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ANALYSIS OF MULTITEMPORAL CHANGES IN THE ENVIRONMENT USING GIS AND REMOTE SENSING IN THE ASPECT OF CONSTRUCTION PROJECTS

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Summary

Modern changes of environment are the result of many factors, of which anthropogenic activities and the development of infrastructure play the leading role in environmental, morphometric changes. The dynamics of expansion of construction lands, which until recently have changed only as a result of natural factors, makes it invariably important to analyse time changes and forecast potential effects of construction projects on the environment. A good source of information about changes, for example the course of rivers, hydrological conditions, diversity of vegetation in the areas of investment, are cartographic sources, in particular GIS techniques, satellite images, and aerial photographs. Proper assessing of the territory using GIS techniques may allow constructing roads not only with less damage to the environment and human health, but also avoiding technical problems, such as low bearing capacity of soils.

The main objective of the study is to evaluate multitemporal changes of the environment in the course of the ongoing construction project, which is the construction of the A4 motorway in its Rzeszów Wschód – Jarosław Zachód section, in the area of the Wierzbna junction. The analysis was carried out on the basis of Landsat satellite images recorded in two different investment periods of the tested object: in 2006 – prior to the start of construction works, in 2015 – in the course of the ongoing construction works.

In addition, the analysis of the obtained Landsat multitemporal satellite images made it possible to examine the morphology of the substrate conditions of river valleys of the San, Wislok, and Mleczka.

Keywords

environmental protection • Landsat • remote sensing • construction projects

1. Introduction

Implementation and operation of roads is associated with a significant impact on the environment so their construction process should be accompanied by an environmental impact assessment. A motorway affects directly in the extreme areas within

a distance of 20 m from the road edge, an area within up to 50 m can be considered a hazard zone, and an area within up to 150 m an inconvenience zone [Badora 2004]. The range of influence of motorways on the ownership structure of land significantly extends beyond the zone of direct impact of the project on the environment [Wegener and Fürst 1999, Tesařová and Halounová 2006]. In fact, the influence zone of motorway on ground cover is higher and can reach up to several kilometres. It depends both on the position of junctions, crossings over highways, appropriate policies of local authorities, and on the surrounding space [Ziobrowski and Korecki 2009].

Construction of the road results in a permanent occupation of land designed for the route, and temporary occupation for access roads, storage yards, collection of aggregates, etc. Vegetation is removed from those areas, small animals are killed, and contractors strip the topsoil. The land configuration is converted into a terrain and altitude differences may even be several metres. Water relations become modified. Valleys of the courses (especially those with supra-regional ecological importance) are an essential element of the ecological system, which is why a motorway should be conducted on flyovers across the entire width of their valleys. As a result, there would be no damage to the function of the ecological corridor. The development of communication networks is accompanied by creation of ditches, embankments and crossheadings. They are geometric forms, formed in accordance with the design assumption, aimed at reducing slopes of road base profiles. They are extensively modelled in the areas of concentrated water run-off from roads (e.g. in the vicinity of bridges and viaducts). Classic material that comes among others from the destruction of roadsides, erosion of the surrounding fields and from the flushing of transport-related contaminants from roads outflows by ditches or undergoes a local sedimentation [Ciupa 2005]. Accumulations force embankments that separate valley bottoms and cause damming at raised water stages.

The environmental changes can be monitored using conventional inventory methods based on the in situ measurements, however multi-temporal satellite remote sensing provides greater amounts of information on the geographic distribution of land use and changes caused by human activities [Elvidge et al. 2004, Fichera et al. 2012, Kędzierski et al. 2014, Pirowski et al. 2014, Butt et al. 2015, Glowienka et al. 2016, Hejmanowska et al. 2016].

The objective of this paper is to analyse temporal changes of the environment in the course of the ongoing construction project, which is the construction of the A4 motorway, its eastern section near the town of Przeworsk. The analysis was carried out on the basis of satellite images taken before the construction of the motorway in 2006, and those made during the ongoing work in 2015.

