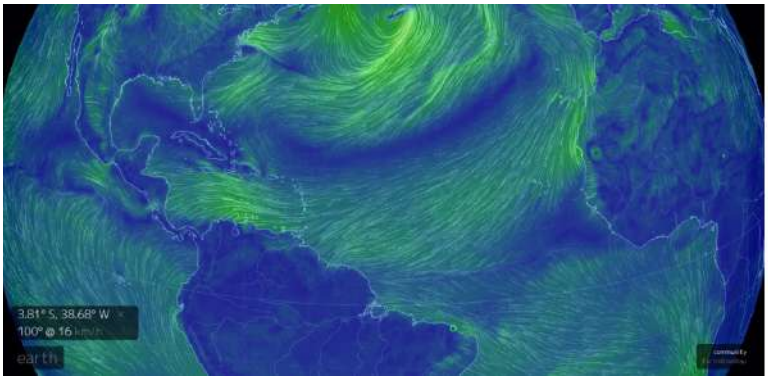


✓ The airborne permissible exposure limit (PEL) for the settlements is 0.5 mg/m^3 (maximum single exposure).

Determine the area of air polluted with sulfur dioxide (with concentrations above normal)  .



9. Using the Air Mass Movement Online service (https://earth.nullschool.net/#current/wind/isobaric/1000hPa/orthographic=-280.32,55.90,486), compare the movement of air masses on June 4, 2018, and the movement of sulfur-containing air masses (from *EO Browser*). To display the image of the desired date, select the ***Earth*** tool from the bottom left sidebar, and a menu tab will show up with a calendar icon where you can set the time.



Are the dominant directions of air flows similar?

Check yourself

Sakurajima Volcano erupted in Japan on September 19, 2019. Take a look at this volcano using a ***True color*** mode and the band combination you have applied to explore the volcanic activity. View eruption of the volcano on the Landsat satellite images.

What is the highest temperature recorded above the erupting volcano by the Landsat satellite?

Building a Web GIS Project (Using ArcGIS Online Cloud-Based Platform)

Case

Following investigation and analysis of a certain phenomenon or issue, for instance, related to the environment, you may need to share your outputs with others. The best way to do so is to tell your story via a map. With ArcGIS Online web-based software, you can build interactive maps, as well as cartographic web services, blocks, and stories. For example, the Ukrainian Data Journalism Agency, Texty, creates interesting cartographic visualizations. One of them is a story about illegal sand mining on the Dnipro River (https://texty.org.ua/d/2019/sand/). Interestingly, this problem was also investigated by one of the students of the GIS and Remote Sensing Section at the Junior Academy of Sciences of Ukraine (https://cutt.ly/We6bEoF).

Task 1

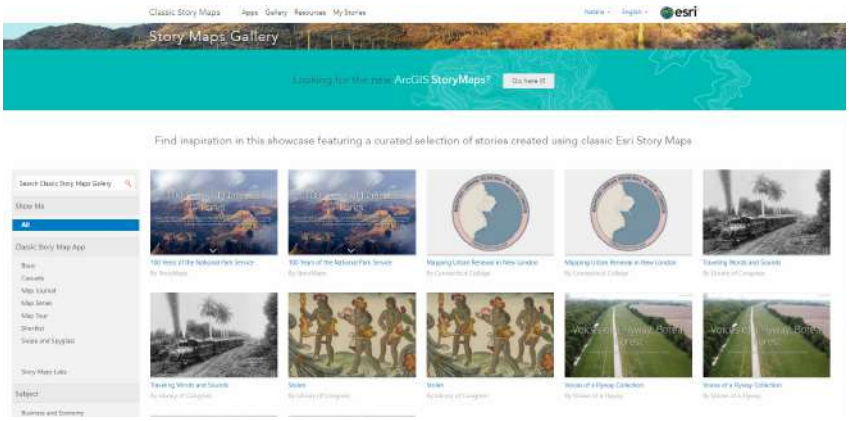
Review ArcGIS Online. Build a web map using ArcGIS Online.

With ArcGIS Online web-based mapping software you can:

- search for and add basemaps from the ArcGIS catalog;
- apply thematic layers in a convenient way;
- save changes;
- add your data to the map (point, line, polygon, and raster features);
- disseminate research results – your web GIS project (including via the Internet).

1. Go to https://www.arcgis.com/home/index.html select and analyze any web-based project.

Or any map from MapStory gallery – https://storymaps.arcgis.com/en/gallery/#s=0.



Check yourself

What is this map about?

_____

What data has been used?

_____

What analysis method has been utilized?

_____

Now let's build a new web map. Combine several map layers available in the ArcGIS Online database to check relationships between them. Via an example given below, we will analyze whether there is a relationship between the world's population and soil type.

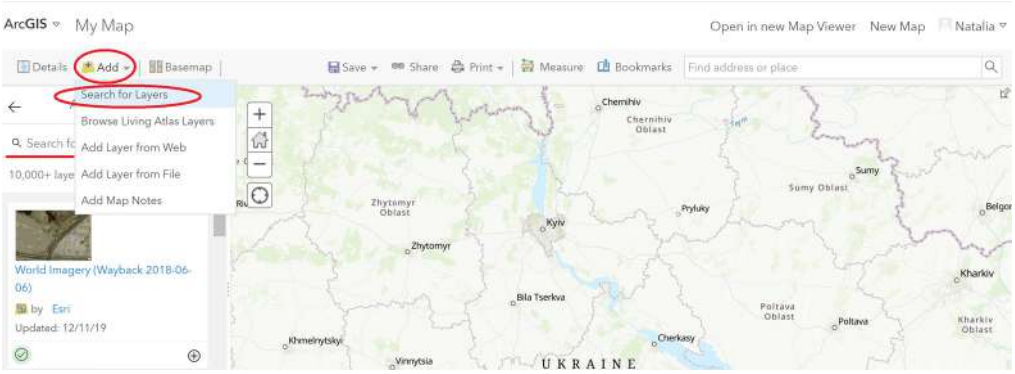
2. First, you need to create an ArcGIS account: go to https://www.arcgis.com/sharing/rest/oauth2/signup?client_id=arcgisonline&redirect_uri=http://www.arcgis.com&response_type=token and complete the form (Create a Personal Account).

To use a free version for an unlimited time, it is important to create a personal account, not a trial or any other subscription.

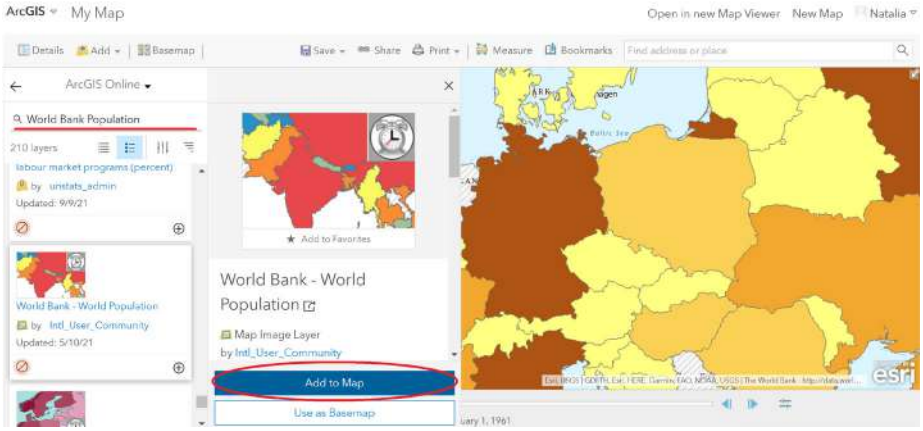
3. Log in to your account and open the page to create a map (you can use this link https://www.arcgis.com/home/webmap/viewer.html).

4. Switch to ***New map*** tab.

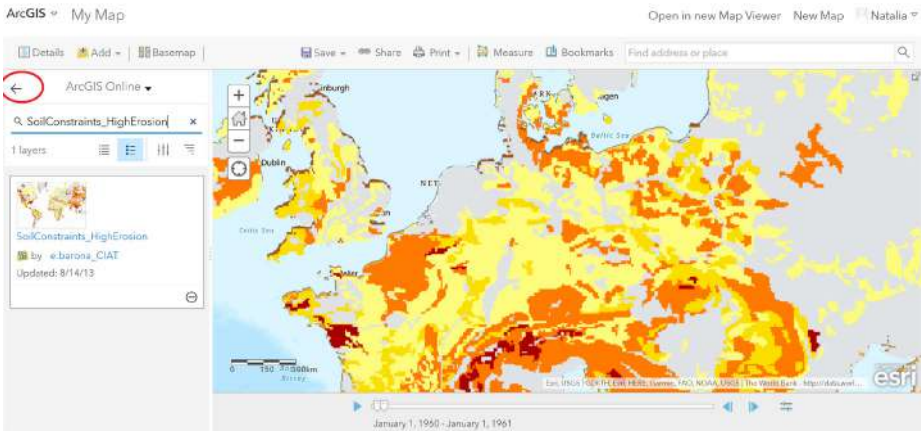
5. Click **Add** and select ***Search for Layers*** from the drop-down menu. Type *World Bank Population* in the search field that appears in the top left-hand corner of your screen, and press the *Enter* key.



