# Application of GIS-Technologies in Ecological Education

A.S. Sokolov, O.V. Kovaleva

***Abstract*** –Full-time training and distant courses for teachers` continuing education of ecology-related subject corresponding to principle directions of state programmes in the sphere of ecological education within the context of multilevel system of education were developed and implemented by academicians of Educational Institution «Francisk Skorina Gomel State University» jointly with partners (Educational Institution «Vitebsk State Technical University» and Educational Institution «Polessky State University») within the framework of EcoBRU project. The article presents the opportunities of the developed course «Application of GIS-technologies in ecological education».

***Keywords*** – ecological education, GIS-technologies.

## I. INTRODUCTION

Ecological education and upbringing is a relevant social, economic, psychological pedagogical, humanitarian and ethic problem the essence of which is revealed through the development of environmentally friendly behavior of an individual. There is no need to prove the significance of ecological upbringing. There are two reasons for such particular attention to this subject: a necessity to consider ecological upbringing and education as a continuous systematic process during the whole period of study and relevance of formation of elementary ecological culture. One of the most significant ethical and ecological peculiarities acquired in the process of ecological education and study is ecological responsibility revealed through appropriate, that is, environmentally friendly behavior of a person. Ecology related perceptions enter all the spheres of scientific and social life, serving as a factor which unites the world community during the process of globalization. Ecology becomes a leader of scientific picture of world whereas ecological education is a top-priority and system developing factor for education at large [1].

It is also difficult to overestimate the significance of information and society IT development processes in XXI century. Information is becoming a resource of continuously increasing importance aiming at society development. Development of computer technologies provides both enhancement of already used data processing and constant application of new data, computerization of new areas of knowledge and management. Programme and technical means which implement information technologies in practice are used for information resources access. Great deal of the real world information and practical activities – techniques, economics, ecology, politics, management – are of spatial reference. Spatial information processing systems are of great importance nowadays with the leading role of geographic information systems taken into consideration.

Educational Institution «Francisk Skorina Gomel State University» is engaged in implementation of «Ecological education for Belarus, Russia and Ukraine» (EcoBRU) project within the framework of Tempus programme of TACIS European Community. The project, aiming at qualification enhancement of secondary school, college and university teachers, has as its goal the development of ecological education oriented study programmes in the system of continuous education for teachers and academicians in the context of multilevel system of

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education in Belarus, Russia, Ukraine; testing, implementation, official recognition and gradual use of distant study courses in ecology in the context of multilevel system of education; modernization of the existing study programmes in the context of ecological education and environmental protection.

At present there are scarcely any methodological materials for teachers concerning GIS technologies and its application in ecological education and ecological researches in Belarus. The absolute majority of teachers are unaware of this subject, as well as of GIS-systems methods and the possibilities which they open for study and research activities. Meanwhile the possibilities of ecological mapping, acquisition, visualization and analyzing of various ecological information by means of GIS-technologies are numerous and increasing annually.

Application of GIS-technologies enables its applicants to diversify forms of activities and possibilities in ecological education, organize ecological education and researches in a way corresponding to modern requirements of society and integrated with global trends in this area.

## II. CONTENTS OF GIS-TECHNOLOGIES APPLICATION IN ECOLOGICAL RESEARCHES STUDY PROGRAMME

Study of GIS-technologies application in ecological education aims at development of the following skills:
- possibility of independent creation of three-dimension models of any geographic objects, from global to local; having both traditional map and its three-dimension model applicable, learners will be able to master the technique of «catching» spatial three-dimension information on flat two-dimension maps considerably quicker than ever;
- possibility to transform the existing flat two-dimension images (of a map, space image) into three-dimension model promptly;
- thematic mapping using free software and all types of cartographic images, choice and performing of any mapping;
- free acquisition of administrative division maps of any level of all countries;
- acquisition of space images of any territory and of different resolution from various satellites and processed material of space survey from profile organizations resources (for example, relevant cloud map, forest fire map, ice map, map of sea and ocean pollution, Arctic ices dynamics, desert advancing map, etc.);
- possibility of free acquisition and processing of basic materials of space survey (images separated by shooting channels), mastering of many study and research possibilities of processing such materials;
- mastering of dimensional analysis methods realized with GIS-technologies application (calculation of morphometric figures, calculation of distance between objects, buffer zone development, maps layering and resulting maps development, attachment of additional materials – images, text files, video files, audio files, etc. – to e-maps);
- use of geological and social servers, media servers aiming at acquisition of relevant and visual materials on various topics illustrating natural, social and economic peculiarities of different Earth regions;
- mastering of global e-maps activities methods (including animation maps) appearing in the latest years (meteorology and hydrology figures maps, geology maps, forestry maps, political development bearing maps, etc.);
- use of other free sources of ecological and geographical information.

