IMPLEMENTATION OF SCIENCE EDUCATION PRINCIPLES AT THE JUNIOR ACADEMY OF SCIENCES OF UKRAINE USING REMOTE SENSING DATA

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There is a global trend towards information-based society. Increase in the amount of information, development of modern geo-information technologies and extension of remote sensing capabilities open up new horizons in education. This article reviews implementation of students' projects involving the use of satellite data as a new line of science education activities of the Junior Academy of Sciences of Ukraine (JASU) within the context of the challenges driven by the formation of global information society. The article gives examples of implemented students' projects, in particular on the study of Dnipro River islands changes over 70 years, with the aim to draw attention to the issue of conservation of natural landscape flood-plains of Dnipro River. It also describes a project on the study of historic mapping of Kyiv Pechersk Lavra, one of UNESCO World Heritage Sites, from the perspective of identification of illegal construction sites with scandalous "skyscrapers" on the adjoining territory. The project on evaluation of wood processing potential of Kyiv

Region aimed at the development of sustainable forest management by analyzing the volumes of wood wastes from logging. The results of the projects are indicative of the students' interest in the new line of studies and the necessity of conducting training seminars for teachers in order to promote GIS use in Geography.

Key words: science education, remote sensing, GIS, Junior Academy of Sciences of Ukraine, pedagogical concept.

Introduction

Our world faces massive digital transformations. We automate processes, and measure all moving and changing objects from satellites and unmanned aircrafts. The volumes of space monitoring data are rapidly growing; therefore there is a great need in the development of new mechanisms for its processing and application. Satellites and unmanned aircrafts deliver data in real-time mode and in different formats. This constant information gain and open databases create favorable conditions for innovations.

Development of technical means, high frequency, efficiency and accessibility of satellite imagery make it possible to perform tasks on a PC that could have been previously accomplished on expensive professional equipment only. Earth observation data are becoming the principal moving force of the so-called Forth Industrial Revolution – the era of Big Data analytics. The uniqueness of geospatial data lies in the fact that it is a tool allowing for integration and analysis of time and space. It is geospatial data revolution that gives us a comprehensive picture of the world and enables us to find more effective solutions to problems. Application of Earth observation data for education leads to a new round of informatization of natural sciences, which is one of the principles of science education.

Science Education as a Means of Promoting Science

The global coordination of science education is currently performed, among others, by the United Nations Educational, Scientific and Cultural Organization (UNESCO). In 1972, UNESCO supported the creation of the International Council of Associations for Science Education (ICASE), which aim is to extend and improve science education throughout the world. ICASE is a vast network of science teacher associations, institutions, foundations and companies from over 75 countries, including Ukraine, working together to promote science around the world.

Working group "Science Education" within All European Academies deals with the issues of science education. For many years now, Ukraine has been represented in the Working Group by the President of the JASU, Academician, Stanislav Dovgyi, and Director of the Institute of Gifted Child of the National Academy of Pedagogical Sciences of Ukraine, Maksym Galchenko. Having studied the efforts of the JASU, at the end of 2017, UNESCO recognized the organisation as the leader in the science education activities in Eastern Europe. The 39th session of UNESCO's General Conference adopted a resolution to create UNESCO Centre

vat the JASU [UNESCO, 2018].

Implementation of science education principles in all 27 regions of Ukraine is one of the main pedagogical concepts used by the JASU. Currently, over 250 000 students participate in the JASU extracurricular research activities in 64 science fields [JASU, 2018].

Science education as a pedagogical concept aims at the training of new generation of scientists based on special methodologies, methods, forms of teaching and educational content. Educator is not a sole source of information, who transfers it to students; instead, educator is a mentor, who supervises the whole complex of students' researches. Such training should eventually lead to the development of a new way of thinking in students, according to which science is perceived as a tool or instrument to deal with real-world problems of certain person, family, city, country or global population.

According to the World Economic Forum data, by 2020, the ability to take a comprehensive approach to problem solving, creativity and critical thinking will be the key skills that employers will value in their employees [World Economic Forum, 2016]. Project work is a universal algorithm for developing students' critical thinking, creativity at lessons and through educational projects.