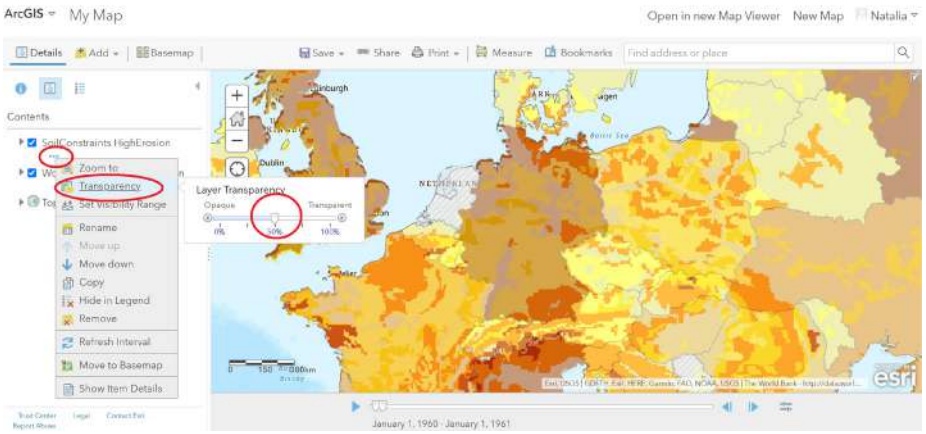
The required layer will display in the search results. Sometimes it is necessary to scroll through the list of search results to find the layer you need. By clicking on this layer, a window with layer details will open. Click the ***Add to Map*** button at the bottom of the dialog box and this layer will be added to the layers of the map viewer.



6. Using the same procedure, add a soil map to the project (for example, enter the search phrase: *SoilConstraints_HighErosion*). Next, click on the Back arrow to display the list of layers in the content pane.



To analyze the data simultaneously, adjust the transparency for the top layer (click the icon under the layer name to open the drop-down menu; select ***Transparency*** and adjust its level using the slider).



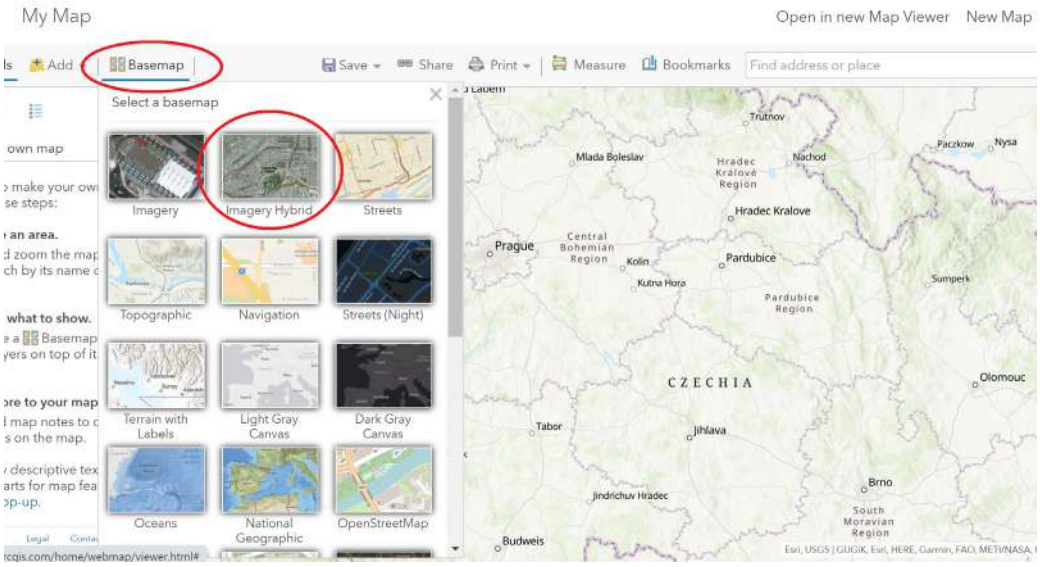
7. Analyze the resulting map consisting of two superimposed maps. Can we identify a certain spatial pattern on the two selected maps (for example, is there a relationship between population density and soil type)?

Task 2

Add new features to the map in ArcGIS Online.

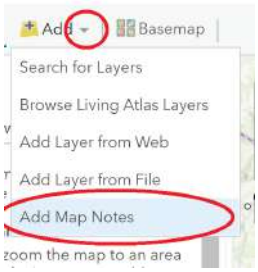
1. Open a new map by clicking the ***New Map*** button.

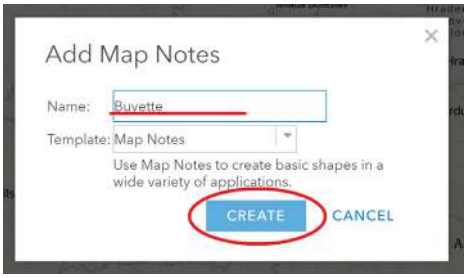
2. Select the ***Imagery Hybrid*** base layer in the ***Basemap*** tab.



3. Add a layer to create new features (go to the ***Add*** tab and select ***Add Map Notes***) – you can add new features to this layer. In this task, we will add the location of pump rooms (drinking water buvettes) in Podil District of Kyiv, or another location of your choice.

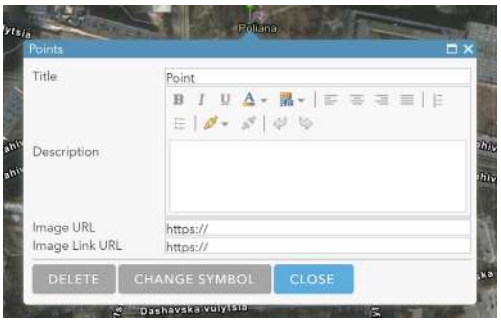
4. Enter *Buvette* in the ***Name*** field in the ***Add Map Notes*** dialogue box. Select the symbols for displaying new features (select ***Map Notes*** or ***Recreation***, or another as the ***Template***).





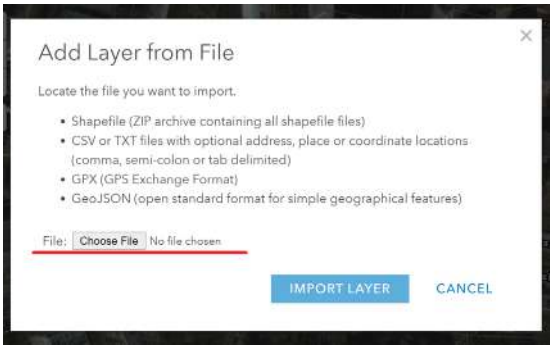
5. Find the location of a pump room on the map or an image and click on the map in that place.

6. In the pop-up window, add feature title, description (for example, an address), image link (the image can be found on the Internet), change the symbol, if desired, and click ***Close***. This window will appear each time the user clicks the feature on the map.



7. Similarly, create a new layer – trails, and draw a path to the pump room from one of the public transport stops (for example, near the subway exit).

You can also import your own layers created in other GIS applications and add them to the map. Go to the ***Add*** tab and select ***Add Layer from File*** from the drop-down list. Acceptable file formats for uploading are Shapefile, CSV/TXT files with coordinates, GPX, or GeoJSON.



8. Using the tools from the *Contents* menu, you can switch between the layers' display mode or the map legend.

9. Finally, save the map using the tool and, if desired, share it by clicking the icon.

Tracking Climate Change with NASA Satellite Images

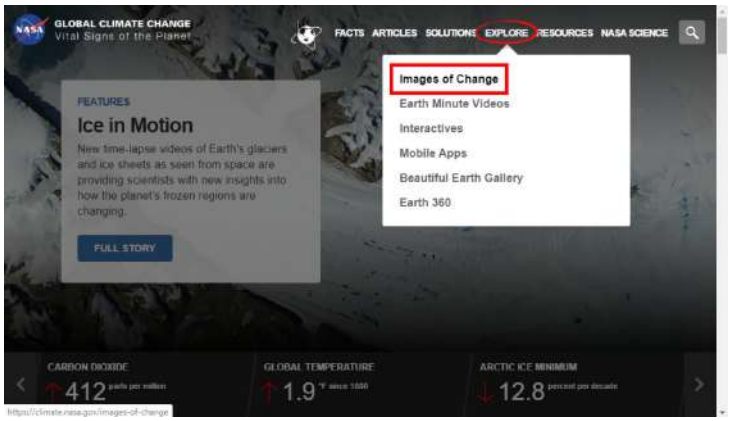
Case

After you have completed all the tasks in this Practice Book and familiarized yourself with various GIS resources, you can create your own research project. In this regard, you may wonder: what is the most interesting phenomenon to explore, what can be clearly seen in the images and how shall I choose a topic? So, in conclusion, we will review the NASA website, which provides examples of changes occurring on our planet as seen from space, in an easy and logical way and according to thematic areas.

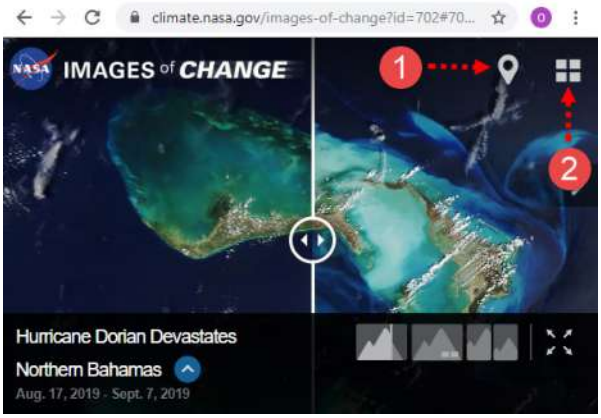
Task 1

Review the examples of climate change or anthropogenic effects using NASA's satellite imagery at https://climate.nasa.gov/.