The programme of mastering the subjects dedicated to use in ecological education and researches space survey related materials, as well as the correspondent acquired possibilities, is presented below as an example.

### III. ECOLOGICAL RESEARCHES AND PROJECTS IMPLEMENTATION BY MEANS OF EARTH DISTANT SOUNDING MATERIALS

Earth distant sounding materials (space images, digital surface model, etc.) can be used for acquiring information about various territories land management structure, zones of the most transformed areas, principles of ecosystems dimensional dissemination, natural, social and economical objects and phenomena. Mainly these data serve as a foundation for territories ecological evaluation, its dynamics and implementation of study and research projects in learning process.

Learning of space materials application in ecological researches was organized in numerous stages. The first stage is acquisition of space materials from free sources. For this purpose such web-sites as the USA Geological Services (http://earthexplorer.usgs.gov), University of Maryland (http://glcf.umd.edu), Roscosmos geoportal (http://gptl.ru), etc. Multi zone space survey can be acquired through these servers - scenes Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Aster, EO-1 ALI, EO-1 HYPERION. Kanopus-B, Resurs-DK1, SPOT 5, Formosat-2, Ikonos.

The images represent sets of pictures made in various spectral ranges. For example, scene Landsat 7 comprises panchromatic image with values varying from 520 to 900 nm with 15 m in GSD distance , infrared image with values varying from 10400 to 12500 nm with 60 m in GSD distance and multi spectral image comprising 6 pictures (values: 1-450-515; 2-525-605; 3-630-690; 4 – 760-900; 5 – 1550-1750; 6 – 2080-2350 nm) with 30 m in GSD distance and radiometric resolution corresponding to 8 bit.

The second stage is synthesis of multispectral image colour picture and its further thorough analysis. We propose to consider MultiSpec programme (https://engineering.purdue.edu/~biehl/MultiSpec/) as a software for such purposes. The programme is designed for computer processing of multispectral and hyperspectral images and has a wide range of functions. Every version comprises the following: data import, images screening, intensity distribution histograming, data formatting changes, development of data layers on the basis of existed ones, image clustering, determination of classes features, best spectral zones depiction, classification of the chosen image or its unit, classification of results output, spectral brightness graphic output, colour layout of the chosen class correlation with spectral zones of initial image, supplementary utilities, including export of pixels brightness values for processing in other packages, etc.

Colour image synthesis means that each picture in three shooting channels has its own colour. RGB system is applied. Depending on the colour related ranges, a great deal of colour synthesized combinations of shooting channels can be specified. Each of these combinations enables its applicants to acquire particular information about surface objects and depict its ecological features [2].

Such values as 0,4-0,5; 0,5-0,6 and 0,6-0,75 mcm (that is, in the example with multispectral image Landsat 7 images 1-2-3 are presented) are spectral zones (of blue, green and red colour correspondingly) the most frequently used for synthesizing. This type of synthesis is a standard one (natural colour transfer).

Picture 1 demonstrates examples of image synthesis with distorted colour transfer. Type of synthesis 5-4-3 (picture 1a) presents a decoder much information and colour contrasts. Healthy vegetation has bright green colour, soils – pinky purple. This combination enables an applicant to analyze the cultivated lands, it is also very convenient for analyzing flora and forest communities.

