# Educational Aspects of Using Google Earth Engine: Training Course for Educators by the Junior Academy of Sciences of Ukraine

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**Abstract**

Google Earth Engine (GEE) is a cloud-based geoinformation platform that enables the processing of satellite data, offering substantial computing capabilities. This publication addresses the potential applications of the Google Earth Engine platform in the field of education, as well as the prerequisites and conditions for the organisation of the course for educators. The stages involved in organising the course, along with the topics and tools that formed the basis for the lectures and practical classes, are described in detail. The efficacy of the developed course is evaluated based on the responses of the participants obtained through questionnaires and a final interview. It is important to note that the application of cloud platforms for the processing of large volumes of geodata represents a current global trend, particularly within the field of education. Consequently, the development and implementation of the course for educators that is aligned with this trend constitutes a significant contribution to the advancement of innovative educational practices in Ukraine.

## 1. Introduction

The field of Earth sciences is undergoing a period of rapid transformation as a consequence of global environmental challenges and the fast-paced development of Earth observation technologies (Zhao et al., 2021). Therefore, new tools are needed to monitor, measure, analyse, evaluate, and model observational data (Fediv & Davybida, 2015; Hordiienko et al., 2023; Trevisani & Omodeo, 2021). The use of these tools and platforms in various applications, including remote sensing, is rapidly evolving.

Google Earth Engine (GEE) was launched in 2010 as a cloud computing platform with substantial computational capabilities (Amani et al., 2020). GEE combines a multi-petabyte catalogue of satellite imagery and geospatial datasets with planetary-scale analysis capabilities, enabling the assessment of environmental activities at high spatial and temporal resolution (Pérez-Cutillas et al., 2023).

GEE facilitates the generation and examination of geodata, which can prove beneficial for those engaged in geographical and other academic pursuits. GEE's functionality enables educators and students to investigate tangible data pertinent to environmental concerns and other pivotal subjects (Cardille et al., 2023). Furthermore, GEE offers data visualisation tools that facilitate the observation and comprehension of changes on Earth. In addition to its applications in the fields of geography and environmental studies, GEE can also be employed in the investigation of mathematical, physical, urban, historical, and computer science subjects. This is made possible by the fact that GEE utilises extensive data sets and offers a range of tools for analysing and processing such data. In conclusion, GEE is an effective and valuable tool for studying Earth, the environment, and data science in education. It allows educators and students alike to gain access to a vast array of geographic data and the tools necessary for its processing and analysis (Demirci et al., 2013; Franceschini & Ali, 2022). Furthermore, GEE offers the chance to investigate a range of subjects related to climate change, agricultural production, forestry, geography, and other areas of science (Gorelick et al., 2017; Callejas et al., 2023).

Since its official launch in 2010, GEE has quickly become a cornerstone of the global remote sensing community. The platform's powerful geospatial processing capabilities have spurred a significant increase in scientific research. Results of bibliometric analysis of 1,995 peer-reviewed articles indexed in the Scopus database up to December 2022, published in (Pham-Duc et al., 2023), revealed a rapid growth in GEE-related publications, with nearly 85% published in the last three years. The analysis highlighted the widespread use of GEE in three main fields: earth and planetary sciences, environmental sciences, and agricultural and biological sciences. Similarly, a steady increase in scientific research on GEE since its release, with a diverse range of spatial analysis applications across multiple domains, was described in (Pérez-Cutillas et al., 2023). The applications were categorised into key areas: agriculture, climate change, natural hazards, forestry, water resources, soils, urban studies, land use, etc. These findings underscore the growing importance and versatility of GEE in supporting diverse scientific research and applications worldwide.

Aware of the significant demand for new knowledge to work with satellite monitoring data and, accordingly, advanced training courses, especially now that Google Earth Engine has become popular, the GIS and Remote Sensing Laboratory of the National Centre "Junior Academy of Sciences of Ukraine" identified a need for educational publications and courses for educators to gain proficiency in the capabilities of modern remote sensing technologies based on cloud platforms.

The purpose of this article is to present the findings of a teacher training course on the application of the GEE platform for satellite data processing. The training course has been designed to enhance teachers' practical knowledge and skills for use in the

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classroom by exploring the use of cloud technologies to analyse geospatial data and investigate practical problems in the environmental and earth sciences field. Integrating the acquired knowledge in Geoinformation Systems (GIS) and remote sensing into educational practice is facilitated by the studied educational methodology in practice.