1. Open the website and select the ***Images of Change*** in the ***Explore*** tab.

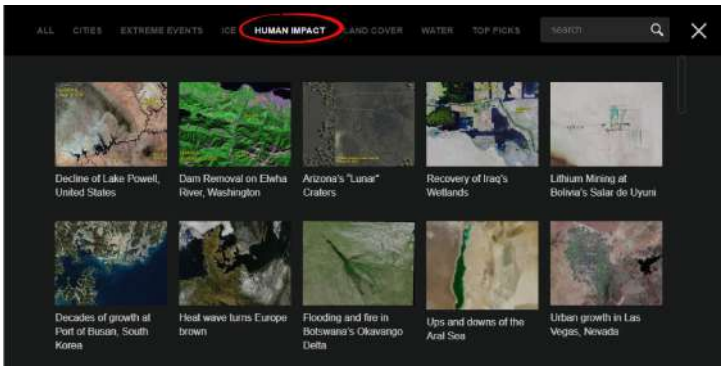


An image representing one of the dynamic changes of Earth opens immediately.

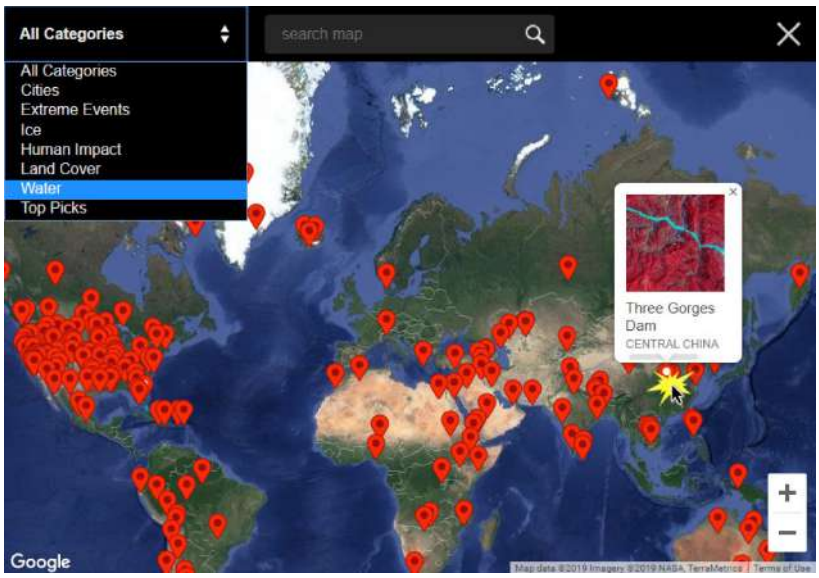


2. Select a view mode:

- a list (2);



- a map displaying the locations (1).



Note! You can select the satellite images from the following categories:

- ***Cities***;
- ***Extreme events***;
- ***Ice***;
- ***Human impact***;
- ***Land cover***;
- ***Water***.

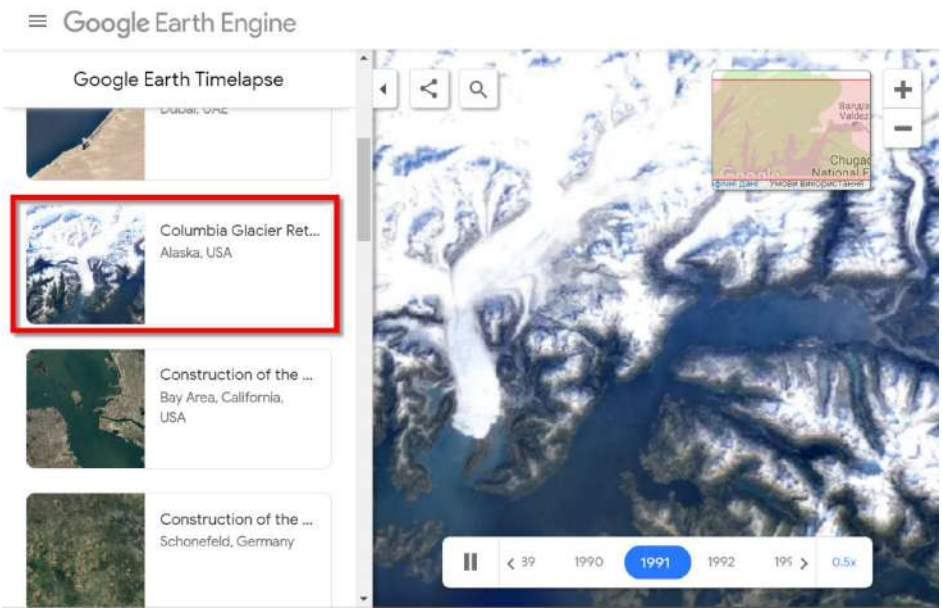
Choose a category of interest and view the images available in this category: the melting of Alaska glaciers, fires in the United States, floods in South Dakota, etc.

Task 2

Explore the timelapse video at: https://earthengine.google.com/timelapse/.

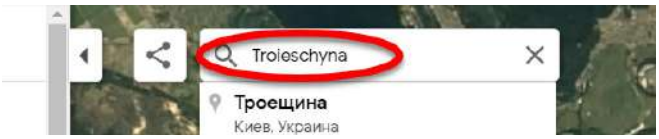
A timelapse feature is used to display a history of relatively slow processes, in our case – sets of satellite images taken from the same scene at different times.

Back in 2013, Google Earth mapping service launched the Timelapse tool. With this tool, it is possible to see historical satellite images stitched together to show the changes our planet has undergone over a few decades. The animation map contains more than five million images: the earliest are taken from the Landsat 5 archive, and the most recent ones came from the Landsat 8 and Sentinel-2 satellites. In such a way, over 25 million spectacular videos have been created, which show the Earth's surface from 1984 to 2018.

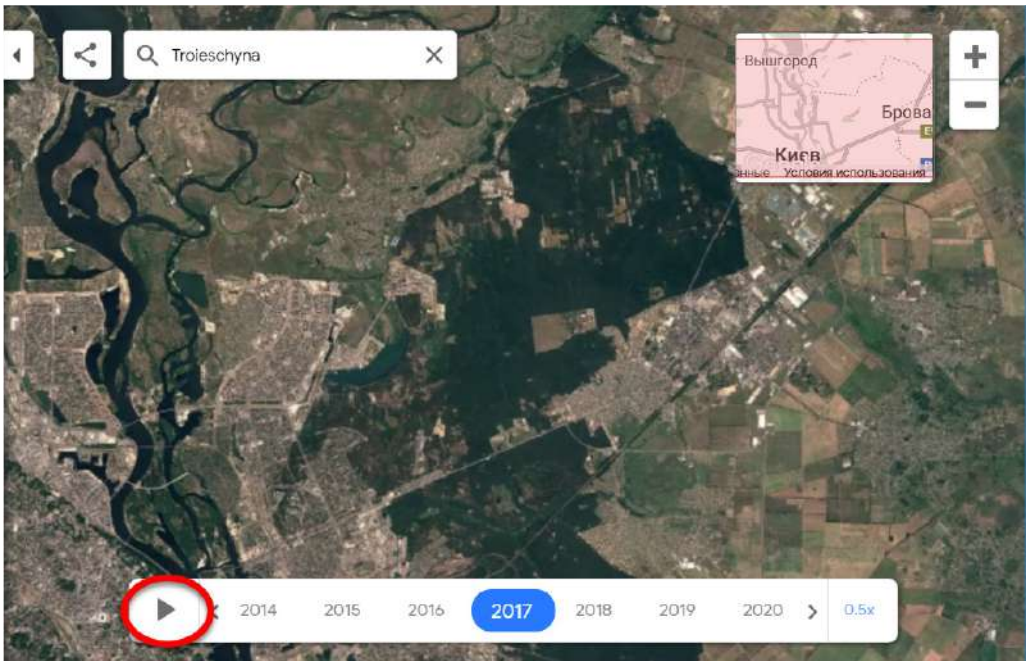


Choose any location and see how it has changed over the decades. For example, explore the changes of the Aral Sea, construction of artificial islands in Dubai, etc.

Let's explore the growth of Kyiv city, namely, the emergence of the Troieschyna housing estate. Enter *Troieschyna*, Kyiv in the search field to display the location in the map window.



Move the map to the left to display the other bank of the Dnipro River and zoom into the forested area in the north of Kyiv, near Vyshgorod. This example demonstrates clearly the scale of deforestation over the past 40 years.



By clicking the ***Share*** tool in the upper corner of the map window, you will get a link to the selected area or a code that can be added to your web page.

LandsatLook
(Downloading Satellite Image of Kyiv)

Case

Landsat is a joint USGS (US Geological Survey) and NASA (National Aeronautics and Space Administration) program. Since 1972, Landsat satellites have gathered data about Earth. The Landsat archive contains several million images that can be downloaded and used for free. In this task, you will learn how to use the LandsatLook resource for downloading any Landsat satellite images available.

Official website: https://landsatlook.usgs.gov/explore.