In combination 4-3-2 (picture 1b) flora is red, city buildings are green and blue, soils colour varies from dark to light brown. Ice, snow and clouds are white or light blue (ice and clouds are presented on the edges). Pine woods will be of dark red or even brown colour in comparison with leaf bearing ones. This combination is rather popular and is used primarily for flora study, drainage and soil mosaic monitoring, as well as agricultural studies. In general, bright red

colours serve as an indicator of healthy and (or) broadleaf vegetation, whereas lighter colours characterize grassy vegetation or light forest/shrub vegetation.

Other types of synthesis applied for geological processes study, atmosphere features, water objects, smoke, forest cutting, soil humidity, etc. are applicable for ecological researches as well.



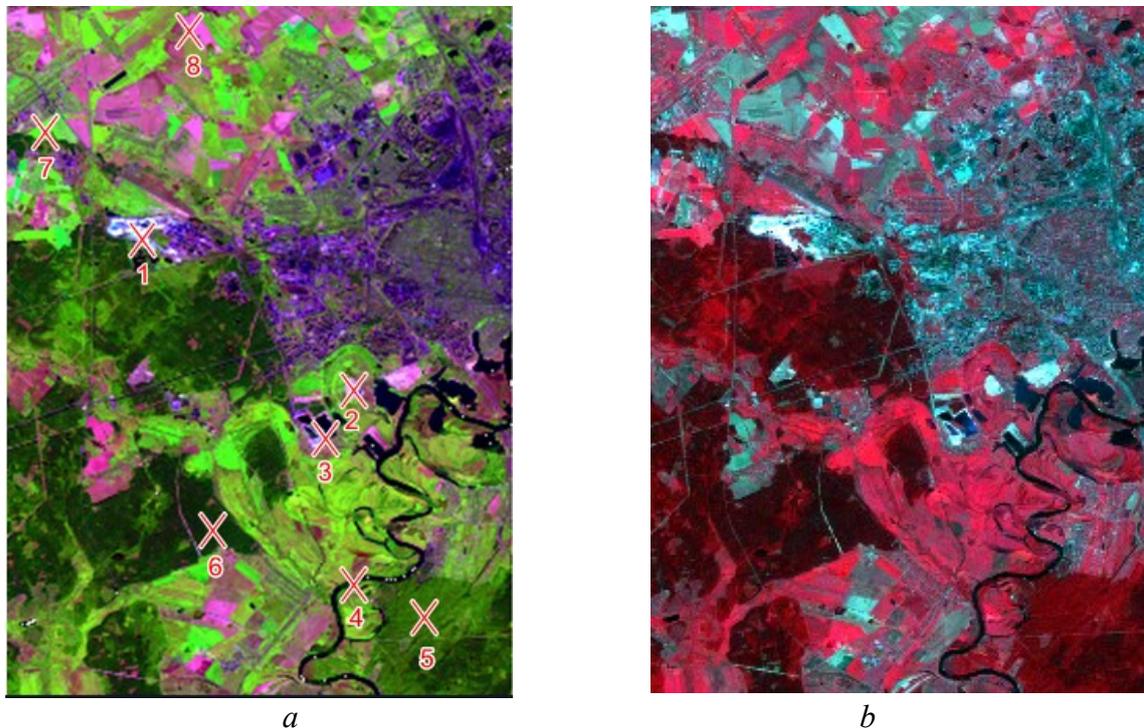*a*                                                          *b*

Fig 1 – Colour image synthesis of image Landsat 7 (western part of Gomel and Gomel suburbs): a – combination 5–4–3; b – combination 4–3–2

The third stage is dedicated to mastering methods of objects depiction on images by means of its decoding features. Residential areas, cultivated lands, forests, water objects, meadows and other natural and anthropogenic objects can be distinguished on the images [3]. Setting of images with maps of administrative territorial or natural (landscape, river estuaries, geomorphological objects) divisions makes it possible to find out proportion of land types within the limits of separate territorial divisions, evaluate its ecological state, make comparison of various territories and depict correlation between natural territorial features, level of anthropogenic influence on this territory and its ecological state. This stage also presupposes mastering of opportunities of acquisition vector shape-files of administrative division units of various levels of all countries (web-site: https://gadm.org) and creation of natural zone division files by means of GIS-packages.