In order to assess the effectiveness and practical impact of the educational event, the authors set out a series of objectives. These are as follows:

1. To assess the relevance of education in the field of GIS and remote sensing and to determine the benefits of learning and using the Google Earth Engine cloud platform.
2. To outline the methodology and organisational structure of the teacher training course developed by the GIS and Remote Sensing Laboratory of the National Centre of the Junior Academy of Sciences of Ukraine.
3. To examine the outcomes of the course in relation to the pre-course survey, post-course survey, and the research projects conducted by the participants.
4. To establish the viability of further developing and scaling the educational course for teachers to facilitate the effective integration of the programme into the educational process.

## 2. Theory and methods

Nowadays, considering the fast development of technologies of artificial intelligence (AI), computing systems, and, at the same time, the growing threat of climate change and military conflicts, the importance of GIS and Remote Sensing education can hardly be doubted (Gorelick et al., 2017; Zhao et al., 2021; Trevisani & Omodeo, 2021). The current state of global challenges forms the predicaments of conditions of the professional and private environment in which the next generations will live (Longley et al., 2015).

Geospatial education aims to impart practical skills that students can apply in their professional and/or scientific careers (Lee & Bednarz, 2009). The GIS and Remote Sensing tools are widely used in various fields such as Environmental Sciences, Urban Planning and Design, disaster management, and the military sector (Demirci et al., 2013; Franceschini & Ali, 2022). Therefore, learning to use these tools in practice can give young people a chance and perspective in realising their achievements (Duro, Franklin, & Dubé, 2012).

While learning the skills in the GIS and Remote Sensing field has immense value, there are specific factors in the education of this sphere that need to be considered. First of all, fast technological development poses a significant challenge for educational organisations; they must adapt their curricula and learning approaches as new updates in the field arise (Wegmann et al., 2020). For example, the integration of AI tools and machine learning into GIS software – such as the Google Earth Engine platform and others – is changing the perspective on how we analyse geospatial data and the learning principles of using such programs (Gorelick et al., 2017; Zhao et al., 2021).

Secondly, with the rapid advancement of GIS and the Remote Sensing field comes the problem of the "skill gap" and the need for accessible, up-to-date learning materials. This course is designed to bridge this gap, especially for educators in Earth and Natural Sciences at the K-12 school level, since teachers in secondary schools often have limited access to modern materials and resources compared to university/college teaching staff.

Thirdly, data access and availability have been significant obstacles to creating practical learning materials in the GIS and Remote Sensing sphere. Major institutions such as ESA and NASA have provided substantial public data catalogues and services on Earth observation – through initiatives such as Copernicus and NASA Earthdata – but access to high-resolution images of our planet remains either restricted or costly, thereby limiting opportunities for high-quality research and educational applications (Dannwolf et al., 2020).

Comparing the cloud platform GEE to the aforementioned services of ESA and NASA, it offers significant advantages for educational practice. There is free access to the most widely used and popular datasets (Sentinel, Landsat, MODIS, etc.), as well as JavaScript and Python APIs for rapid data extraction and analysis, services for creating multiple types of infographics and interactive apps, and integration of machine learning algorithms for complex and prompt research (Gorelick et al., 2017; Franceschini & Ali, 2022; Longley et al., 2015; Duro et al., 2012). All these features are free for academic research and educational use and are suitable for conducting interactive classes in schools tailored to the level of students' skills (Wegmann et al., 2020).

It is important to note that GEE developers support educational initiatives at both the grassroots and systemic levels that promote learning and the popularisation of the platform by publishing open-access training materials. This initiative is designed to familiarise interested users with the capabilities of GEE for processing and analysing geospatial data (Gorelick et al., 2017; Oshiro, 2018; Fediv & Davybida, 2015).