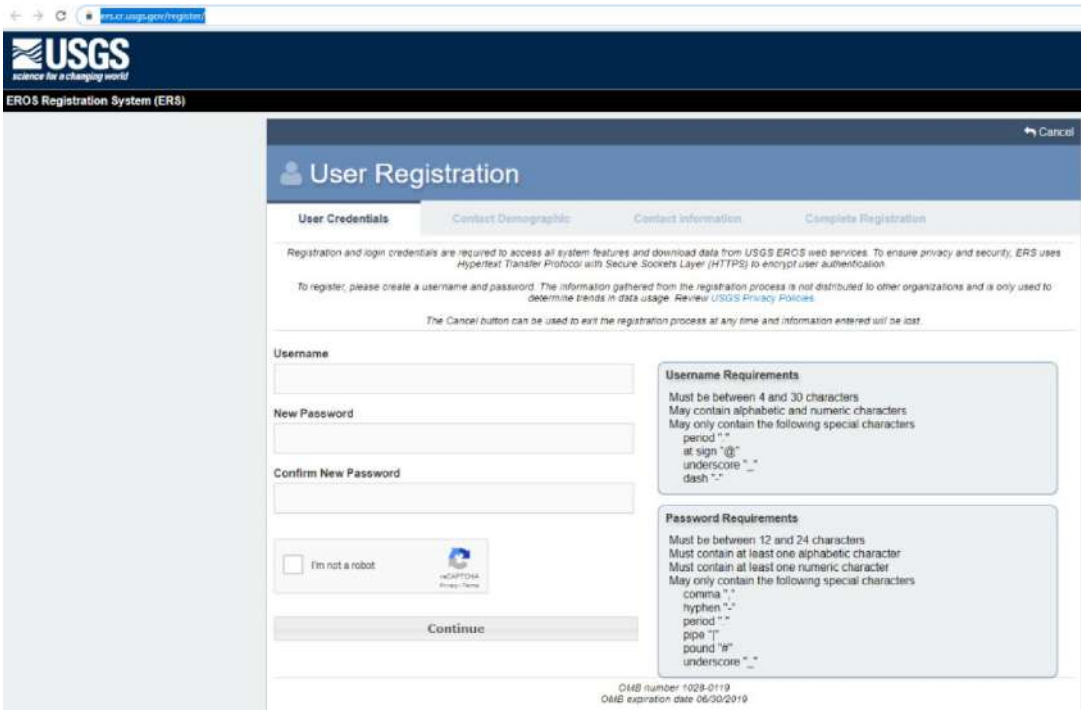
Task

Have a look at the interface of this website and create an account. Download Landsat 8 image of Kyiv from the LandsatLook website archive.

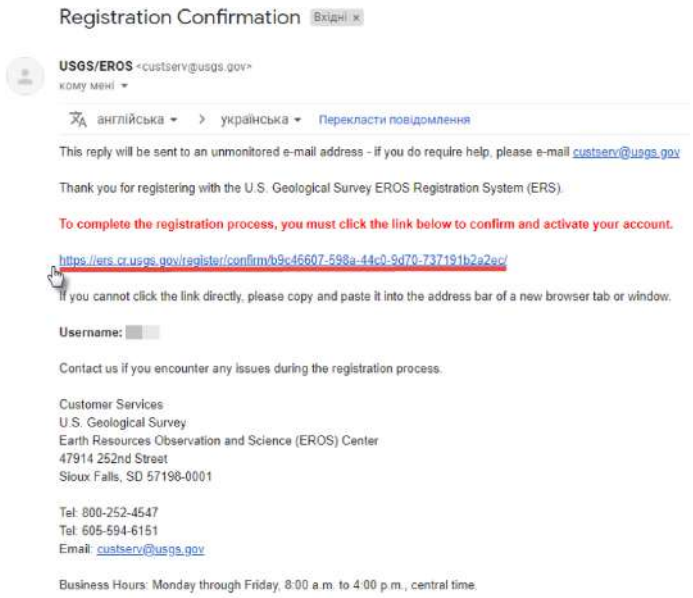
Instructions for self-guided work:

To download images from this website, you need to create an account, i.e. sign in. The account is free and allows you to use this resource and download as many images as you want. If you have already registered with the USGS EROS system, skip the section below.

1. Go to the registration page at: https://ers.cr.usgs.gov/register/.



2. Enter all required information paying attention to the notes specified on the page. You will receive a registration confirmation letter to the e-mail address you provided in the application form. To activate your account, click the link and enter your username again in the box that opens. Congratulations, you can use this resource for free now.



Registration Confirmation Вхідні ×

USGS/EROS <custserv@usgs.gov>
кому мені

англійська › українська Перекласти повідомлення

This reply will be sent to an unmonitored e-mail address - if you do require help, please e-mail custserv@usgs.gov

Thank you for registering with the U.S. Geological Survey EROS Registration System (ERS).

To complete the registration process, you must click the link below to confirm and activate your account.

https://ers.cr.usgs.gov/register/confirm/b9c46607-598a-44c0-9d70-737191b2a2ec/

If you cannot click the link directly, please copy and paste it into the address bar of a new browser tab or window.

Username:

Contact us if you encounter any issues during the registration process.

Customer Services
U.S. Geological Survey
Earth Resources Observation and Science (EROS) Center
47914 252nd Street
Sioux Falls, SD 57198-0001

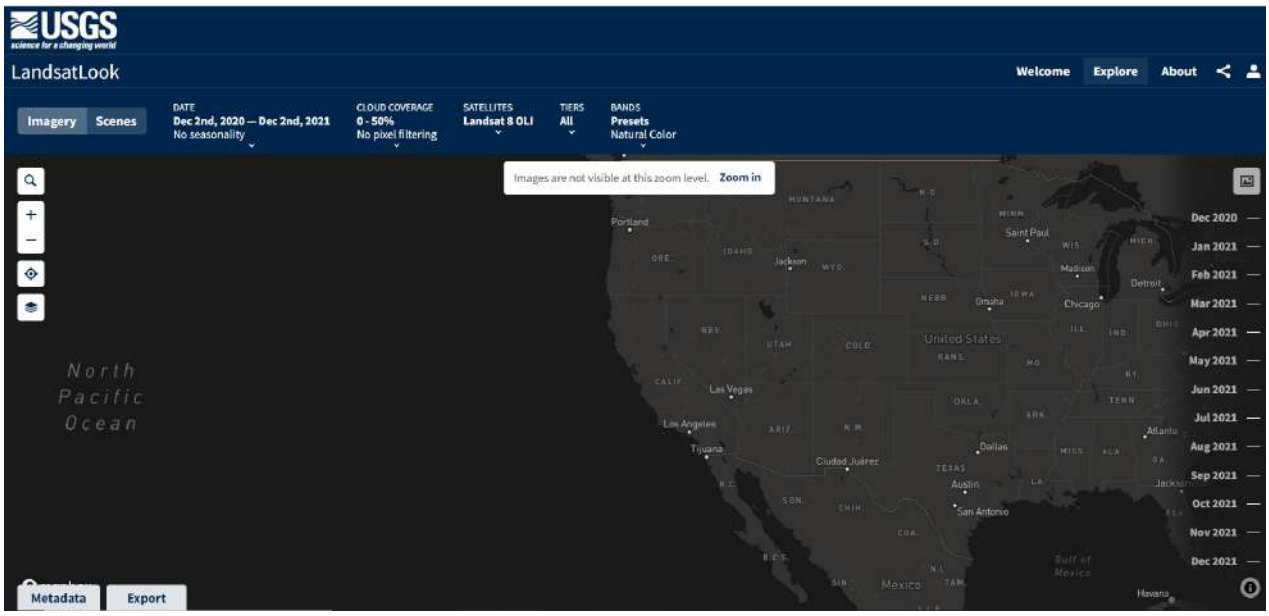
Tel: 800-252-4547
Tel: 605-594-6151
Email: custserv@usgs.gov

Business Hours: Monday through Friday, 8:00 a.m. to 4:00 p.m., central time.

Searching for location of interest

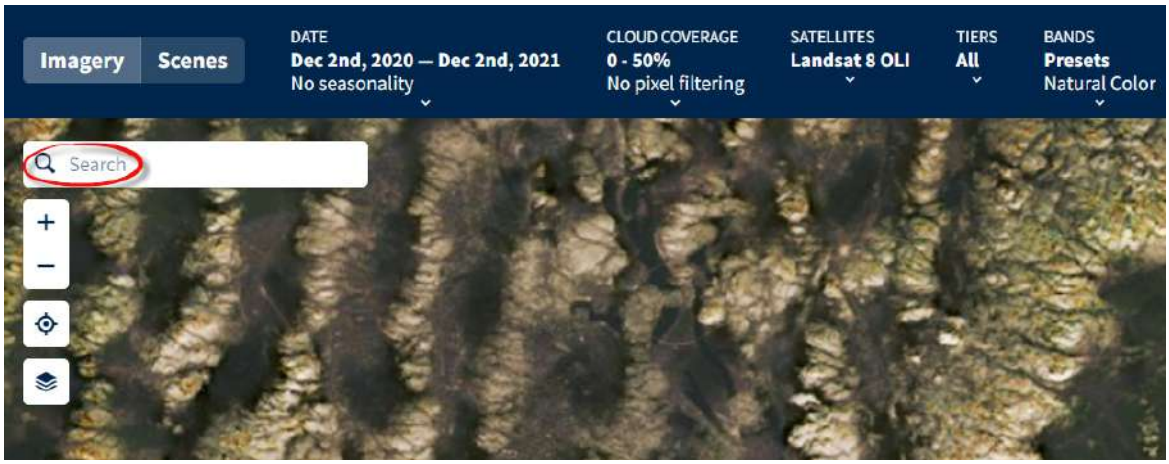
1. Log in to your USGS EROS account at https://ers.cr.usgs.gov/login/.

2. Open LandsatLook Viewer – https://landsatlook.usgs.gov/explore.

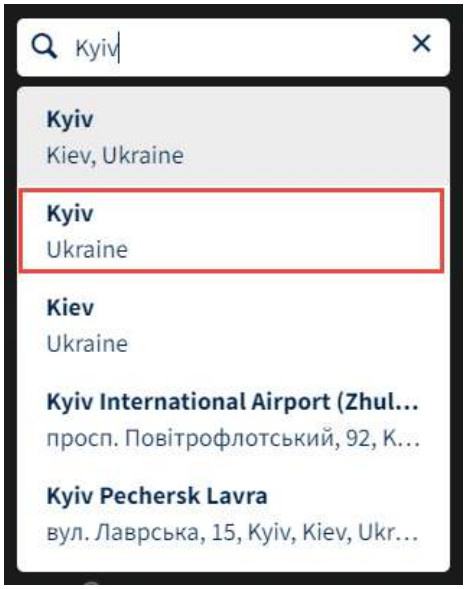


3. By default, the LandsatLook Viewer displays a map of the United States. The ***Load Image*** box is located in the upper left-hand corner of your screen and contains all options for Landsat images' search.