Besides decoding features, graphs of spectral brightness – graphic depiction of correlation between wave length and reflex coefficients of the analyzed object (picture 2) – are used for decoding of objects and its features on space images. Multispectral image ranges numbers (levels of brightness are determined by means of MultiSpec programme) are indicated on X axis. Brightness characteristics in the considered spectral zones are indicated on the scale from 0 to 255 on Y axis. Each of surface objects is characterized by individual brightness in various ranges. Graphs of spectral brightness drawn for areas of eight natural and anthropogenic objects (picture 1a, the objects are marked and numerated) are presented as an example.

Graphs of spectral brightness enable to decode precisely various types of objects, even the visually identical ones. So, the following peculiarities of objects spectral brightness can be

specified for the presented example. Level of brightness in optical range channels for curve of phosphogypsum dumps spectral brightness of Gomel chemical factory is maximum among all the analyzed objects. Then, with the growth of wave length taken into consideration, it declines abruptly in infrared area of spectrum, brightness is the lowest in the sixth channel. As for the sand pit, brightness is the highest in the fifth channel. In general, shape of the graph is the same as previously, but the brightness in all channels is lower. Besides, for sand pit, unlike phosphogypsum dumps, brightness in the fifth channel is higher than in the fourth one.
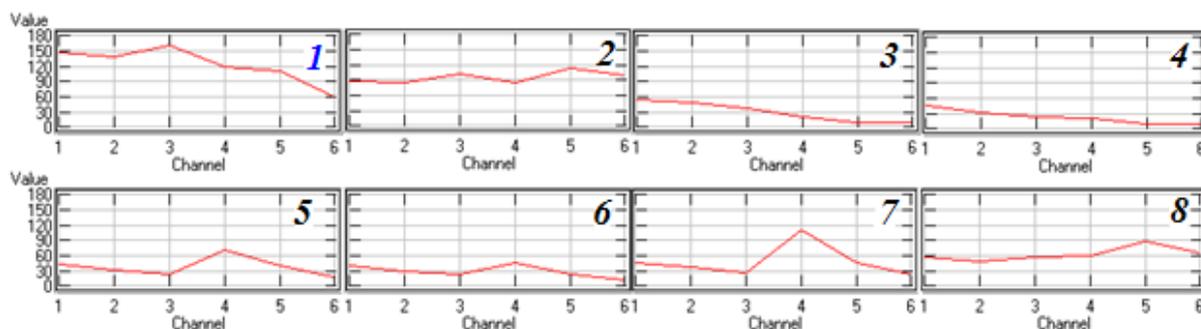


Fig 2 – Graphs of spectral brightness of natural and anthropogenic objects: 1– phosphogypsum dumps, 2 – sand pit, 3– water with suspensions, 4 – pure water, 5 – broadleaved forests, 6 – pine woods, 7 – unharvested cultivated lands, 8 – harvested cultivated lands

The minimum brightness is observed for water objects and declines with the growth of wave length. However, for polluted water objects brightness in all channels of visible range is higher than for pure ones. Graphs for pine forests differ from leaf bearing ones in brightness characteristics in the channels 4 and 5 (brightness is higher for leaf bearing forests). Curve of harvested cultivated land is of a similar character of curve of unharvested cultivated land, but there is no peak in the fifth one and brightness increases in the first, third, fifth and sixth channels.

The forth stage is dedicated to mastering methods of creation of derived images on the basis of space survey. Classification maps, clustering maps and characteristics distribution maps calculated by means of pixel brightness characteristics use in every channel are considered to be such derived images.

Classification map is the result of automated shots decoding by means of «studying» method, that is, initially a researcher depicts sample areas of the objects reflected on the image and then the programme classifies the other images pixels comparing it with the samples.

Clustering map is the result of automated decoding «without studying». In this case the programme divides all the pixels in the given class number itself with the application of ISODATA algorithm.

Knowledge of connection of vegetation structure and state relation with its reflective features enables to use space images for identification of vegetation types and its state [4]. For this purpose vegetation index is used – a criterion calculated as the result of operations with various spectral ranges (channels) of distant sounding data and related to vegetation characteristics in the given image pixel. Index effectiveness is determined by reflective peculiarities; these indices are of empirical nature.

