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FEATURES OF CREATING AN INTERACTIVE MAPPING WEB APPLICATION FOR THE ANALYSIS OF SPACE IMAGES

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Abstract
In the era of the high level of technological achievements of remote sensing of the Earth and the high level of development of web cartography, interactive web applications for the analysis of data of remote sensing of the Earth are gaining more and more popularity. Considering the large amount of space image data, and the complexity and heterogeneity of the analysis tools that need to be developed, the question arises of quickly and efficiently creating an interactive web application for the analysis of space images that will help scientists monitor and study changes in the Earth's surface and predict optimal ways of territory development with minimal expenditure of time and resources. In solving such a question, the specialized web platform Google Earth Engine (GEE) can help. The purpose of the article is to highlight the characteristics and advantages of the GEE platform by creating an interactive web application using the example of analyzing changes in the NDVI index. Analyzing GEE allows us to conclude that this web-platform provides a comprehensive solution for creating interactive cartographic web applications for the analysis of space images with a built-in IDE. It will help to significantly reduce development time and costs, allowing for quick and efficient analysis of Earth remote sensing data.
Key words: web cartography, interactive web application, aerospace images, integrated development environment

Introduction

In the modern world of web cartography, web mapping is considered as a scientifically based process and algorithm, creation or use and paperless distribution of cartographic works of various types and purposes. Web mapping focuses mainly on technological issues, while web cartography addresses theoretical aspects, including the use of web maps, evaluation and improvement of methods and workflows, usability of web maps, social aspects, etc. (Bondarenko, 2021; Kraak M.Y., 2020). The modern level of development of web cartography allows you to explore and interact with geospatial data from satellite images in real time. The emergence of mobile devices and big data played an important role in the formation and development of opportunities for creating web applications for analyzing Earth remote sensing data. (Kraak M. J., 2020; Krol K., 2020). Today, web applications for space image data analysis mainly consist of interactive web maps. The term "interactive web maps" can refer to a wide range of cartographic products, from simple online maps to complex cartographics information systems. In order for such interactive web maps to meet the needs of users, developers and designers of interactive maps must consider the goals, objectives and preferences of their users to create effective web maps. (Roth R. E., 2013). Accordingly, web cartography plays an important role as a tool for efficient and quick analysis of space image data. Thanks to various software products and web platforms, web applications are created that provide the opportunity to predict the potential ways of development of individual areas of the earth's surface, as well as to respond quickly to possible unforeseen natural disasters or cataclysms. (Bondarenko, 2021).

At the same time, the development of such web applications can be quite complex and time-consuming. The main problems may arise when searching or processing a large amount of geospatial data, developing specific analysis tools or low quality of the obtained data. Desktop software products will require additional customization and involvement of developer hardware resources to develop such web applications. Existing web platforms usually provide limited access to space image data and tools for their analysis. To solve the problems of resource-consuming, slow and inefficient development of a web application for the purpose of analysis and research of space image data, it is worth turning to the specialized web platform GEE. When developing interactive maps, it is necessary to take into account the property of interactivity and use a large number of interactive functions, the research of which is devoted to a recent work (Krakovskii, Kurach, 2022). This article aims to study the main features of creating an interactive mapping web application for the analysis of space images using the Google Earth Engine web mapping platform, which helps to reduce the time and resources required for the development of this type of web application. The focus will be on the analysis of the Normalized Difference Vegetation Index (NDVI) as an important tool for assessing the health of vegetation.

To achieve this aim, the methodology of this research involves a review of relevant literature on web cartography, interactive web applications, aerospace images, and integrated development environments. There was conducted an empirical study by developing an interactive mapping web application using the

Google Earth Engine cartographic web platform to analyze the NDVI index. This study will evaluate the platform's main features and functionality in terms of its ability to support interactive mapping web applications for space image analysis.
The materials for this research consist of various aerospace images and datasets that will be used to create the interactive mapping web application. The research methods applied will include software development, data analysis, and evaluation of the platform's features and functionality.
This research is significant because it highlights the benefits of using specialized cartographic web platform with built-in IDE for creating interactive mapping web applications. By examining the main features and functionality of the Google Earth Engine cartographic web platform, there will be provided insights into how this platform can be used to create interactive mapping web applications for analyzing space images. Moreover, this research will contribute to the development of innovative technologies for remote sensing and analysis of the earth's surface, which can have important applications in various fields, such as environmental monitoring, agriculture, and urban planning.
In summary, this article will examine the features of creating an interactive mapping web application for the analysis of space images, with a focus on the Google Earth Engine cartographic web platform. The article will justify the rationale of the study by providing appropriate theoretical and empirical backgrounds and materials. The article will also describe the research methodology and highlight the significance of this research for the development of innovative technologies for remote sensing and analysis of the earth's surface.