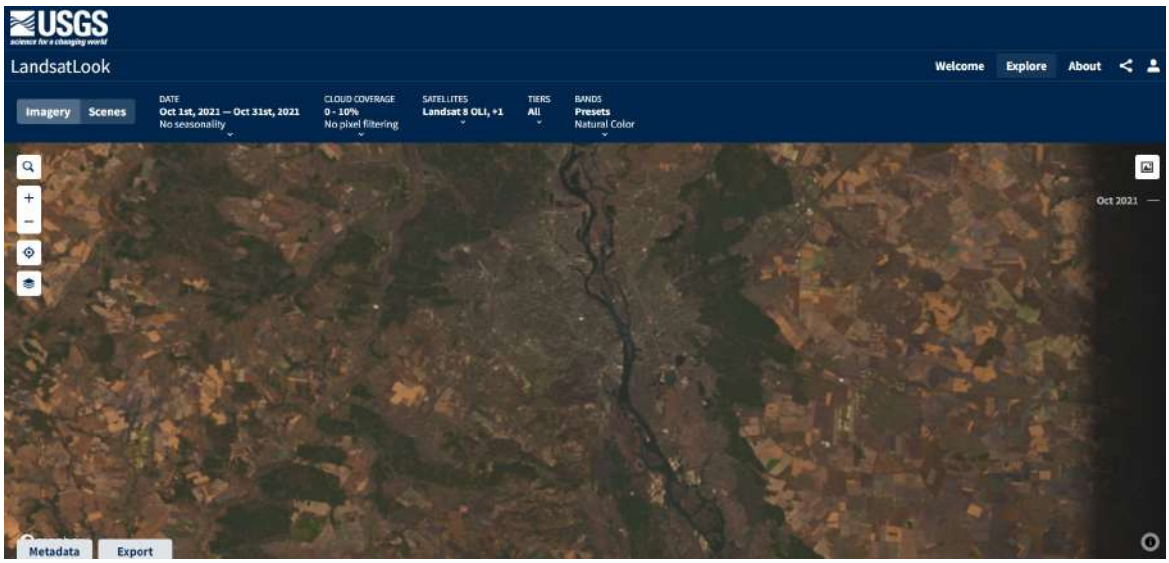
Select the ***Search*** button from the upper left-hand sidebar.



Enter *Kyiv* in the search field and select **Kyiv**, **UKR**.



You can zoom in or out of the map using the navigation buttons or your mouse wheel. The map extent will change accordingly.



Check yourself

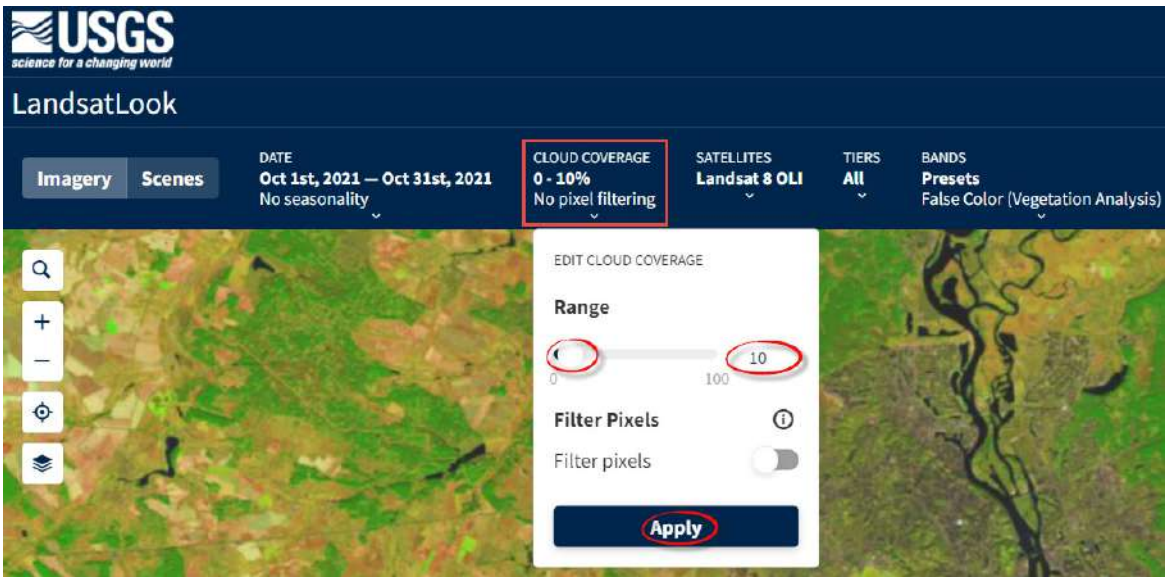
What is the map extent?	

Searching for and Saving the Images

High-quality images that you may use in your research contain various data. Landsat images are multispectral, i.e. it is possible to view them in different bands of the visible spectrum, and explore many features, such as urban development, agricultural lands, vegetation, coastlines, etc.

1. Set the period, from 01.10.2021 to 31.10.2021, in the ***Date*** field (select these dates in the calendar).

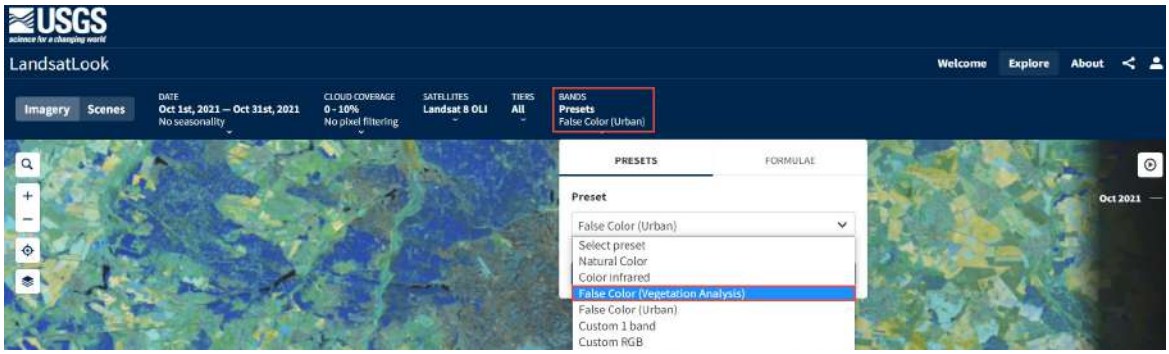
Another important property of satellite imagery is cloud coverage. Clouds cover the Earth's surface and can hide features of our interest. To get images with minimal cloud coverage, select *10% or less* from the ***Cloud Coverage*** field.



You can choose the Landsat sensor from the ***Satellites*** tab. The sensors differ by their operation time, type, and image pixel size. The default sensor is Landsat 8 OLI sensor. To perform this task, select the *Landsat 8 OLI* sensor and click the ***Apply*** button.

2. As a result, a list of all available images that meet the specified criteria will appear. Click ***Request timelapse data*** to get images for the selected period that display the changes in the territory.

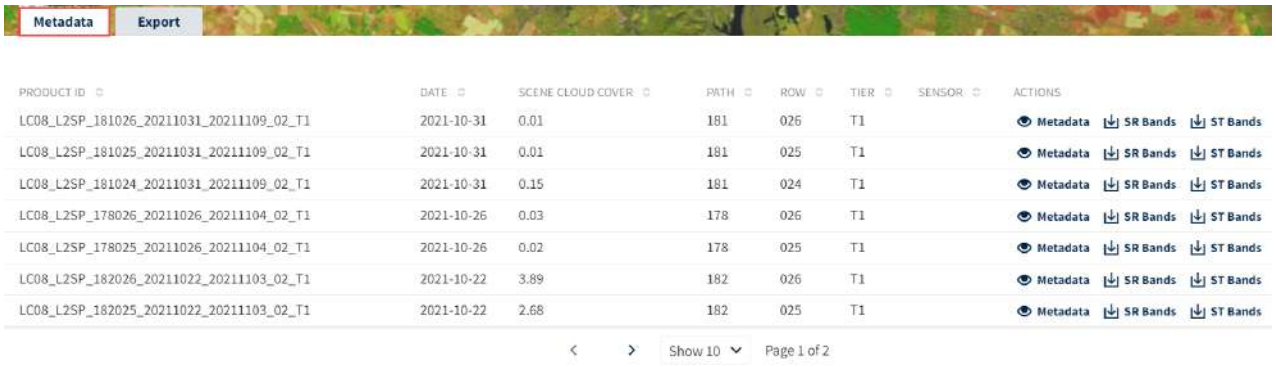
3. You can change image visualization under ***Bands***. Change visualization for ***False Color*** and click ***Apply***.



Downloading Image

To download the displayed image, select ***Metadata*** at the bottom of your screen. Now, you can review all the information about available images.