Since the 1990s, scientists from around the world have been discussing the importance of studying remote sensing at different educational levels [Maio et al, 2002; Yusoff et al., 2008]. In 1994, remote sensing became a part of school educational course in Geography in Indonesia [Somantri, 2016]. According to a survey conducted by the University of Education Heidelberg, more than 50% of students in Germany and Poland worked with satellite imagery during their studies at school, and in the UK this percentage exceeds 80%. In general, over 70% of students were interested in carrying out projects using remote sensing data [Naumann et al, 2009].

The purpose of this publication is to present the experience of implementing science education concepts involving the use of remote sensing data in the JASU activities in the context of the challenges posed by formation of global information society.

Remote Sensing: From Technology to Science Education

Space exploration is a very fast-paced process. According to the United Nations Office for Outer Space Affairs (UNOOSA), as of 2018, there are 8100 satellites from more than 40 countries orbiting the Earth, and over 22% of them have been launched into space over the last 8 years. Of these, 661 satellites are engaged in remote sensing (RS), i.e. Earth observation. In particular, they monitor cyclones, analyze vegetation status, monitor volcanic activity, etc.

RS data is a body of reliable and up-to-date information on the state of our planet. This information may be applied for statistical and mapping purposes, is useful for researchers and all persons concerned. This data allow identifying the trends in environmental changes. Satellite monitoring helps us to observe the planet,

take care of the environment, and analyze data, which is essential for effective decision-making.

Using RS data, it is possible to measure the content of ozone-depleting aerosols, analyze the atmospheric composition and the effects on biodiversity, regularly monitor glacial melting, assess water quality, measure ocean levels in coastal areas, and etc. Satellite data, along with other sources of information, improves risk assessment and limits the potential damage resulting from earthquakes, floods, fires and other emergencies. RS data is one of the fastest ways to acquire information about the state of the territory prior to and following an emergency.

Satellite imagery is a unique resource for researches in agriculture, cartography, geology, forestry, national security, and etc. RS techniques open up great opportunities in the field of socio-geographical studies, in particular for investigation of the features of spatial development. Satellite images give an overview of the current state of housing system, transport infrastructure development, land cover, land use, etc.

The range of satellite monitoring tools is constantly expanding: there emerge new applications, new opportunities, and the number of users applying this data is increasing. There are available both commercial (fee-based) − for example, WorldView, GeoEye, RapidEye, and free applications (Sentinel, Landsat, Modis) that deliver satellite images with varying frequency. In particular, Landsat 7 satellite provides images in 8 spectral ranges with a spatial resolution of 15 to 60 meters, and the data collection frequency is 16-18 days globally.

The main advantages of the space imagery are as follows: simultaneous coverage of large territories, continuity of information content of the image in each point, high frequency of recording the captured area state. In spite of many opportunities, however, RS data has many limitations too, as often images with sufficient spatial resolution have poor imaging frequency, and vice versa.

Unfortunately, there is a lack of specialists in RS field now, thus satellite monitoring opportunities have not been fully explored and their use is rather limited. However, there will be even more satellite monitoring data collected in the future, since the cost of launching satellites decreases and the technologies and operating performance of devices improve.

Training of specialists in remote sensing and development of educational resources able to raise students' interest in this field remain the topical issues for Ukraine. Since 2012, geoinformation systems and RE are among the top domains of the science education in the JASU. In particular, there has been established "GIS in Geography" unit at the JASU's Kyiv Territorial Branch, which uses the authorial research-experimental program for extracurricular education (recommended by the Ministry of Education and Science of Ukraine (letter by the Ministry of Education and Science of Ukraine No.1/14-14727 of 15.09.2014); there have also been published two educational and methodical manuals, "Basics of Electronic Mapping Based on ArcGIS 10.1 Application" and "Ukraine's Cultural Heritage Illustrated by Electronic Maps in Geoinformation Setting of JASU", and the monograph "Application of GIS and Remote Sensing in Research Activities of High School Students".

All this contributed to obtaining by the National Center "Junior Academy of Sciences of Ukraine" of the Copernicus Academy status. Currently, the JASU is the only Ukrainian organization holding this status. The Copernicus Academies Network connects European universities, research institutions, and business schools around the world to disseminate the results of remote sensing data processing. The Copernicus Academy is a program of the European Union that offers education and information services based on the satellite system of Sentinel family. The program of the Copernicus Academy is coordinated by the European Commission and the European Space Agency (ESA). The ideas of the program are implemented by the Member States of the European Union, the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), and EU agencies. As an integral part of the European Space Strategy, the Copernicus Academy has the ambition to develop new tools, to foster exchanges of knowledge as well as cross-border and cross-sectorial collaboration, with a view to contribute to unleashing the vast potential of Copernicus Sentinel data and other monitoring information.