Methodology of research and materials

The research was conducted to demonstrate the features of creating an interactive mapping web application for the analysis of space images using Google Earth Engine (GEE) cartographic web platform. The study focused on creating an interactive cartographic web application for the analysis of the Normalized Difference Vegetation Index (NDVI) data for Ukraine territory as an example to highlight the main characteristics, functionality and advantages of GEE.
The NDVI is a measure of vegetation greenness and is calculated using near-infrared and visible red light reflectance from satellite imagery. (Remote Sensing of Environment, 1988) The NDVI data used in this study were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on board the Terra satellite. Data were obtained with an average value for each season for the years 2000 and 2022 with a spatial resolution of 500 meters and a temporal resolution of 16 days (MODIS/Terra Vegetation Indices…, 2023).
To create an interactive mapping web application for the analysis of NDVI data, the GEE platform was used with the JavaScript programming language and GEE API for it. The GEE platform provides a wide range of tools and algorithms for analyzing satellite geospatial data and allows for the creation of interactive web applications (Google Earth Engine: Planetary-scale…, 2017). In addition, the platform provides access to a vast repository of satellite imagery and other geospatial data, which can be processed and visualized using JavaScript API code.
The NDVI data for Ukraine were imported from the satellite imagery library of GEE platform and were processed using the GEE API to calculate the mean NDVI value for each season for the specified years for the territory of the entire country (Google Earth Engine. Platform overview, 2023). As a result, the interactive web application was created with a web-based user interface that allows users to visualize and analyze the NDVI data within the Ukraine territory for specified period of time.
Overall, the methodology used in this study demonstrates the features and advantages of creating an interactive mapping web application for the analysis of space images using Google Earth Engine cartographic web platform. As an example, the study shows how interactive web applications created by GEE can be used to visualize and analyze NDVI data to analyze vegetation growth patterns within a region.

Discussions and results

The Google Earth Engine web platform is a powerful tool for analyzing and visualizing geospatial data of satellite imagery. It could be used for scientific and commercial purposes. It provides a wide range of functionality, including data processing and analysis, cloud-based storage, and visualization tools (Google Earth Engine: Planetary-scale…, 2017). GEE allows users to access and analyze massive amounts of satellite data, such as Landsat, MODIS, and Sentinel-2, which is particularly useful for monitoring land cover changes, analyzing agricultural patterns, and assessing ecosystem health (Exploring the Google Earth Engine…, 2018).

Researchers around the world are actively using Google Earth Engine to study various aspects of the environment. For example, the study (Fernández, Gil, 2022) examines the functional capabilities of the Google Earth Engine web platform for creating a web application for mapping, assessing and monitoring forest areas. The results presented in (Gorelick et al., 2017, Zhao et al., 2021) confirm that the GEE web platform has significant progress in solving global challenges associated with the processing of large volumes of geodata, which allows users to attract a minimum of resources without using supercomputers or specialized equipment. At the same time, the development of GEE does not stand still. The study (Yang et al., 2022) provides a comprehensive overview of the features and challenges of integrating artificial intelligence with GEE, which will further improve and automate the solution of major scientific and social problems, such as climate change and natural disaster risk management. Additionally, based on the following studies (Hamud et al., 2021, Varghese et al., 2021, Jaafa, Mourad, 2021), we can see that GEE can be used for various tasks: to monitor the effects of urbanization on changes in land use, to assess soil moisture, to monitor growth dynamics and to calculate the yield of various cultivated plants necessary areas. As we can see, scientists and researchers around the world are taking advantage of GEE, using it as the main platform for developing their web applications, or as an auxiliary tool for accessing a catalog of space imagery data and tools for their analysis.

To highlight the basic functionality and advantages of the platform, a small web application was created for the analysis and comparison of the NDVI index for the relevant years of the territory of Ukraine. (Fig. 1.)