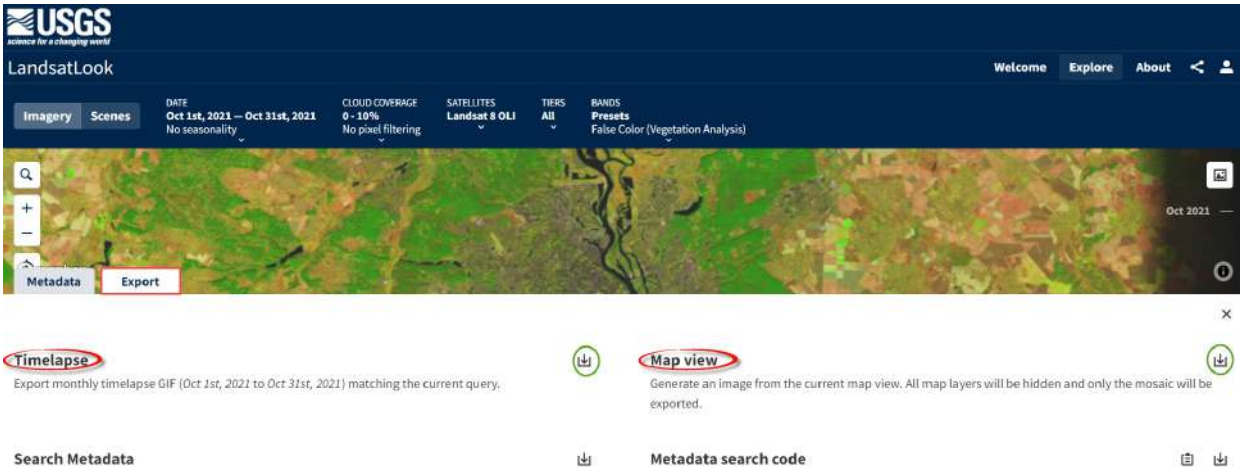
1. General information about all the images from the search results will be shown in the table. To download the image, click the ***Download*** button.



You can download SR (Surface Reflectance) bands and ST (Surface Temperature) bands. This is a different set of bands that can be downloaded and used for further analysis in GIS programs. Level-2 products (Landsats 4-8 only) include the Level-1 QA bands as well as SR aerosol QA band for Landsat 8 (SR_QA_AEROSOL), a surface reflectance cloud quality assessment band (SR_Cloud_QA) for Landsat 4-7, and a surface temperature QA band (ST_QA) for Landsat 4-8.

2. The image bands that you have selected for downloading will appear in a new window. To start the download, log in to your USGS EROS account if you have not done it yet.

3. In this task, you need to download ***Timelapse*** and ***Map view*** files. Switch to the ***Export*** tab and click the button. The download may take a few minutes, so please wait.



І в наступному вікні натисніть ***Download (Завантажити)*** поруч з **Level** 1 GeoTIFF Data Product. Завантаження може тривати декілька хвилин, тому зачекайте.

Check yourself

How do you think ***Map view*** image differs from GeoTIFF Data Product?	
Is it possible to download a 1972 Landsat satellite image of Kyiv using LandsatLook?	

Annexes

Annex 1

Common Sentinel-2A and Landsat Band Combinations

In this Practice Book, we have used images captured by Landsat 8, Sentinel-2A, and Sentinel-5P satellites. The description of the special characteristics of these satellites and examples of the most commonly used band combinations are given below.

Landsat satellites

The Landsat program is the longest-running enterprise for the acquisition of satellite imagery of Earth. The first Landsat satellite was launched in 1972, and the most recent on September 27, 2021.

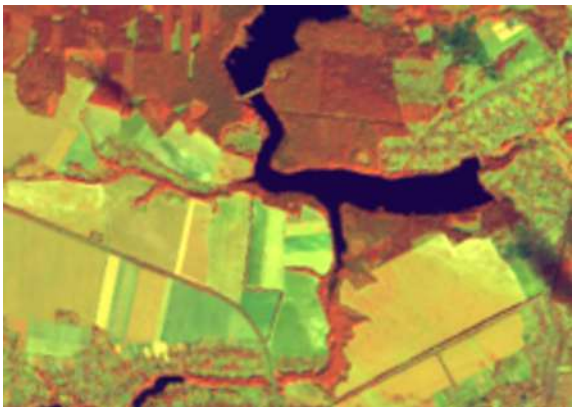
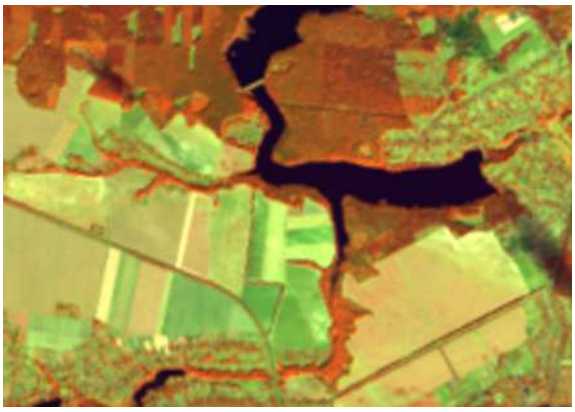
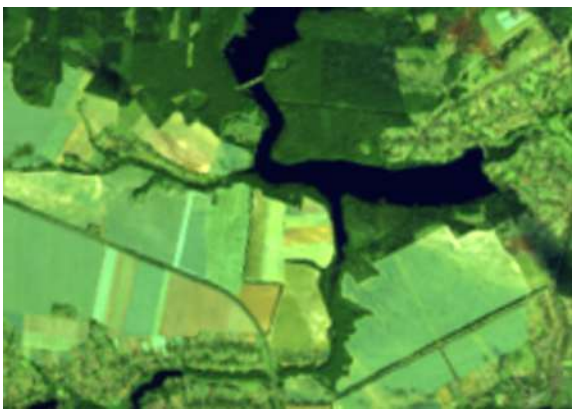
Landsat 1 (originally ERTS-1, Earth Resources Technology Satellite 1) – launched on July 23, 1972, terminated on January 6, 1978.
Landsat 2 (ERTS-B) – launched on January 22, 1975, terminated on February 25, 1982.
Landsat 3 – launched on March 5, 1978, terminated on March 31, 1983.
Landsat 4 – launched on July 16, 1982, terminated in 1993.
Landsat 5 – launched on March 1, 1984, terminated on December 21, 2012.
Landsat 6 – launched on October 5, 1993, but it failed to reach orbit.
Landsat 7 – launched on April 15, 1999, and is still active. Landsat 7 has the same 7 bands as Landsat 4 and Landsat 5 but also includes an additional band with a wide spectral range and a resolution of 15 m*15 m. In addition, the Band 6 spatial resolution (thermal IR spectral region) has been increased from 120 to 60 m.
Landsat 8 is currently (2019) in orbit. It provides images in 11 spectral bands with a spatial resolution ranging from 15 m (panchromatic band – B8) to 30 m per pixel (all other bands: B1-B7, B9); thermal bands, B10 and B11, were oversampled from 100 m to 30 m; its orbit allows <= 8-day repeat coverage of any area on the globe.
Landsat 9 – launched on September 27, 2021, and is still active. It is a rebuild of its predecessor Landsat 8.

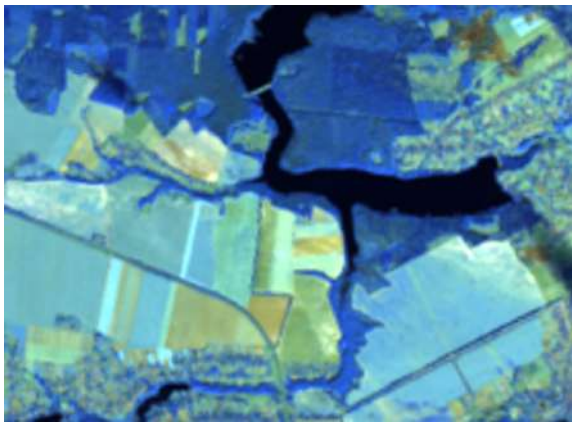
Landsat 8 Bands

Bands	Wavelength [micrometers]	Resolution [meters]
Band 1 – Coastal aerosol	0.43 – 0.45	30
Band 2 – Blue	0.45 – 0.51	30
Band 3 – Green	0.53 – 0.59	30
Band 4 – Red	0.64 – 0.67	30
Band 5 – Near Infrared (NIR)	0.85 – 0.88	30
Band 6 – SWIR 1	1.57 – 1.65	30
Band 7 – SWIR 2	2.11 – 2.29	30
Band 8 – Panchromatic	0.50 – 0.68	15
Band 9 – Cirrus	1.36 – 1.38	30
Band 10 – Thermal Infrared (TIRS) 1	10.60 – 11.19	100 (oversampled to 30)
Band 11 – Thermal Infrared (TIRS) 2	11.50 – 12.51	100 (oversampled to 30)

Common Band Combinations for Landsat 5, 7, 8

<table>
<tr><th>Band Combinations for Landsat 5, 7</th><th>Band Combinations for Landsat 8</th><th>Information</th></tr>
<tr><td>B03, B02, B01</td><td>B04, B03, B02</td><td rowspan="3">The natural color composite replicates close to what our human eyes can see. While healthy vegetation appears green, cleared fields are light, unhealthy flora is brown and yellow, roads are grey, and coastlines appear whitish. This band combination is well suited for the analysis of aquatic ecosystems, determining water depth. It is also used to study man-made features. With this band combination, logged areas and sparse vegetation are poorly detected, and it is difficult to differentiate one type of vegetation from another.</td></tr>
<tr><td colspan="2">Red, Green, Blue</td></tr>
<tr><td colspan="2">  </td></tr>
<tr><td>B04, B03, B02</td><td>B05, B04, B03</td><td rowspan="3">This is the standard false-color composite. Vegetation appears in shades of red, urban areas are green-blue, and the soil color varies from dark to light brown. The shades of deep red indicate healthy and/or broadleaf vegetation, while grassy or sparse/shrubby vegetation appears in lighter shades. This combination is very popular and is used for analyzing vegetation, monitoring soil and crops.</td></tr>
<tr><td colspan="2">NIR, Red, Green</td></tr>
<tr><td colspan="2">  </td></tr>
<tr><td>B07, B04, B02</td><td>B07, B05, B03</td><td rowspan="3">This band composite produces an image close to natural colors, and at the same time allows analyzing the atmosphere and smoke. Healthy vegetation appears bright green, the grass is green, bright pink areas indicate bare earth, brown and orange hues are characteristic of sparse vegetation. Dead vegetation appears orange, and the water is blue. This band composite is well suited for the analysis of deserts and deserted areas. It is also useful for studying agricultural lands and wetlands, monitoring the dynamics of fires, and post-fire analysis of the territory. Burnt-down areas will appear bright red.</td></tr>
<tr><td colspan="2">SWIR-2, NIR, Green</td></tr>
<tr><td colspan="2">  </td></tr>
</table>