2. Materials and methods

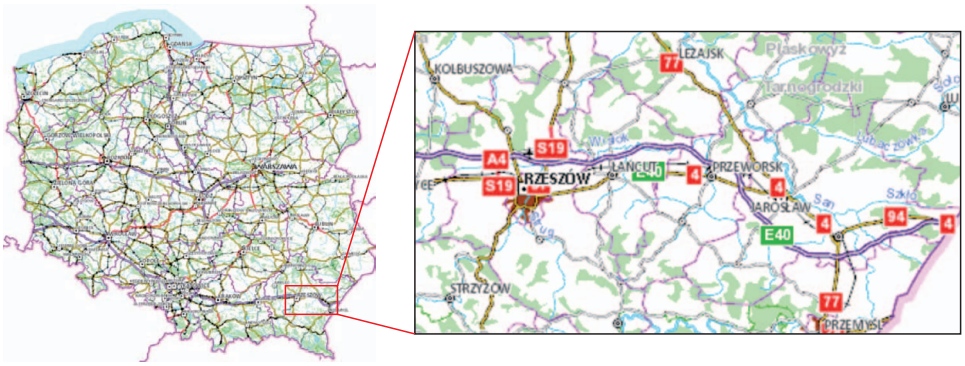
In the study Landsat (TM, OLI) multispectral satellite images of were used. These images are available on USGS (U.S. Geological Survey) servers free of charge. The detailed parameters are presented in table 1. On the basis of spectral channels (infra-

red, red, green) of the obtained satellite images, false colour composites (FCC) were created (Figure 4). The composites have enabled a detailed interpretation of changes in the environment for the study area. For the analysis the hypsometric map was also used. The applied elevation data were obtained from the ISOK project (average density of 4 or 6 points · m^{-2} – the standard I), and shared as a Web Map Service on GUGiK Geoportal.

Table 1. Properties of applied satellite images

Satellite sensor systems	Landsat-5 TM	Landsat-8 OLI/TIRS
Spatial resolution [m]	30	30
No. of Spectral Bands	7	11
Revisit cycle [days]	16	16
Swath width [km]	185	185
Date of registration	2006	2015

The analysed area includes part of the accomplished A4 motorway section Rzeszow East - Jaroslaw West in the Podkarpackie province (Figure 1). The whole project includes the construction of 41.2 km of motorway with technical parameters of the class A road. Besides the construction of the main section of the motorway, there are numerous additional projects being carried out within the framework of those works, such as: construction of engineering objects, highway bridges, service roads, access roads, technological reconstruction of already existing roads, not to mention construction and rebuilding of utilities infrastructure, i.e., among others, power lines, water mains, gas mains, telecommunication lines. In the immediate vicinity of the analysed area there are NATURA 2000 natural areas, nature reserves, protected landscape areas, a landscape park, and ecological areas (Figure 2).



Source: authors' study on the basis of (http://geoportal.gov.pl)