The GEE web platform provided a range of tools and functionality that helped effectively and quickly create the interactive web application. For example, GEE's data processing capabilities made it possible to analyze and extract NDVI data from satellite imagery, while its visualization tools allowed for the creation of interactive map that could be easily navigated and manipulated by users. The cloud-based storage provided by GEE made it possible to store and access large amounts of data, and the platform's programming interface (integrated development environment) allowed developers to customize and extend the functionality of the web application

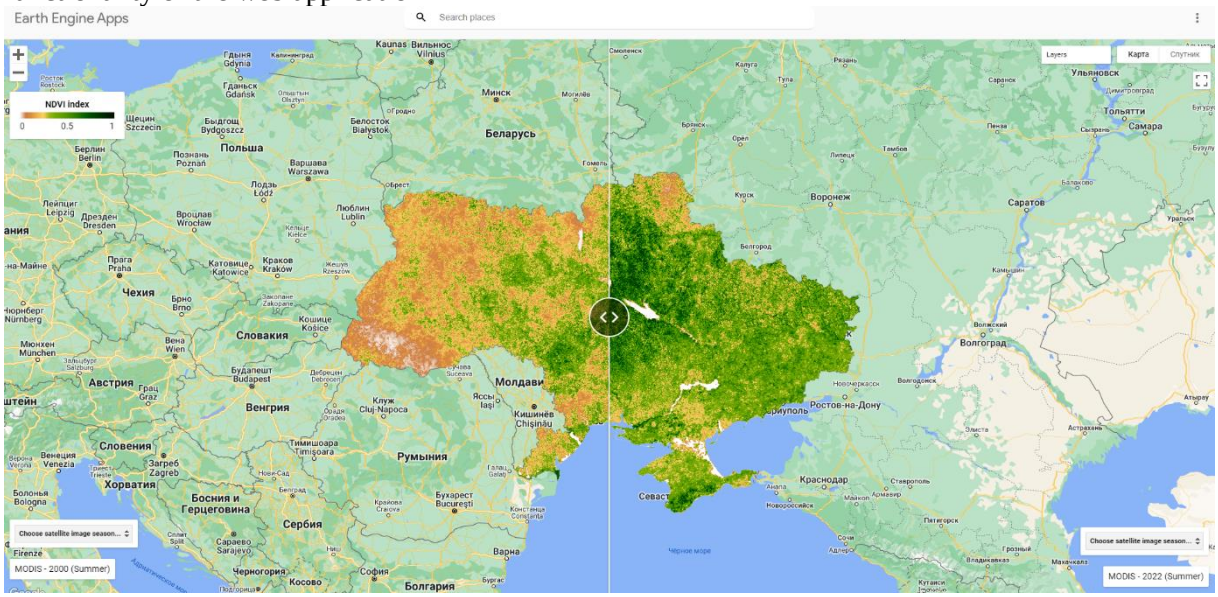

Fig.1. View of web-application for analyzing NDVI within Ukraine territory for the relevant years

The developed application allows users to explore different NDVI values across the Ukraine and compare data for the corresponding seasons of 2000 and 2022 years. The program is available to anyone with the appropriate link (https://work-folder-0.users.earthengine.app/view/ndvisplit-maps) to it and an Internet connection. In addition, if necessary (for example, in the case of crowdsourcing), the developer can provide direct access to the application code through a separate link, which is generated using the GEE functionality. The display of the NDVI index of the territory of Ukraine was reproduced on two separate maps, for the years 2000 and 2022, and it was also possible to obtain NDVI data for different seasons within the specified years, for a more detailed comparison of changes and development of vegetation cover territory of Ukraine over the past 22 years. Between the two separately created maps, an element of the user interface was reproduced - a partition panel that allows dynamically changing the received datasets from one year to another, which in turn allows for interactive analysis of changes in vegetation cover. Added web app legend to match color to NDVI values on maps. Directly, such a web application can be renewed and filled with

various tools or interactive components of the user interface provided by GEE for even more detailed analysis and research of the development of the vegetation cover of the territory of Ukraine based on the values of the NDVI index.

Thanks to the capabilities of the GEE web platform, it is possible to create a web application of this level in a short term, without involving third-party resources for obtaining satellite image data. All data, their processing, visualization and presentation in the form of a ready-made web program are executed and stored on Google servers. This makes the GEE web platform quite convenient, mobile in use and efficient in the development of web applications for the analysis and research of geospatial data of space images.