B04, B05, B01	B05, B06, B02	
NIR, SWIR-1, Blue		
		Healthy vegetation appears in shades of red, brown, orange, and green. Soils can be green or brown, urban areas may appear whitish, grey, and green-blue. Bright blue may indicate recently logged areas, while areas of revegetation or sparse vegetation may appear reddish. The added mid-IR band makes it possible to distinguish well the vegetation age.
B04, B05, B03	B05, B06, B04	
NIR, SWIR-1, Red		
		With this combination of the near, mid-IR, and visible red bands, it is possible to clearly distinguish the boundaries between water and land. Vegetation appears in different shades and hues of brown, green, and orange. This band combination is useful for the analysis of soil and vegetation moisture. In general, since water absorbs nearly all light at this wavelength, the higher the soil moisture is, the darker such soil will appear in the image.
B07, B05, B03	B07, B06, B04	
SWIR-2, SWIR-1, Red		
		This band composite produces an image close to natural colors, and at the same time allows analyzing the atmosphere and smoke. The vegetation appears in shades of dark and light green, urban areas are whitish, green-blue, and crimson, while soil, sand, and minerals may appear in different colors. Since water, snow, and ice absorb nearly all light at the mid-IR range, this combination can be useful for defining the water/land interface. Hot spots (such as volcanic vents and fires) appear red or yellow. One of the possible applications of this band combination is fire monitoring.

B05, B04, B03	B06, B05, B04	
SWIR-1, NIR, Red		
		Similar to B04, B05, B01 combination, this band composite provides a lot of information and color contrasts. Healthy vegetation appears bright green, and the soil is purple-pink. Unlike B07, B04, B02 composite, which uses band 7 and allows studying geological processes, this band combination enables agricultural lands analysis. It is well suited for the study of vegetation and is widely used to analyze forest health.
B07, B05, B04	B07, B06, B05	
SWIR-2, SWIR-1, NIR		
		This combination does not use any bands in the visible range and is well suited for aerosol studies. With this band combination, the coastlines are clearly visible. It can be used to analyze the soil texture and moisture. Vegetation appears blue.

Sentinel Satellites

Copernicus is the European Union's Earth observation programme managed by the European Space Agency (ESA). It provides data for real-time monitoring of the environment and civil security. All data is free and publicly available.

Sentinel missions:

ESA is currently developing **10 missions** called Sentinels. Each Sentinel mission is based on a constellation of two satellites.

Sentinel-1 is an all-weather, day-and-night radar imaging mission. The first Sentinel-1A was successfully launched in 2014, and the second – Sentinel-1B – on April 25, 2016.

Sentinel-2 is a multispectral high-resolution imaging mission for land monitoring. The first Sentinel-2 satellite was successfully launched on June 23, 2015.

Sentinel-3 is a mission for the ocean and global monitoring. The first Sentinel-3A satellite was launched on February 16, 2016.

Sentinel-4 will be launched in 2023. It will be used for atmospheric monitoring and embarked upon a Meteosat Third Generation-Sounder satellite.

Sentinel-5 Precursor features a set of Sentinel 5 sensors. It was taken into orbit on October 13, 2017. It has been developed to reduce data gaps, in particular for the atmospheric SCIAMACHY instrument, between the ENVISAT satellite termination in 2012 and the launch of Sentinel-5 in 2021.

Sentinel-5 will provide data for atmospheric monitoring. It is planned to be launched together with the post-EUMETSAT Polar System (EPS) spacecraft in 2021.

Sentinel-6 aims to support high-precision altimeter missions (measuring global sea-surface height) of the Jason-3 satellite. The first Sentinel-6A was launched in November 2020.

Sentinel-7 is a Carbonsat mission (measuring atmospheric carbon).

Sentinel-8 is a thermal infrared imaging mission.

Sentinel-9 is an infrared imaging mission for measuring and monitoring ice and snow thickness.

Sentinel-10 is a hyperspectral imaging mission.

The Sentinel-2A satellite has nearly the same spectral bands as Landsat 8 (except for the thermal band of Landsat 8 thermal infrared sensor). Among the eleven Landsat 8 bands, only shortwave (1-4 and 8) correspond to the visible spectrum, others are sensitive to the regions of the spectrum that the human eye cannot distinguish. The Sentinel-2 satellite has 12 spectral bands; the spatial resolution of RGB and NIR bands is 10 m.

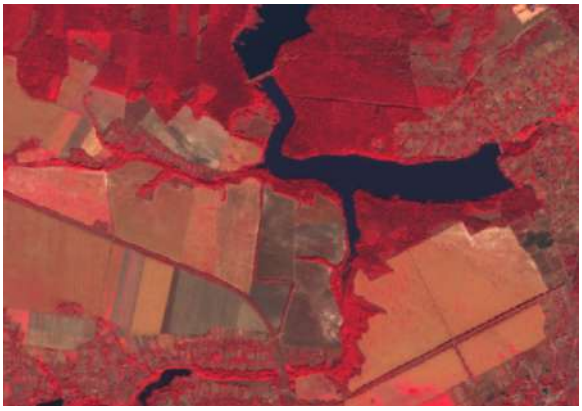
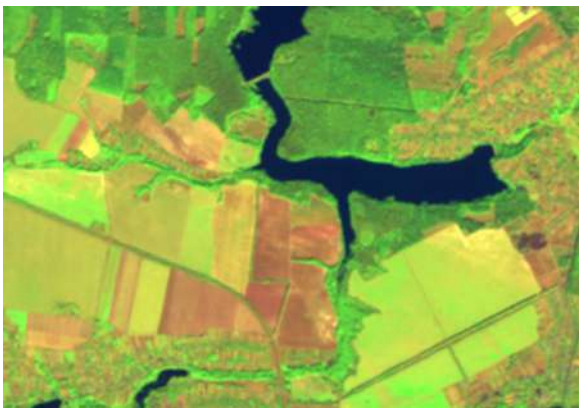
QR code to watch the video tutorial on the use of standard Sentinel-2 bands in *EO Browser*

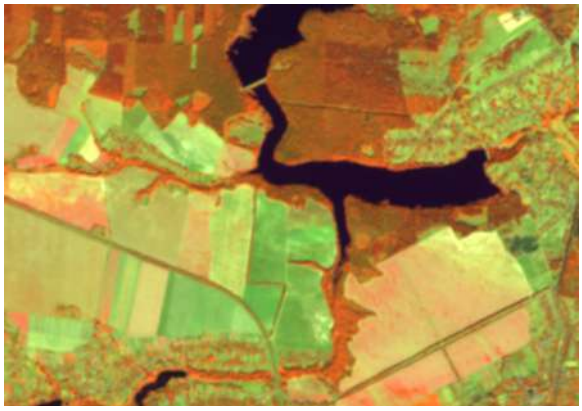
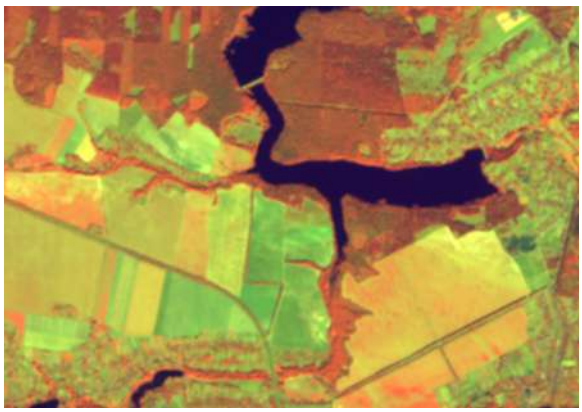
Sentinel-2 Bands

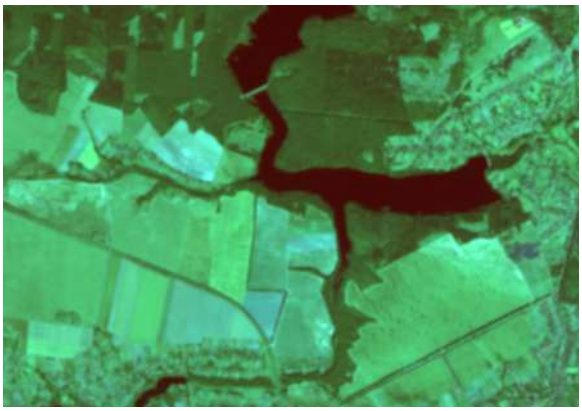
Sentinel-2 Bands	Central Wavelength [micrometers]	Resolution [meters]
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Red	0.705	20
Band 6 – Red	0.740	20
Band 7 – Red	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Red	0.865	20
Band 9 – Water vapor	0.945	60
Band 10 – SWIR – Cirrus	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

Common Band Combinations for Sentinel-2A

Sentinel-2A Combination	**Information**
Natural color B04, B03, B02 ***Red, Green, Blue*** 	The **natural-color** composite uses the visible range of the spectrum and displays imagery the same way our eyes see the world. Healthy vegetation appears green, cleared fields are light, unhealthy flora is brown and yellow, roads are grey, and coastlines appear whitish. Water bodies, however, appear too dark with this combination due to the scattering of blue light in the atmosphere. It is possible to analyze the condition of water bodies and determine their depth according to the color intensity. This band combination is also suited for the study of man-made features.