As part of the activities of the Copernicus Academy, the National Center "Junior Academy of Sciences of Ukraine" is intended to give educational seminars in each region of Ukraine for teachers and students (there have already been held seminars in Solomianskyi and Shevchenkivskyi Districts of Kyiv city) – "Theory and Practice of Remote Sensing"; there has been published a guidance manual, "Fundamentals of Remote Sensing: History and Practice", for the students of institutions of general secondary education. Ukrainian students, members of the JASU, have already showed success in their scientific projects involving satellite data use.

Experience of Remote Sensing Use in JASU Competitions

An overview of several projects carried out by the students and involving remote sensing data use is given below.

Project: "Study of Areal Dynamics of Dnipro River Islands of Kyiv Group and Landscapes of Velykyi Pivnichnyy Island" by Oleksiy Malets, 10 grade student of Rusanivskyi Lyceum (Kyiv city) [Tomchenko et al., 2017, 2019]. This project won the second prize at the 2nd stage of Ukrainian Nationwide Research Paper Defense Competition for Student-Members of the JASU in 2017.

The idea of the student's scientific work was to reconstruct the historical appearance of Kyiv islands on the basis of aerial images made during the World War II and modern satellite imagery, in order to draw attention to the issue of preservation of typical biotopes of river floodplain, i.e. islands within Kyiv city, as an important component of the green corridor of Dnipro River.

The floodplain of Dnipro River within Kyiv, which was formed nearly 10 thousand years ago after glaciation, gives the city its uniqueness, since it is possible here to trace the formation of river floodplain, which changed over the whole historic period. Islands as one of floodplain elements, have also been formed, changed, and disappeared in parallel with modern floodplain formation. The issue of natural

changes of island landscapes and the role of anthropogenic factors is one of numerous problems our city faces.

The study of areal and configuration changes of the coastline of islands belonging to Kyiv Group over the period from 1942-1945 to 2017 using GIS/RS techniques showed a significant decrease in the area of Kyiv archipelago islands, from 3563 to 2732 ha. It has been determined that islands began to shrink as a result of human influence (construction of Kyiv Hydroelectric Station, sand deposition for urban construction), which negatively affected the state of their biotopes (Fig. 1).