One of the main features and advantages of the GEE web platform is the built-in web-oriented integrated development environment (IDE), which allows developers to quickly and efficiently develop, test and publish a web application right in the browser, using built-in JavaScript API classes and methods. This IDE is structured around several core components, including the Code Editor, the Catalog, and the Assets (Fig. 2.).

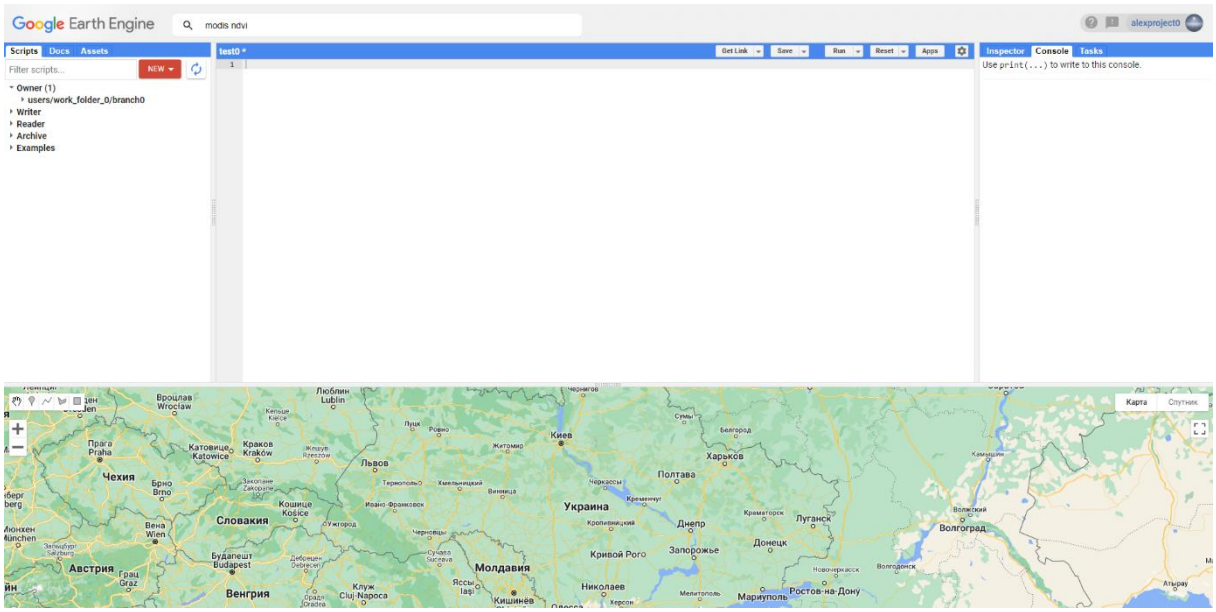

Fig.2. View window Google Earth Engine web-based IDE

The Code Editor is the central hub for writing and executing code on the GEE platform. It allows users to write JavaScript code that can access GEE's vast library of geospatial data and apply various analysis techniques to that data. The Code Editor also includes tools for debugging code and visualizing results. The Catalog is a repository of geospatial data available on the GEE platform. This includes satellite imagery, terrain data, climate data, and more. The Catalog allows users to search for and discover relevant data sets, as well as preview the data and explore its properties. Assets are user-uploaded geospatial data that can be stored and processed on the GEE platform. Users can upload their own data to the platform and access it within their own code, allowing them to perform custom analyses on their own data sets. In addition to these core components of GEE`s IDE, it also includes a number of built-in tools for performing geospatial analysis. These for example include tools for image processing, spatial filtering, machine learning and time-series analysis (Earth Engine Code Editor Overview, 2023).

One of the main advantages of the GEE platform is its scalability. The platform is designed to handle large-scale geospatial analysis tasks, and can process data sets that would be too large to handle using traditional desktop-based analysis tools. The platform also includes powerful tools for parallel processing, allowing users to distribute analysis tasks across multiple machines to speed up processing times.