False color (vegetation) B08, B04, B03 ***NIR, Red, Green*** 	The **false-color** composite shows vegetation in the shades of red, urban areas in blue, and the soil appears in various colors from dark to light brown. Ice, snow, and clouds are white or light blue. This band combination is very popular and well suited for the analysis of vegetation, monitoring soil and crops. Generally, the shades of deep red indicate broadleaf and/or healthy vegetation, while grassy or sparse vegetation appears in lighter shades of red. This combination produces images similar to infrared aerial photography.
SWIR1, Red8, Blue 	This band composite is well suited for crops monitoring. Healthy vegetation appears bright green. Coniferous forests are dark green and deciduous forests are bright green. Sparse vegetation and bare earth appear brown and purple, respectively.
False color (urban) B12, B11, B04 ***SWIR2, SWIR1, Red*** 	This combination also provides a *natural color* image. Growing vegetation appears in shades of dark and light green, areas of urban development are white, grey, blue, or purple. Since water, ice and snow absorb nearly all light at the mid-IR range, this combination can be useful for defining the water/land interface. Snow and ice are blue; the water is black or dark blue. Hot surfaces, such as forest fires and volcanic vents appear in shades of red or yellow. One of the specific applications of this band composite is forest fire monitoring.

Land/Water B8A, B11, B04 ***Red8, SWIR1, Red*** 	This band combination is well suited for the identification of land and water. The land is visible in shades of orange and green, ice is bright purple, and water is visible in shades of blue.
Healthy vegetation B8A, B11, B02 ***Red8, SWIR1, Blue***  Analysis of vegetation B11, B8A, B04 ***SWIR1, Red8, Red*** 	Healthy vegetation appears in shades of red, brown, orange, and yellow. Soils can be green and brown, urban areas – white, blue, and grey; reddish areas indicate new vegetation, potential meadows with thin vegetation. Pure, deep water in this band combination will appear very dark. Shallow water or water that contains sediments will be visible in shades of light blue. This composite is not well suited for studying man-made features, such as roads and runways. This combination provides the user with a large amount of information and color contrasts. Healthy vegetation appears bright green, while the soil is purple. It is useful for studying vegetation and is commonly utilized in forestry to identify areas of tree infestation.

Short-wave infrared B12, B8A, B04 ***SWIR2, Red8, Red*** 	This composite is well suited for the analysis of vegetation since the reflectivity in SWIR depends mainly on the moisture content in leaves or soil. Thus, healthy vegetation with high moisture content and coastal areas appear bright green, while arid areas are dark green. Coniferous forests are visible in deep green color, and deciduous forests are bright green. Soils appear brown and purple. This combination is well suited for the study of vegetation, detecting soil disturbances, soil type, etc.
Eliminating atmospheric effects B12, B8A, B03 ***SWIR2, Red8, Green*** 	This combination provides a natural color reproduction. Healthy vegetation appears bright green and the color intensity can change depending on the growing season, meadows are green, and barren soil is pink. Dry vegetation is orange and water is blue. This band composite provides vivid images of the deserts. The combination is useful for geological, agricultural, and wetland research. The fire appears red in the images, and this combination is used to control fires and analyze burned-down forest areas. Urban areas are visible in different shades of purple. Meadows appear light green. Light green spots inside the city indicate grassy vegetation – parks, cemeteries, golf courses. Olive-green or bright green shades usually indicate coniferous forests while deciduous forests appear dark green.
Snow/Clouds B02, B11, B12 ***Blue, SWIR1, SWIR2*** 	This combination is suited for detecting snow and ice because they are reflected well in the visible part of the spectrum and highly absorbed in the short-wave infrared range. Snow and ice appear bright red. The more ice, the higher the absorption in the SWIR bands and the more intense the red color. Thick ice and snow are bright red (or red-orange). Vegetation appears greenish with this band combination. Bare earth is bright blue. The water appears very dark because it absorbs red and SWIR but small drops of water in the clouds scatter light equally in both the visible and SWIR bands and therefore will appear white.

List of Suggested Research Projects for Ukraine's Junior Academy of Sciences Students

Hydrology

Monitoring River Flooding Caused by Heavy Rainfalls *(western Ukraine, Romania).*

Monitoring Flooding during High Water or Spring Freshets *(Dnipro river, Desna river).*

Dynamics of River Delta Formation or Growth *(Danube, Ganges, Nile).*

Eutrophication in Reservoirs / Water Blooming *(Dnipro river reservoirs).*

Waterlogging / Overgrowth of Reservoirs, Lakes *(Dnipro river reservoirs).*

Ice Monitoring *(ice motion in large navigable rivers, reservoirs).*

Melting of Glaciers *(Arctic, Antarctic, Greenland).*

Landscape Study / Urban Planning

Urban Growth or Development / Expansion *(Paris, Kyiv, Warsaw).*

Changes of Coastline *(Dubai, Odesa).*

Drying up of Lakes, Seas / Shallowing of Rivers *(Aral Sea).*

Increase in Land Areas Occupied by Solar Power Plants *(the largest area in Ukraine is in Dnipropetrovsk Oblast – 400 hectares).*

Forestry

Processes That Adversely Affect Forests: Impacts of Pests and Diseases, Drainage or Waterlogging of Forests, Leading to their Degradation and Dieback *(bark beetle infestations in coniferous forests in northern Ukraine).*

Dynamics of Forest Fires *(Ukraine's Chornobyl Exclusion Zone, Australia, California).*

Detecting and Monitoring Wood-Felling Sites *(any forest land within Ukraine).*

Planting of Forest / Reforestation *(Oleshky Sands – a Ukrainian desert).*

Agricultural Science

Comparison of Agricultural Models in Different Countries *(Iraq, Germany, Belarus).*

Soil Reclamation (irrigation), Construction of a Dam *(Iran).*

Monitoring Land Degradation Processes (erosion, salinization, waterlogging, overgrowth of agricultural lands with shrubs).

Mapping Crop Rotations, Determining Real Structure of Areas Under Cultivation.

Protection of Environment

Detecting Illegal Dumps *(within one administrative district of any oblast).*

Preservation of Nature Reserve Fund.

Burning Dry Grass, Reed Beds within Nature Reserves *(lowland spring fires in the Danube reed beds).*

Consequences of Emergencies

Tsunami *(on December 26, 2004, an earthquake in the Indian Ocean triggered a large tsunami, which affected Indonesia, Sri Lanka, southern India, Thailand).*

Volcanic Eruptions *(2010, Eyjafjallajökull volcano).*

Landslides, Rockfall, Sloughing, Karst Processes, Abrasion.

Avalanches *(February 23, 1999 – Galtur, Austria).*

Flash Floods *(May 6, 2018 – Ankara, Turkey).*

Tornado *(May 20, 2013 – Oklahoma, the USA).*

Earthquakes *(February 27, 2010 – Chile, South America).*

Major Terrorist Incidents *(September 11, 2001 – New York).*

Disasters and Accidents of Freight Trains, Ships, Air and Space Disasters, Oil Pipeline Accidents, Oil Rig Disasters, Emissions from Oil and Gas Production Operations *(explosions and fires at military warehouses in Ukraine; 09/26/2017 - Kalynivka, Kalynivskyi District, Vinnytsia Oblast).*

Climatology, Meteorology

Thermal Abnormalities on Earth Surface *(volcanic eruptions).*

Formation of Cyclones, Typhoons, Storms.

Dust Storms, Deflation *(the Sahara Desert, Sydney in eastern Australia).*

Ambient (Outdoor) Air Pollution *(identification of largest air pollutants and monitoring monthly dynamics).*

Notes

Notes

Notes

Навчальне видання

Бабійчук *Світлана Миколаївна*
Юрків *Лілія Ярославівна*
Томченко *Ольга Володимирівна*
Кучма *Тетяна Леонідівна*

Робочий зошит з основ дистанційного зондування Землі

Частина І

Коректура *І. В. Братащук*
Верстання *О. А. Жупанська*
Дизайн обкладинки *Б. Л. Лісовський*

Формат 60×84 1/8. Папір офс. 80 г/м^2.
Друк цифровий. Ум. друк. арк. 13,86.
Наклад 300 прим.

Видавництво: Національний центр «Мала академія наук України»,
Кловський узвіз, буд. 8, м. Київ, 01021

Свідоцтво суб'єкта видавничої справи:
ДК № 6999 від 04.12.2019

Робочий зошит є практичним доповненням до навчального посібника «Основи дистанційного зондування Землі: історія та практичне застосування» (С. О. Довгий, В. І. Лялько, С. М. Бабійчук, Т. Л. Кучма, О. В. Томченко, Л. Я. Юрків).

Практичні роботи, що містяться в робочому зошиті, укладені з метою ознайомити читача з можливостями застосування космічних знімків сім'ї Sentinel та Landsat у різнотематичних дослідженнях, зокрема кліматичних, гідрологічних, лісових, сільськогосподарських тощо.

Робочий зошит може використовуватися методистами і педагогами Малої академії наук України, викладачами і студентами закладів вищої освіти, вчителями й учнями, які здобувають освіту наукового спрямування у закладах спеціалізованої освіти наукового профілю, а також усіма, хто прагне самостійно опанувати основи дистанційного зондування Землі та геоінформаційних систем.