A prevalent educational methodology employed is project-based learning (PBL), a pedagogical approach emphasising the real-world application of knowledge and skills in a hands-on, problem-solving environment (Oshiro, 2018). This approach has gained significant traction in both out-of-school and non-formal educational settings, creating an engaging environment for learners to explore practical problems and challenges and apply their knowledge and skills to develop solutions (Lee & Bednarz, 2009). The project-based learning method is particularly well-suited to developing practical skills – such as satellite image processing and interpretation – as it reinforces the theoretical concepts acquired through other learning methods.

However, in order to scale up areas of learning in GIS and Remote Sensing, it is advisable to conduct specialised training for teachers. Enhancing educators' competencies in acquiring and developing practical skills and techniques leads to diversifying lessons for students, thereby addressing the educational needs essential for professional fulfilment (Trevisani & Omodeo, 2021).

One of such training event for teachers, which is based on the project-based learning method and organised by the GIS and Remote Sensing Laboratory of the National Centre of the Academy of Sciences of Ukraine, is "Processing and Analysis of Satellite Data on the Google Earth Engine Platform". The following discussion will address this training event's organisational and content components in more detail.

The course for GEE educators included an introduction to the methods of writing scripts using the JavaScript programming language and an overview of the various ways in which data in GEE can be visualised, including creating animations and statistical graphs. Additionally, the course covered the development of user interfaces and interactive applications. In particular, the participants engaged in discourse about resolving practical issues connected to alterations in forest cover, water bodies, anthropogenic landscapes, vegetation indices, and atmospheric monitoring.

The organisation of the special course consisted of the following elements:

1. The dissemination of information letters regarding the course's organisation to educators.
2. The administration of tests to ascertain the initial level of knowledge of registered participants.
3. The direct conduct of the course's intensive theoretical and practical training.

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4. A final conference, during which course participants presented their independent projects, demonstrating the skills acquired.
5. The administration of final tests to evaluate the course's effectiveness and assess the change in remote sensing knowledge.

Six months later, interviews were conducted with the participants to ascertain the extent to which the acquired knowledge was effectively integrated into the educational process by those who had undergone advanced training.

In addition, educational and methodological support was developed, including the manual 'Remote Sensing of the Earth: Processing and Analysis of Satellite Images on the Google Earth Engine Platform' and a workbook on 'Fundamentals of Remote Sensing of the Earth'. Part 3 (Babiichuk, et al. 2023). The manual facilitated the organisation of high-quality educational courses for educators (Fig. 1) and was endorsed for use in the educational process on the official website of Google Earth Engine. In addition to the written instructions provided in the workbook, a brief video tutorial was prepared for each practical task and made available on the Laboratory's YouTube channel (Fig. 2).

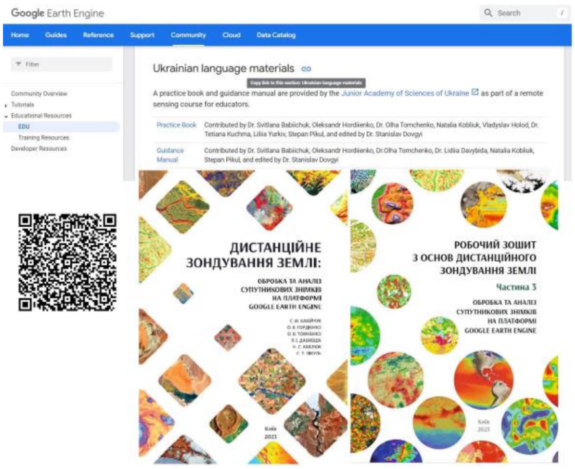


Figure 1. The appearance of textbooks developed for GEE courses (Google Developers, n.d.)

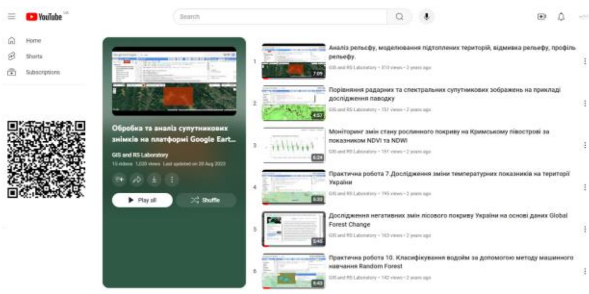

Figure 2. Video instructions for completing practical tasks of the course on the YouTube channel of the GIS and RS Laboratory (GIS and RS Laboratory, n.d.)