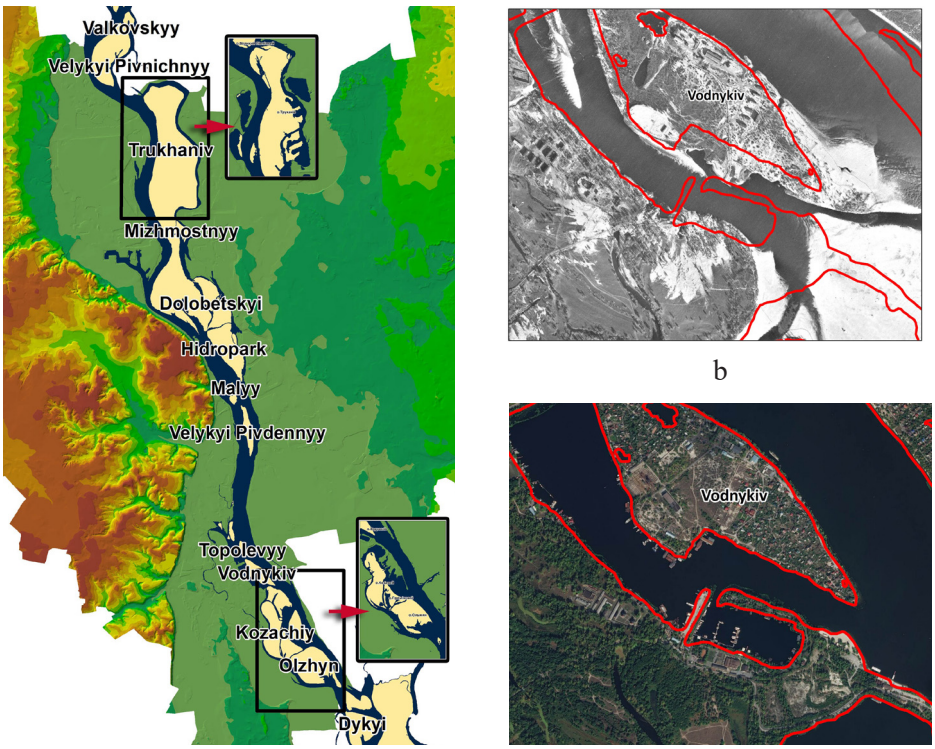

Fig.1 *Visual representation of Dnipro River floodplain transformation within Kyiv:* ***a*** *– boundaries of Kyiv islands as of 1945, superimposed on the relief in ArcGIS application (selected portions represent modern appearance of islands);* ***b*** *– aerial image from archive as of 1945, Vodnykiv island (red line represents modern boundaries of land);* ***c*** *– modern satellite image of Vodnykiv island (from Google Earth program).*

On the basis of more detailed study of Velykyi Pivnichnyy island formation using archival cartographic materials and RS data, there have been performed 3-D modeling of the changes in the island shape and area that have occurred over more than seventy years, as well as mapping of modern landscapes and development of a new ecological trail (Fig. 2).

It has been determined that the island started to shrink in the 1990s due to anthropogenic factors, in particular, extraction of sand for construction of

Troyeshchyna housing estate and cottages on the site of floodplains and leafy groves north of Verbliud gulf.

The ultimate purpose of the project was to substantiate the need of granting a nature reserve status to Dnipro River islands of Kyiv group, which experience increasing anthropogenic load. Moreover, the developed tourist mapping scheme of Velykyi Pivnichnyy island with ecological trail will expand the opportunities for exploration of Dnipro River islands (near Kyiv city) by tourists. This may help to raise awareness among general public about the exceptional value of these territories, and will contribute to the recognition of their special conservation interest and need to create natural reserve fund (Fig. 3). The results of the project may be used in Geography lessons at schools, as well as in specialized clubs and for tours.

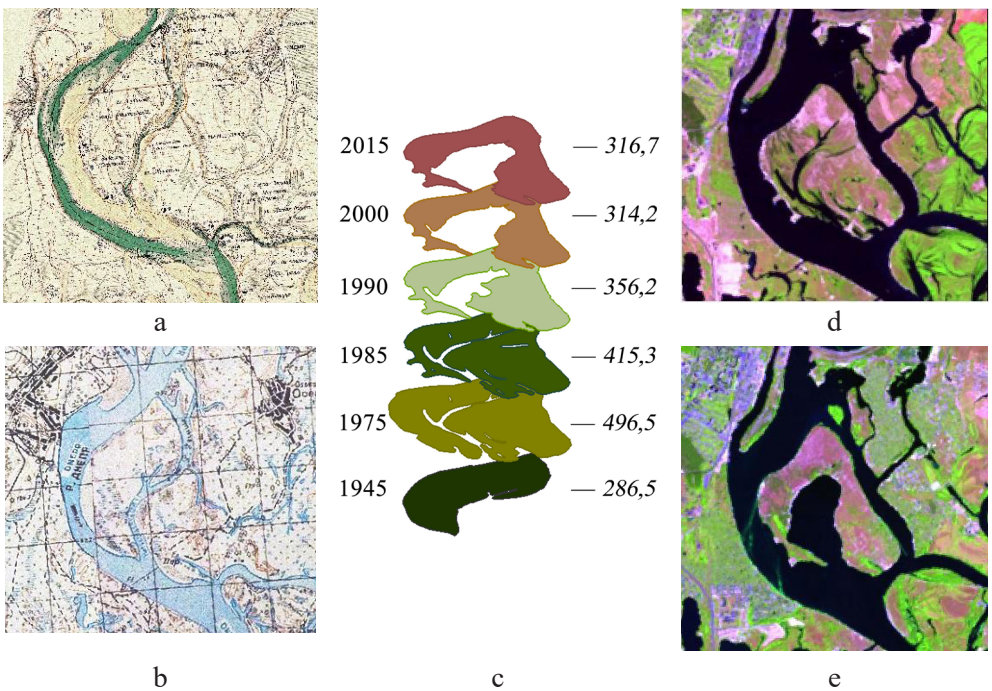

Fig.2 *Study of areal changes of Velykyi Pivnichnyy island based on cartographical documents and RS data (**a** – historic map as of 1914; **b** – German topographical map as of 1945; **c** - 3D-modelling of the changes in the shape and area of Velykyi Pivnichnyy island; **d** – satellite image delivered by Landsat 5 in 1985; **e** - satellite image delivered by Landsat 8 in 2015).*