Fig. 1. Study area

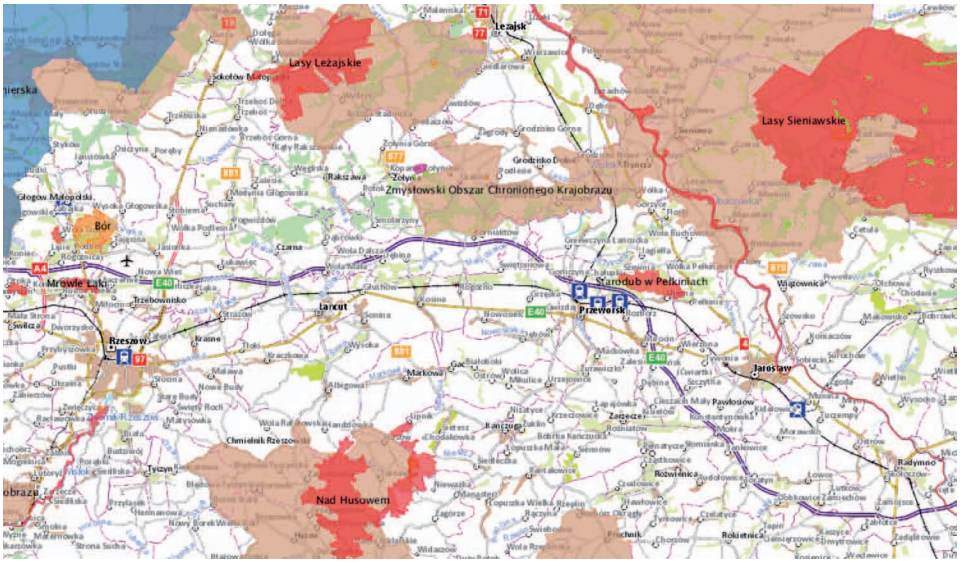


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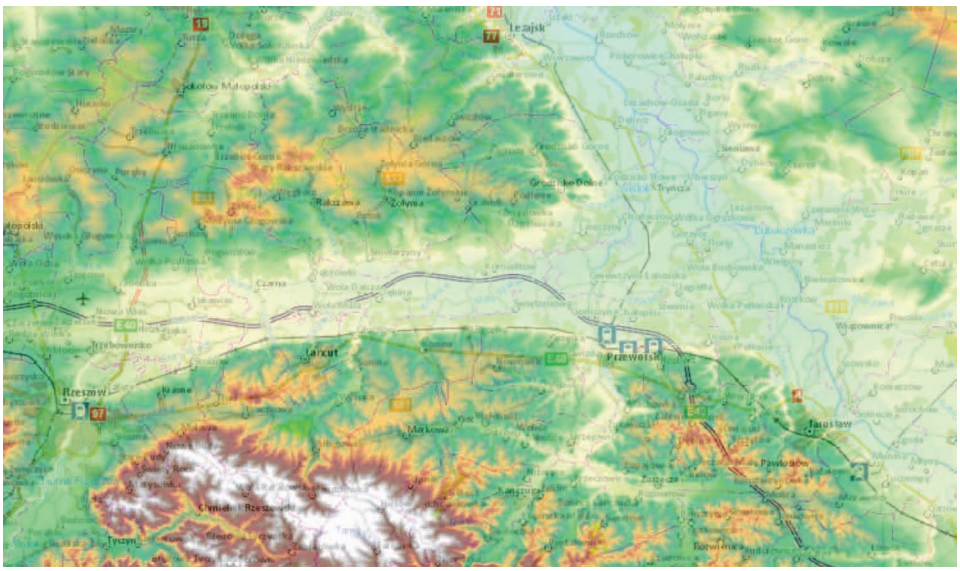
Fig. 2. Forms of the protected landscape of the studied area of A4 motorway section (NATURA 2000 – in red, brown and blue)

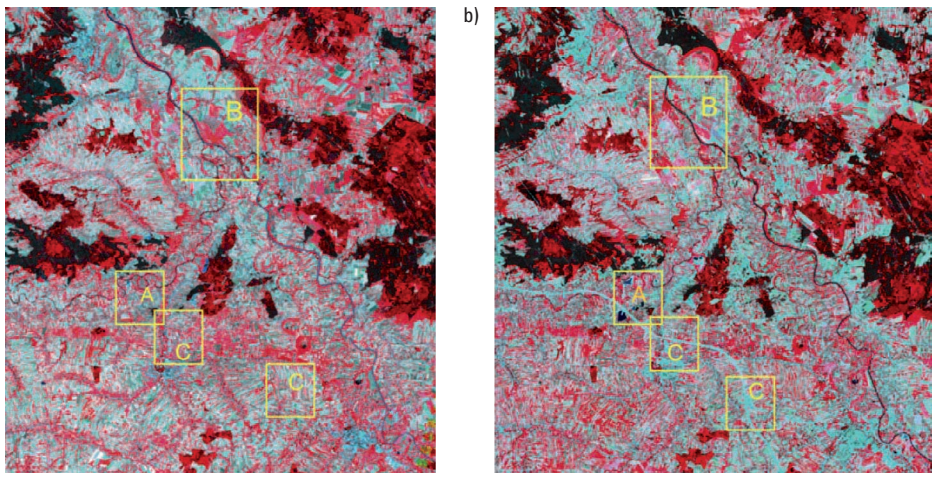


Source: authors' study on the basis of (http://geoportal.gov.pl)

Fig. 3. The hypsometric map of the studied area

On hypsometric maps it can be seen that the analysed area lies in a valley and in the vicinity of the San, Wislok, and Mleczka river beds (Figure 3). The San River flowing around Przeworsk can be classified as a sinuous river. In the analysed area, the section of the San is located in its middle course. In the Przeworsk area, the San flows partly in an artificial, regulated river bed. On hypsometric maps one can see numerous meanders and oxbow lakes (Figure 3). Other important watercourses in the analysed area are the Wislok River, the largest left tributary of the San River, and the Mleczka River. The Mleczka River in its upper part is a mountain river, and its nature in the estuary section of the study area is that of lowland. It flows into the Wislok River to the south of the village of Gniewczyna Lancucka, near the implemented construction site of the A4 motorway.