The course was structured around ten online lessons comprising both theoretical and practical components. Each topic was initially addressed for an hour through a lecture format, accompanied by a demonstration of the training material in the form of a presentation. Subsequently, the subsequent hour was dedicated to an online demonstration of a practical task relevant to the topic under discussion. The participants were required to complete a series of practical exercises from the workbook, which included additional tasks of a descriptive or research nature. These results were to be submitted to the course organisers via the appropriate Google forms, as detailed in the student guide. The quality of the work performed was to be assessed by the organisers.

## 3. Results and outcomes

The category of course participants encompasses pedagogical personnel from both out-of-school and general secondary educational institutions, including those occupying leadership roles in science clubs and those engaged in the instruction of natural sciences, in addition to professors and associate professors from higher education institutions.

This article presents a comparative analysis of the outcomes of the special training courses "Processing and analysis of satellite images on the Google Earth Engine platform" conducted by the GIS and Remote Sensing Laboratory of the National Centre “Junior Academy of Sciences of Ukraine” in 2024 and 2025.

The 2025 course saw a significant increase in engagement compared to the previous year. While 31 participants had pre-registered in 2024, this number more than doubled to 67 in 2025. The number of educators who completed the training also increased from 18 (2024) to 27 (2025), and the geographical reach expanded from 11 to 21 regions of Ukraine.

Regarding professional background, geography was the prevailing field among participants in both years, with 53.2% in 2024 and 47.7% in 2025. However, the 2025 class showed greater disciplinary diversity: the share of ecology teachers increased from 6.7% to 14.9%, computer science from 3.3% to 10.4%, and physics remained relatively stable (3.3% in 2024, 3% in 2025). It is also noteworthy that the percentage of participants representing higher education institutions nearly doubled, rising from 23.5% in 2024 to 44.8% in 2025. The specialisations of these participants encompassed geography, geology, geoinformatics, geodesy and land management, thereby signifying an expanding academic interest in earth observation technologies.

A shift in the urban/rural distribution of participants was also observed. In 2024, 64% of attendees were from urban areas; in 2025, this figure rose to 80.6%. Conversely, there was a marginal decline in the participation of individuals hailing from small villages, from 26% to 19.4%. This decline could be attributed to the increased accessibility of training opportunities for urban educators, primarily facilitated by advancements in information flow and internet connectivity.

A comparison of participants' prior familiarity with GEE in 2024 and 2025 reveals a shift in the composition of the training groups. In 2024, approximately half of the participants (51.6%) had previously engaged with GEE, while the remaining 48.4% were new to the platform. On the other hand, the 2025 course had a higher proportion of beginners, with 68.7% of participants having no background and only 31.3% reporting previous engagement. This shift indicates an expanding interest in the course among educators without prior experience with GEE, highlighting the growing reach, interest and accessibility of the course.

Post-course surveys revealed that the majority of participants – 70% in 2024 and an even higher 88% in 2025 – cited a lack of formal training in GIS, remote sensing or programming as the main barrier to mastering GEE tools. Despite this, all participants in both years successfully completed their assignments and reported high levels of satisfaction with their learning outcomes, underlining the effectiveness and relevance of the course content.

Individual projects and their presentation were an obligatory part of the course, with participants independently selecting their study topics and objects. Figure 3 presents the distribution of individual project study areas among participants in 2024 and 2025, showing the number and percentage of projects focused on different topics. Generally, the chosen topics align with relevant international studies using GEE (Pham-Duc et al., 2023; Pérez-

Cutillas et al., 2023). Also, the data indicates shifts in the primary focus of the research, with climate change and war impact gaining prominence in 2025.