Monitored objects of ecological trail:

1. Start of tourist trail (water stop) ***"Pier"***;
2. Short rest place "***Leafy grove"***;
3. Object for monitoring ***"Relict gulf"*** – review of rare meadow plants;
4. Object for monitoring ***"Starosilskyi arm"*** – review of Ptashynyy and Valkovyi islands;
5. Object for monitoring ***"Open pine woodland"*** – review of pine plantations;

6. Object for monitoring ***"Zhuravel gulf"*** – review of remnants of Zapisocchya lake;
7. Object for monitoring ***"Vyshhorod horn"*** – review of poplar bottomland forests.

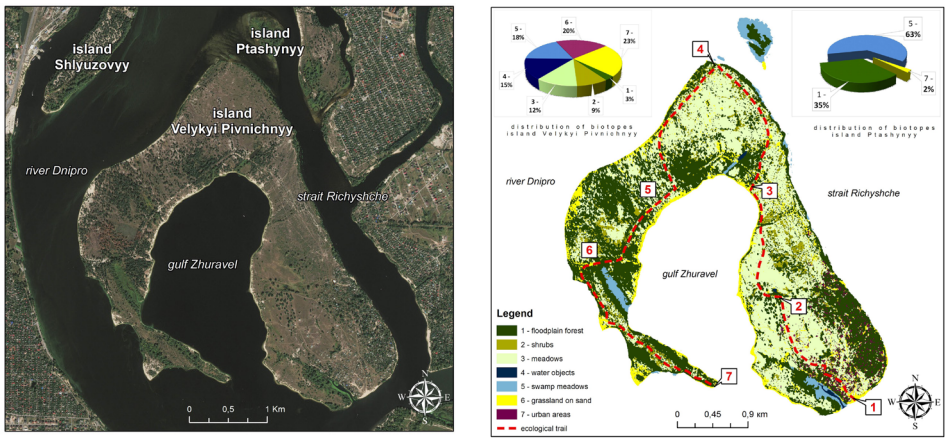

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Fig.3 *Tourist map of Velykyi Pivnichnyy island:* ***a*** *– satellite image of the territory of island delivered by QuickBird;* ***b*** *– thematic landscape map of the island with ecological trail and legend for the monitored objects.*

Project: "Historic mapping of Kyiv Pechersk Lavra" by Natalia Aleksyk, 10 grade student of Gymnasium No. 178 of Kyiv city. This project won the 2nd prize at the 2nd stage of Ukrainian Nationwide Research Paper Defense Competition for Student-Members of the JASU in 2019.

Kyiv Pechersk Lavra has a status of UNESCO World Heritage Site. This status helps to preserve and reconstruct all cultural and historical objects located on Lavra's territory. Therefore, the main ideas of the project were drawing attention to the issue of preserving the territorial integrity of Kyiv Pechersk Lavra as UNESCO site, and application of GIS/RS technologies for the study of its historical changes and current state (similar issues have been investigated by Vadym Lyalyko) [Lyalko et al., 2015].

The next step of the project was to identify sites of illegal development of certain reserve areas according to modern satellite imagery. For this purpose, the boundaries of the buffer zone around Lavra were drawn in Google Earth, following the recommendations of UNESCO, the highest structures were selected according to the length of shadows, and the distances from them to the boundary of the Lavra buffer zone were calculated. Thus, it was determined that the closest "scandalous skyscrapers" are Leipzizska housing complex (13 Leipzizska St.) - located directly on the border of buffer zone, "Senator" business center (32/2 Moskovs'ka St.) - built at 300 m distance from buffer zone, "Diamond Hill" housing complex (11b Mazepy St.) - located at 100 m distance meters from buffer zone (Fig. 4). The leading building in height - the house located at 7a Klovsky Uzviz (Carnegie Center housing

complex), with 48 floors and height of 168 m, has a dubious status. UNESCO has repeatedly demanded to reduce its height (at four sessions) since the building spoils the view of the historical heritage, hanging over the Lavra bell tower.