Currently there are about 160 existing types of vegetation indices which are drawn through experiments (with peculiarities of vegetation and soils spectral reflectivity curves taken into consideration).

Calculation of the majority of vegetation indices is based on two more static (disregarding the other factors) lines of vegetation spectral reflectivity curve. Maximun chlorophyll solar radiation absorption accounts for red spectral zone (0,62 - 0,75 mcm) and maximum cell leaf

structure energy reflection – for near infrared zone (0,75 - 1,3 mcm), that is, high photosynthetic activity (as a rule, regarding big vegetation bio mass) determines lower reflection coefficients in spectral red zone and higher coefficients in near infrared zone. As known, ratio between these indicators enables to distinguish vegetation from other natural objects.

NDVI (Normalized Difference Vegetation Index) is the vegetation index most frequently used. It takes positive values for vegetation and the bigger green bio mass is, the higher this index becomes. NDVI is calculated by the following formula:

$$NDVI = \frac{NIR - ¿}{NIR + ¿}$$

where NIR stands for near infrared range radiation intensity (for Landsat 7 satellite images the range is 760-900 nm), RED – for red range radiation intensity (630-690 nm).

As an example a map of NDVI vegetation index distribution on the territory was drawn (picture 1). For this purpose New Channel from General Algebraic Transformation option of MultiSpec programme was used. Results visualization (picture 3) with pixels ranging by index value was made in Global Mapper GIS.
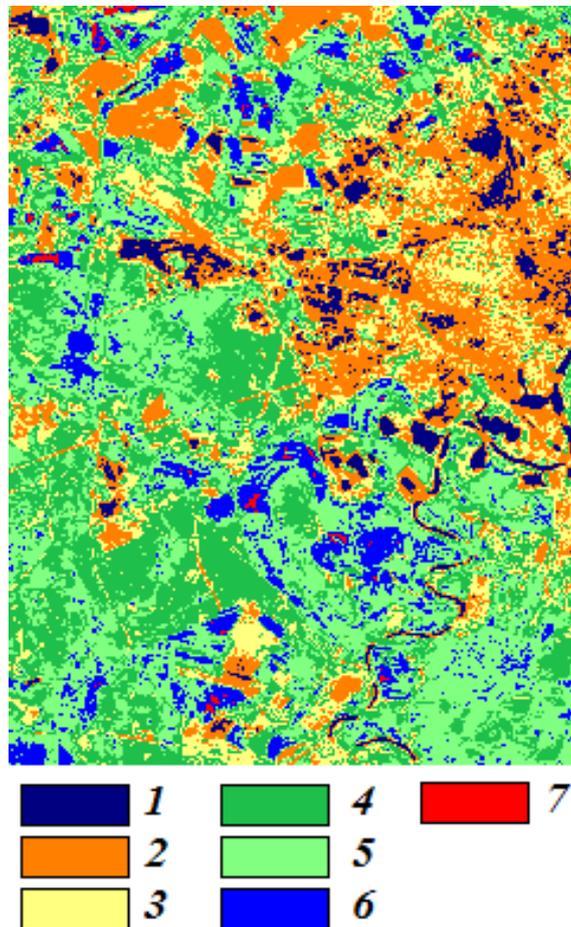


Fig 3 – Territorial distribution of vegetation index NDVI: 1 – less than 0; 2 – 0-0,2; 3 – 0,2-0,3; 4 – 0,3-0,4; 5 – 0,4-0,5; 6 – 0,5-0,6; 7 – more than 0,6.

Vegetation index mapping enables the user to depict ecosystem areas with high bio mass value, which is reflected in high index value.

## IV. CONCLUSION

Ecology-related education of various topics, as well as use of land and water resources, is determined by demand for qualified teachers, specialists and ecologically educated leading staff members in the sphere of management, use and protection of natural resources. Teachers` continuing education in accordance with modern educational programmes, including GIS-technologies application in study process and research activities, is of primary importance as well.

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