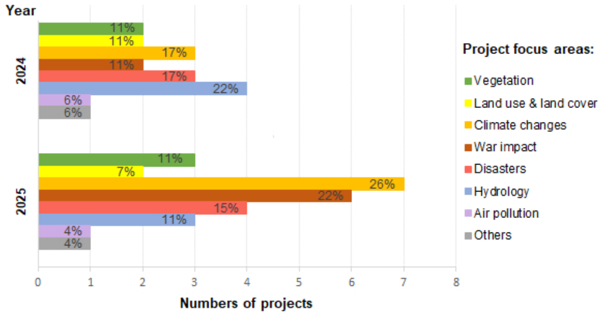


Figure 3. Trends in the individual project study areas among course participants (2024-2025)

Lubomyra Shevchuk, a methodologist and the Head of the GIS and Remote Sensing Science Club at Lviv, assessed the impact of industrial facilities on the state of atmospheric air in Ukraine for the period from 2018 to 2024, using the analysis of satellite images on the GEE platform.
Utilising data on the leading pollutant indicators obtained by the Sentinel 5P satellite, the study proceeded to analyse the level of air pollution with $NO_2$ and $SO_2$ compounds. The investigation further delved into the impact of stationary sources on air quality. The contribution of coal-fired power plants to air quality was determined. Regions with elevated nitrogen dioxide ($NO_2$) concentrations include Donetsk, Zaporizhzhya, Kharkiv, the Dnipro region, and the Kyiv area. Conversely, average levels of $NO_2$ concentration are observed in the Ivano-Frankivsk and Lviv regions. The increased concentration of $NO_2$ levels is significantly correlated with the distribution of cities where coal-fired power plants are located.
The project analyses the pollution levels of sulphur dioxide (SO2), finding that the distribution of $SO_2$ concentrations varies by region. High and medium levels of $SO_2$ are observed near large cities in the eastern part of Ukraine, where heavy industry is concentrated. Furthermore, a downward trend in $SO_2$ air pollution levels is observed from 2018 to 2024.

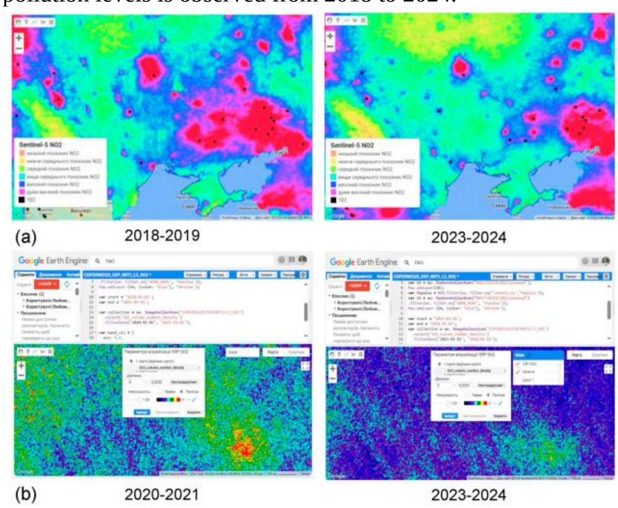


Figure 4. Results of the final project of the study of the impact of industrial facilities on the state of atmospheric air in Ukraine. (a) Levels of atmospheric air pollution with $SO_2$, (b) Study of the impact of industrial facilities on the state of atmospheric air in Ukraine.

Halyna Paskhal, deputy director of the lyceum for educational work from the Kirovohrad region, conducted her research using the Google Earth Engine platform and the LSIB 2017 international borders dataset. The TerraClimate dataset of global monthly climate indicators and the water balance of the Earth's surface for 1970 was filtered, and visualisation parameters were added and subsequently displayed on the map. The creation of a graph displaying the minimum and maximum surface temperature for the territory for 2020-2024 was also undertaken.
Utilising the GEE platform and the knowledge acquired during the course, a study of climate indicators in the floodplain area of the lower Danube was conducted, and a direct dependence of lake area and soil moisture on precipitation and temperature was found.
Significant precipitation in 2021 and a mild summer contributed to both the accumulation of soil moisture and an increase in the lake area.
However, in 2022, the area of lakes underwent a significant decrease, attributable to elevated evaporation from the surface, a consequence of the hot summer and abnormally low precipitation.
The increase in precipitation in 2023 led to an expansion in the lake area, whereas soil moisture levels remained stagnant due to rising temperatures and enhanced evaporation.