Fig.4 *Location of the highest buildings in the surroundings of Lavra buffer zone:* ***a*** *– map with marked "skyscrapers";* ***b*** *– appearance of Leipzizska housing complex;* ***c*** *– appearance of "Senator" business center;* ***d*** *– appearance of "Diamond Hill" housing complex;* ***e*** *– appearance of Carnegie Center housing complex.*

Another area of focus was the study of the condition of preservation of Kyiv fortress (13-14th centuries). The most ancient monument of medieval type on the territory of Old Pechersk Fortress is the defensive wall with towers surrounding the Upper Lavra (late 16th century). The latest fortification systems include the earth bastion forts of the citadel.

During the study it has been discovered that a considerable part of the southern earth citadel fortifications with bastions is currently lost for the city due to the development and functional rearrangement of the territory belonging to private enterprises and organizations, in particular the Cavalry earth fortification with the bastion and Vasylkiv ravelin gates (Fig.5).

Thus, the main result of the project was increased attention to the issue of preserving the integrity of Kyiv Pechersk Lavra territory in order to maintain its UNESCO World Heritage Site status. Satellite images made it possible to represent the current state of Lavra and the changes that have taken place in its territory over time.

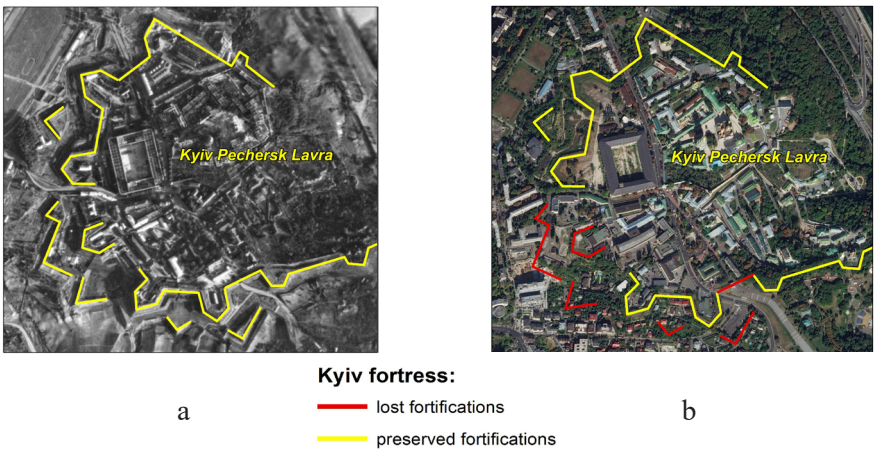

Fig.5 *Study of preservation of Kyiv fortress fortifications around Kyiv Pechersk Lavra (**a** – aerial photo from archive (as of 1942); **b** – modern satellite image).*

Project. "Wood industry. Residues and Wastes of Woodworking as Biofuel Resources of Kyiv Region" by Valeriya Protsenko, 10 grade student of Gymnasium No. 178 (Kyiv city). This project won the 3rd prize at the 2nd stage of Ukrainian Nationwide Research Paper Defense Competition for Student-Members of the JASU in 2019.

Wood industry of Ukraine is one of the most promising export-oriented industries, which development strongly affects the creation of new jobs, replenishment of budget, and increased competitiveness of the regions. However, logging and woodworking processes are associated with big amounts of wastes, such as sawdust, chips, tree branches. These wastes constitute one third of the biomass of the deforested stand and may be used for the production of fuel briquettes, fertilizers, chemicals, i.e. may be converted into energy, and thus contribute to economically and environmentally balanced forest management. The main purpose of the project was to identify possible ways of use of bio resources available in Kyiv Region for the production of solid biofuels based on a comparative analysis of forest cover of various territories and thermal efficiency of different fuels - promising alternative energy sources.

Satellite images have been used in the project as supplementary materials for the assessment of forest cover and determination of actual logging volumes in Kyiv Region. Using Global Forest Watch geoportal (www.globalforestwatch.org), forest maps have been created and deforestation areas have been determined for 2017 and the last ten years (Fig. 6).