Overall, GEE provides as a powerful platform for geospatial analysis, which can be applied to a variety of fields, including environmental science, agriculture, forestry, and urban planning. Based on the research of the main characteristic features of the GEE web platform, while creating a web application for the analysis of NDVI, it is worth highlighting the following types of geospatial analysis that can be performed using GEE:

- image classification: GEE can classify images based on spectral signatures and other features, such as texture and shape;
- time-series analysis: GEE can analyze temporal trends in imagery and data, such as changes in land cover, vegetation, or climate variables over time;

- land cover mapping: GEE can create detailed maps of land cover using various image processing techniques;
- vegetation monitoring: GEE can monitor changes in vegetation health, such as the Normalized Difference Vegetation Index (NDVI), and detect areas affected by drought, pests, or other stress factors;
- climate change analysis: GEE can analyze the impacts of climate change on different environmental variables, such as temperature, precipitation, and sea level rise;
- data fusion: GEE can integrate data from multiple sources, such as satellite imagery, weather data, and ground observations, to provide a comprehensive view of the environment.

There are several web platforms that are similar to Google Earth Engine (GEE) in terms of their functionality, for example such as QGIS Cloud and ArcGIS Online. Despite some similarities between these platforms in their functionality, Google Earth Engine has advantages over other web platforms with similar functionality. In general, the following advantages of the GEE web platform for the analysis of space images over other web platforms with similar functionality should be highlighted (Google Earth Engine as a planetary-scale platform…, 2023):

- large data repository: Google Earth Engine provides access to an extensive collection of satellite imagery and other geospatial data, including Landsat, MODIS, Sentinel, and more. This vast data repository allows users to perform complex geospatial analysis, such as time-series analysis and change detection, on a global scale.
- scalability: Google Earth Engine is built on Google's cloud infrastructure, which allows for the processing of large amounts of data in a short amount of time. This scalability makes it ideal for processing and analyzing large datasets, which is often a challenge for other web platforms.
- code editor: GEE includes a code editor as part of IDE that allows users to write, test, and run JavaScript code directly in the browser. The code editor provides a range of features such as autocompletion, syntax highlighting, and debugging tools.
- JavaScript API: GEE provides a JavaScript API that allows users to interactively explore and visualize geospatial data on a map. Users can also create custom applications and workflows using the API.
- Python API: in addition to the JavaScript API, GEE also provides a Python API for users who prefer to work in a Python environment. The Python API allows users to access and manipulate GEE data using familiar Python libraries such as NumPy and Pandas.
- machine learning capabilities: Google Earth Engine has built-in machine learning algorithms that can be used for tasks such as object detection, image classification, and land cover mapping. This makes it possible to automate many aspects of geospatial analysis and increase the efficiency of data processing.
- open access: Google Earth Engine is freely accessible to researchers, scientists, and developers around the world. This makes it possible for anyone with an internet connection to perform complex geospatial analysis and contribute to global research efforts.

These advantages and features make GEE an ideal platform for large-scale geospatial data analysis and visualization, as well as for developing customized applications for specific environmental or social challenges.

Conclusions and proposals

Web platforms for creating mapping web applications for analyzing satellite imagery have revolutionized the way we interact with geospatial data. These platforms allow users to access and process large amounts of satellite imagery, creating maps and visualizations that can be used to monitor changes in land cover, vegetation, weather patterns, and other environmental factors.

One of the most powerful web platforms for creating mapping web applications for analyzing satellite imagery is Google Earth Engine (GEE). GEE is a cloud-based platform that provides access to a vast amount of satellite imagery and geospatial data, including historical and real-time data from Landsat, Sentinel, MODIS, and other satellites. GEE also provides a variety of tools and functions for processing and analyzing this data, including machine learning algorithms and image processing techniques.

To highlight the main advantages and characteristic features of the GEE web platform, an interactive web application was created for the analysis and comparison of the NDVI index of the territory of Ukraine. According to the results of the reproduced web application, in general, we can observe a decrease in the value of NDVI for 20 years. However, at the same time, the average value of NDVI for the summer of 2022 in some regions of Ukraine exceeds the value of 2000. This may be related to certain climatic anomalies, such as an increase in the amount and frequency of precipitation during the corresponding period of time, which led to a deterioration in the definition and calculation of the NDVI value.