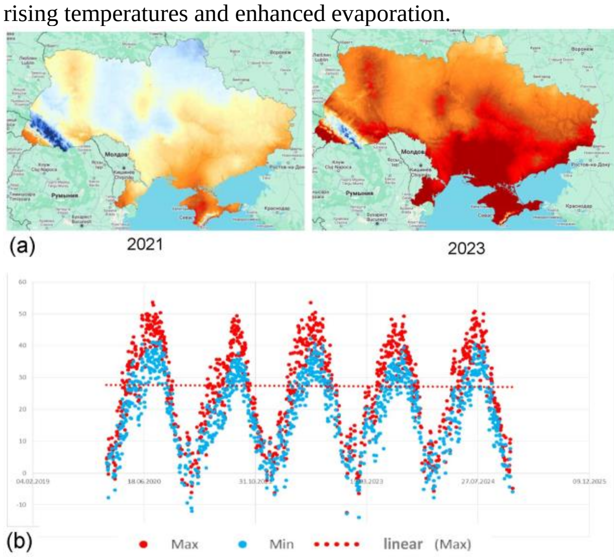


Figure 5. Results of the final project to identify the dependence of the area of the Danube floodplain lakes on climate indicators in 2020-2024. (a) The temperature in the area of Ukraine in 2021 and 2023 (b) Chart of minimum and maximum values for surface temperature based on MODIS images in the area of Lake Yalpug for 2020-2024.

Mykola Pasichnyk, PhD in Geography, Associate Professor at the Department of Geography of Ukraine and Regional Studies of Yuriy Fedkovych Chernivtsi National University, chose as the study objects the Pacific, Atlantic, and Indian Oceans that were 'transferred' to the Southern Ocean and calculated its area. Colour layers were created to represent these shares.
The project's objective was twofold: firstly, to ascertain the boundaries and area of the Southern Ocean, and secondly, to assess changes in the ratio of the world's oceans following this process.
Utilising the GEE tools, the area of the Southern Ocean was calculated to be 21.9 million $km^2$.

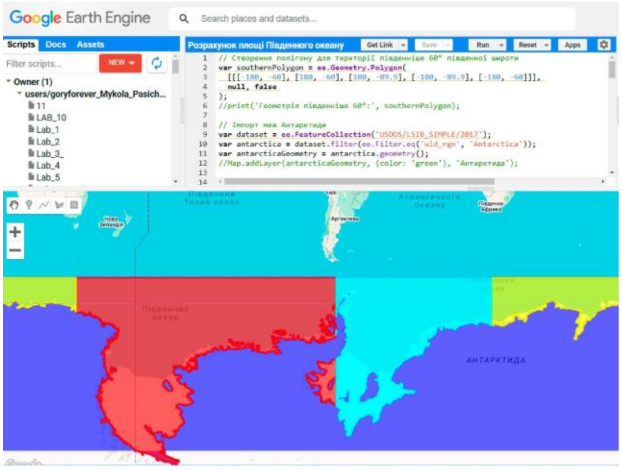


Figure 6. Results of the final project to determine the area of the Southern Ocean

Tetyana Kupach, PhD in Geography, Associate Professor at the Department of Geography of Ukraine of Taras Shevchenko National University of Kyiv, studied flooding processes in the Prut River floodplain with SAR data and the GEE platform.
The creation of water masks is predicated on calculations derived from two Sentinel-1 channels (VV, VH). VV (Vertical Return, Vertical Receive), VH (Vertical Return, Horizontal Receive). Water can be easily identified in the images (i.e., closer to black) in this colour form.
The acquisition of competencies in utilising diverse remote sensing data sets within the GEE platform facilitates the analysis of the hydrological situation in areas susceptible to flooding and groundwater inundation.

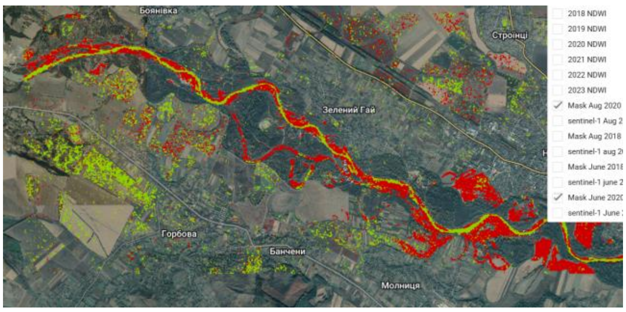


Figure 7. Results of the final project to study flooding processes in the Prut River floodplain using water masks