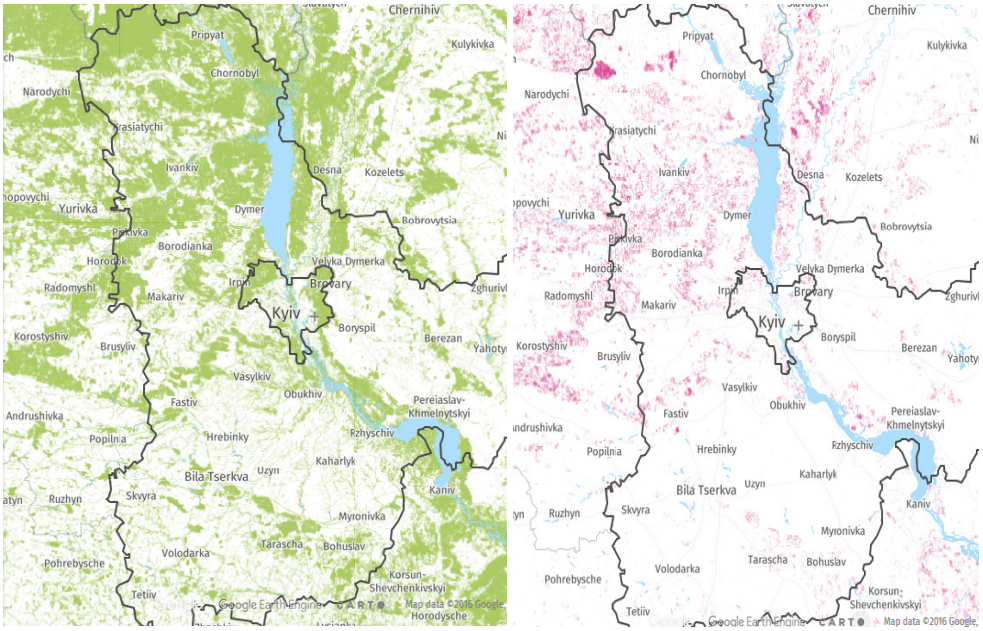

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Fig.6. *Maps of forest resources of Kyiv Region:* ***a*** *– boundaries of forest cover (marked in green),* ***b*** *– lost forest cover (marked in red).*

According to the data obtained, it has been determined that 605 thousand hectares, or 22% of the total territory, are covered by forests in Kyiv Region. 56.2 thousand hectares of forest have been lost as a result of cutting-down and fires over 2007 - 2017. Analysis of annual deforestation dynamics showed that the greatest loss of forest cover over the last ten years was in 2016 (12 thousand hectares). In 2017, 6.7 thousand hectares of forest were cut down, mostly in the northern part of Kyiv Region, namely Ivankiv, Borodyanka and Dniprovsko-Teterivskyi Districts. The next step of the project was to measure the volumes of potential raw materials for bio fuel production using Polissya forestry of Kyiv Region as an example. These volumes have been determined as the difference between the total and marketable raw materials on the basis of logging permits. The losses of biomass of forest stand amount to nearly 13%.

On the basis of determined volumes of logging, it has been concluded that Kyiv Region has a high potential for the development of biofuel industry using woodworking wastes, and 13% losses correspond to the loss of 7.3 thousand hectares of forest over a period of 10 years, which could have been avoided with rational forest management.

Conclusions

Open access to free satellite imagery, both modern and archival, covering over forty years made remote sensing an effective tool for identifying, analyzing and

searching for solutions to environmental problems. As a multifunctional instrument, RS allows performing a variety of studies at the JASU based on an interdisciplinary approach.

The review of the projects by JASU students showed that basic skills in satellite imagery processing allow students to use remote sensing methods effectively for the analysis of chosen area of study and obtain new knowledge while finding solutions to specific problems.

Therefore, there is a pressing need of dissemination information about the possibilities for remote sensing data application, in particular among the teachers of geography and other natural sciences, which will further transfer gained experience to their students. For the purpose of promotion scientific research using remote sensing, National Center "Junior Academy of Sciences of Ukraine" received the Copernicus Academy status and initiated a series of trainings for geography teachers on the basis of district training and methodological centers of Kyiv city.

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