The water and ground conditions and protected landscape areas are conducive to the development of characteristic forms of plants. Low flood terrace along the San and the Wislok river valleys are often the habitat of osier bed, wicker willow and poplar forests. Over smaller streams alder and ash marshy meadows, representing lowland complex of Circaeo-Alnetum, are formed. Outflow depressions are overgrown with alder swamp forests. These communities are associated with glial-silty soils or alluvial soils. The potential vegetation on meadow terraces, on alluvial soils and clay soils are dry-ground forests. Within the inner-forest basins there are preserved fragments of raised bogs, and in the oxbow lakes there is aquatic vegetation and rushes. The poorer soils that were made of sand and gravel are grown with mixed and fresh coniferous trees and in depressions there are swampy pine forests formed. At the edge of the forests there occur grasslands and sandy grass and moorlands [Czylok and Baryła 2003].



Source: authors' study

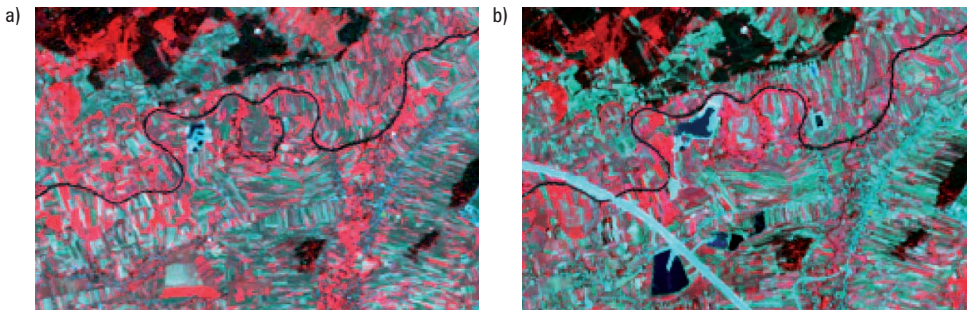
Fig. 4. Fragment of Landsat images with marked areas (A, B, C) of detailed analysis: a) before the construction of the A4 motorway – year 2006; b) during the construction of the A4 motorway – year 2015

In order to compare and evaluate changes in the natural environment of the analysed area Landsat 8 satellite images were used, which were made in 2006, in the period before the construction of the A4 motorway, and those made in 2015 in the course of its implementation (Figure 4). Images were made over the same growing season period. Detailed comparative analysis examined three areas adjacent to the highway, and the area away from it (Figures 5–7).

3. Analysis of environmental changes based on the available satellite images

The carried out comparative analysis of Landsat multi-temporal images allowed to notice significant changes in the environment in the immediate vicinity of the A4 motorway Rzeszow East – Jaroslaw West junction. The identified changes have taken place:

- in the area of indirect impact of the motorway, 500 m from its axis, the biggest transformations are related to the places of raw materials mining for construction purposes, and in the vicinity of transport junctions. In the section of the Mleczka one can distinguish a number of engineering and hydraulic objects (AREAS A),
- in oxbow lakes a visible change in planting undergrowth was noticed (AREA B),
- on aerial photographs a clear tendency of industrial and social building entering the areas of arable land and green areas is visible (AREA C),
- an increase of the area of industrial and service development land, concentrated in the vicinity of transport junctions,
- an increase of the areas of individual ground cover classes took place mainly at the expense of arable land, meadows and pastures. In places, also a decline of afforested and shrubbed areas.