Olena Lisovets, PhD in Biology, Associate Professor at the Department of Biodiversity and Ecology of Oles Honchar Dnipro National University, Head of the Plant Physiology Science Club of Dnipro Division of the Junior Academy of Sciences of Ukraine, investigated the topographical features of the area, which were subsequently presented in a comprehensible format. A visualisation of the relief profile, encompassing all the primary biotopes within the reserve, was created. The detailed representation of the relief provides a foundation for future research, including hydrological analysis and the study of the impact of relief on biodiversity. The modelling of the rise and fall of water levels is significant for predicting changes in the reserve's ecosystems. This modelling facilitates the estimation of the impact of fluctuations in water levels on the distribution of habitats, flora and fauna, and the ecological balance of the territory.

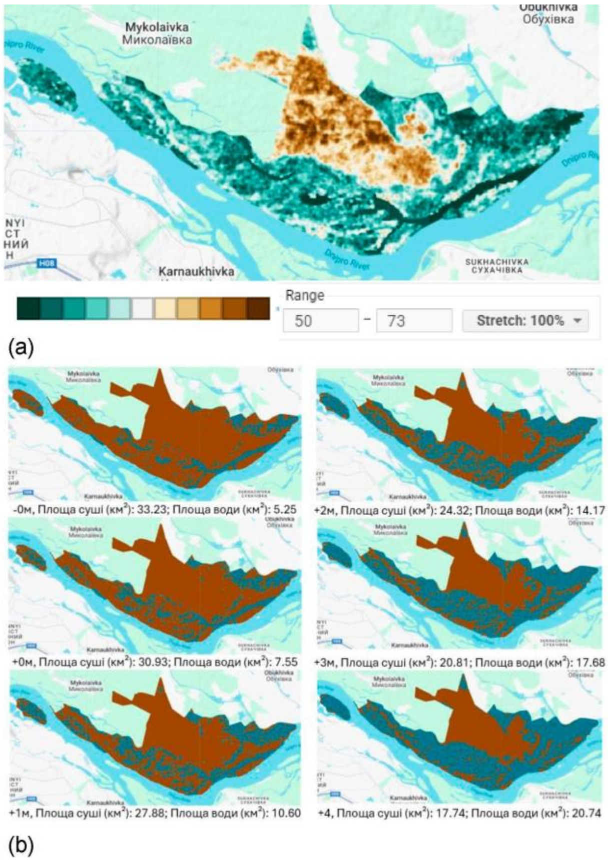


Figure 8. Results of the final project of the study of climate indicators and the consequences of their possible changes in the territory of the Dnipro-Oril Nature Reserve. (a) Visual representation of the digital terrain model for the territory of the Dnipro-Oril Nature Reserve, (b) Modelling possible changes in the ratio of land to water on the territory of the Dnipro-Oril Nature Reserve under conditions of rising water levels

Valentyna Vasilchuk, a geography teacher at Netishyn Gymnasium 'Harmony', created animated images of vegetation index time series by analysing the dynamics of vegetation cover in the territory of Netishyn district from 2014 to 2020.

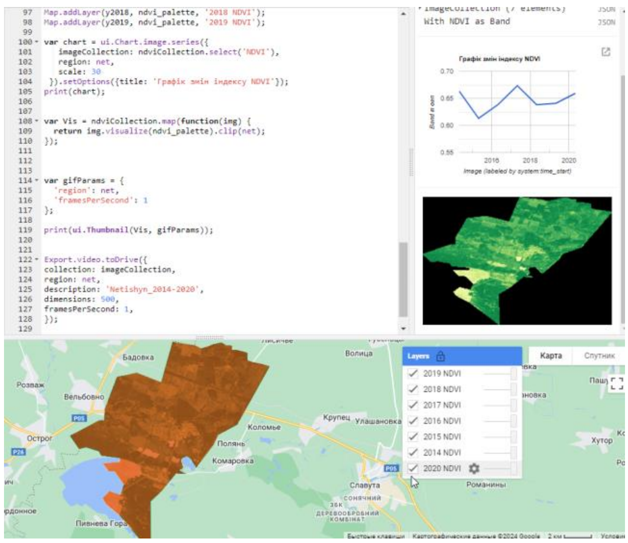


Figure 9. Results of the final project of the study of landscape change in the Netishyn district with elements of forecasting