The following main advantages of GEE can be distinguished: built-in web-oriented integrated development environment, which helps developers get comprehensive facilities for web-application development in the browser, withouth using any additional software; cloud-based architecture with ability to handle large-scale data processing and analysis; providing real-time data processing and analysis, which allows users to monitor changes in environmental factors in near real-time; user-friendly interface that allows users to create and share mapping web applications with ease; provides a variety of templates and widgets that users can use to create custom mapping applications, which can be shared with other users or embedded on websites.

Overall, GEE is one of the most powerful and versatile web platforms for creating mapping web applications for analyzing satellite imagery for researchers, scie ntists, and anyone else interested in geospatial data analysis. Its ability to handle large-scale data processing and analysis, real-time data processing, user-friendly interface, and constant evolution make it an ideal platform for anyone interested in analyzing geospatial data from satellite images.

References

1. Бондаренко Е. Л. (2021) Веб-картографування (Web-Mapping), 82 с. (in Ukrainian)
2. Kraak M. J. (2020) Cartography: visualization of geospatial data, 4th Edition., CRC Press, 261.
3. S. Krakovskyi; T. Kurach (2022) Classification of interactive functions of the electronic atlas: logical scheme and outcomes, Ukrainian geographical journal, No. 3: 55-65.
4. Krol K. (2020) Evolution of online mapping: from web 1.0 to web 6.0. Geomatics, Landmanagement and Landscape, No. 1. P. 33–51. (http://dx.doi.org/10.15576/GLL/2020.1.33)
5. Roth R. E. (2013) Interactive maps: What we know and what we need to know. Journal of Spatial Information Science, № 6., P. 59–115
6. Google Earth Engine. Platform overview. (https://earthengine.google.com/platform/) [2023-03-10]
7. Huete, A. (1988) A soil-adjusted vegetation index (SAVI). Remote Sensing of Environment, 25(3), 295–309. (https://doi.org/10.1016/0034-4257(88)90106-x)
8. MODIS/Terra Vegetation Indices 16-Day L3 Global 500m SIN Grid V006. (https://developers.google.com/earth-engine/datasets/catalog/MODIS_MCD43A4_006_NDVI)
9. Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017) Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sensing of Environment, 202, 18-27. (https://doi.org/10.1016/j.rse.2017.06.031)
10. Singh, A., & Harrison, P. J. (2018) Exploring the Google Earth Engine for Sentinel-2 satellite data processing. International journal of applied earth observation and geoinformation, 68, 260-277.
11. Fernández-Urrutia M., Gil A. (2022) Resource Communication: ForestAz - Using Google Earth Engine and Sentinel data for forest monitoring in the Azores Islands (Portugal). Forest Systems, 31(2), eRC01. (https://doi.org/10.5424/fs/2022312-18929)
12. Zhao Q., YuL., Li X., Peng D., Zhang Y., Gong, P. (2021) Progress and Trends in the Application of Google Earth and Google Earth Engine. Remote Sens., № 13. – 3778 p. (https://doi.org/10.3390/rs13183778)
13. Yang L., Driscol J., Sarigai S., Wu Q., Chen H., D. Lippitt C. (2022) Google Earth Engine and Artificial Intelligence (AI): A Comprehensive Review. Remote Sens., № 14, 3253 p. (https://doi.org/10.3390/rs14143253)
14. A M Hamud, H Z M Shafri, N S N Shaharum (2021) Monitoring Urban Expansion And Land Use/Land Cover Changes In Banadir, Somalia Using Google Earth Engine (GEE). Earth and Environmental Science, 767. (http://dx.doi.org/10.1088/1755-1315/767/1/012041)
15. Varghese D., Radulović M., Stojković S. Crnojević V. (2021) Reviewing the Potential of Sentinel-2 in Assessing the Drought. Remote Sens., № 13(17), 3355 p. (https://doi.org/10.3390/rs13173355)
16. Jaafar H.,. Mourad R. (2021) GYMEE: A Global Field-Scale Crop Yield and ET Mapper in Google Earth Engine Based on Landsat, Weather, and Soil Data. Remote Sens., № 13(4), 773 p. (https://doi.org/10.3390/rs13040773)
17. Earth Engine Code Editor Overview. (https://developers.google.com/earth-engine/guides/playground) [2023-03-10]
18. Google Earth Engine as a planetary-scale platform for Earth science data & analysis, from (https://developers.google.com/earth-engine/datasets/) [2023-03-10]

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