Source: authors' study

Fig. 5. Satellite images of the area A: a) the Mleczka River with cut-off meander (2005); b) hydraulic engineering objects which were formed during construction, an overgrown A4 oxbow lake (2015)

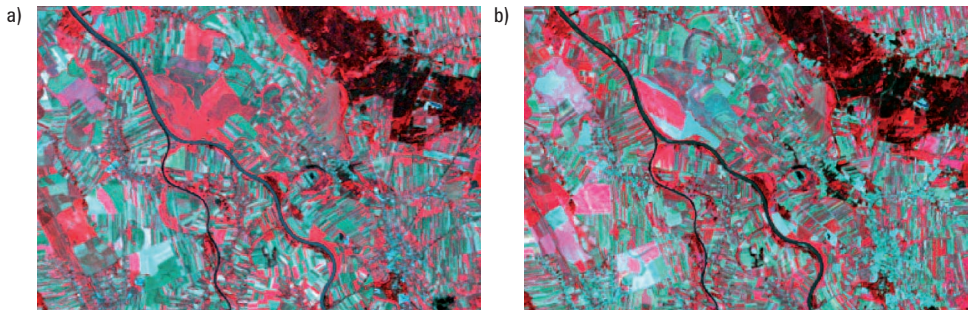


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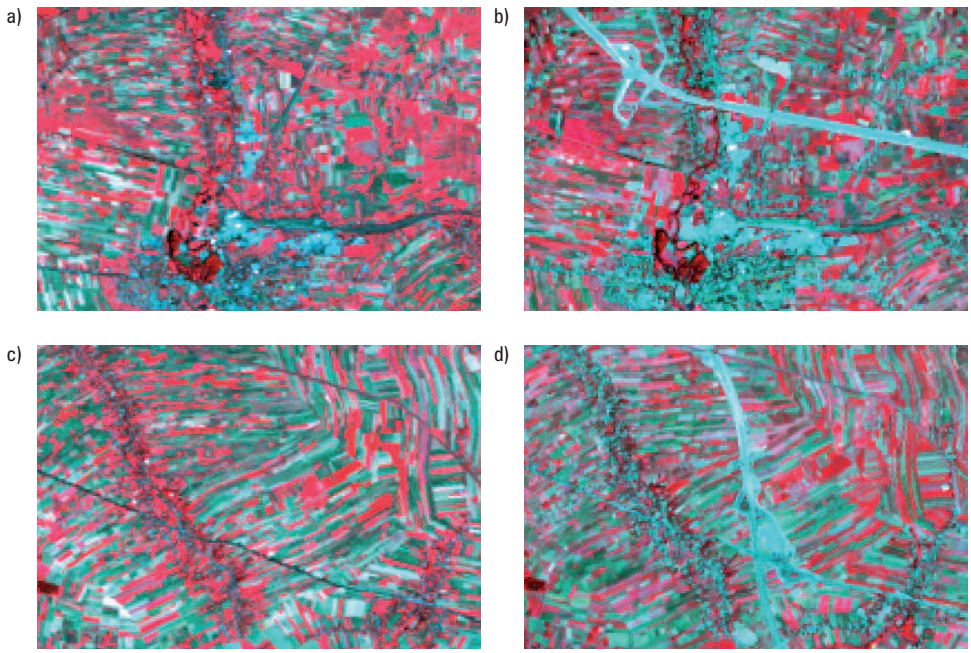
Fig. 6. The San basin and its tributaries. Area B: a); b) visible changes of planting undergrowth in river valleys and within the oxbow lakes



Source: authors' study

Fig. 7. Satellite images from areas C, with road infrastructure encroaching on agricultural terrain: a); c) before the construction of the A4 motorway – year 2006 b); d) during the construction of the A4 motorway – year 2015

4. Conclusions

The analysis of Landsat satellite images confirms the significant impact of the construction of the A4 motorway on adjacent ecosystems and the natural environment. Changes

included areas located both within the reach of direct influence of the motorway, and those far from the project. Construction of the motorway contributed to an increase in the amount of hydraulic engineering structures in the close proximity of the motorway. It forced, in many cases, the regulation of watercourses and drainage of wetlands, both meadows and forests. This situation contributes to the degradation of valuable wetland ecosystems occurring in the San oxbow lakes, protected under the NATURA 2000. It is in these places that the greatest volatility of environment was observed. In addition to thorough analysis of geotechnical conditions, construction of motorways must be preceded with a detailed analysis at the stage of its design in the aspect of assessment of impact on the course of ecological corridors, including primarily troughs of natural watercourses and their valleys.

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