Olena Karpenko, Head of the GIS and Remote Sensing Science Club and a geography, biology, and natural history teacher at the Lyceum in Kyiv, determined the change in the reservoir area indicators on the Crimean peninsula for 2017 and 2023. The geometry area of interest contour was created, and two new land and lake layers were added. Radar data was incorporated into the map in three channels, with minimum and maximum values.
The study monitored the dynamics of changes in the area of the Mizhhirya reservoir. The selection of Sentinel-1 radar data and Sentinel-2 optical data was informed by the knowledge gained from this study. The reservoir area was calculated for 2017 and 2023. The area was measured at 417,055 $m^2$ in 2017 and 115,061 $m^2$ in 2023, representing a 27% decrease from 2017.
The application of remote sensing made it possible to monitor inaccessible areas for field research. A notable example of such a territory is the Crimean peninsula, which was annexed in March 2014 by the Russian Federation.

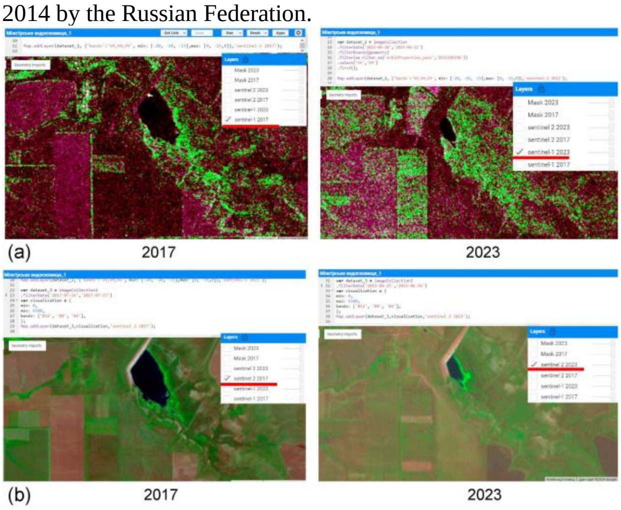


Figure 10. Results of the final project on monitoring the dynamics of changes in the area of the Mizhhirya reservoir on the Crimean peninsula. (a) Visualisation of Sentinel-1 satellite image for 2017 and 2023, (b) Visualisation of Sentinel-2 satellite image for 2017 and 2023

## 4. Conclusions

The implementation of the teacher training course "Processing and Analysis of Satellite Data on the Google Earth Engine Platform", organised by the GIS and Remote Sensing Laboratory of the National Centre "Junior Academy of Sciences of Ukraine", demonstrates the growing relevance and applicability of cloud-based geospatial technologies in education. The course was designed to address the growing demand for accessible, practice-oriented training in GIS and remote sensing.
The training course successfully provided educators with the theoretical knowledge and practical skills necessary for integrating remote sensing and geodata analysis into their teaching practice. A particular emphasis was placed on using the GEE as an educational tool due to its free access, high functionality and scalability. The course content was designed to address current global and national challenges, including climate change, the impact of war, urban development, pollution, etc. Participants created individual projects using their newly acquired theoretical knowledge and practical skills to solve real-world problems with satellite data, thereby enhancing the relevance of their teaching.
A comparative analysis of the 2024 and 2025 courses indicates significant participation expansion, both in quantity and diversity. Specifically, the number of participants doubled, the geographical reach expanded, and the representation of educators from higher education institutions nearly doubled. Of particular note is the observation that the 2025 class had a higher proportion of educators with no previous experience in GEE, indicating the effectiveness of the course in reaching beginners and broadening the entry point to GIS and remote sensing education.
Six months after the course had concluded, a follow-up survey was conducted of the participants in the form of interviews. The objective of this follow-up survey was to determine and analyse the extent to which the participants could utilise the knowledge they had acquired throughout the learning process. The results of the interviews indicated that 90% of the participants would recommend their colleagues and friends to participate in the special course in the future.
Consequently, in view of the demonstrable efficacy of the training, it is recommended that the course be conducted on an annual basis in order to ensure consistent knowledge transfer and skill development among educators. To further enhance integration and scalability, particular attention must be paid to strengthening the network of regional science clubs on GIS and remote sensing.

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