

Chapter 5

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GIS Tools in Analyses of Natural Environment Components with the Nietlickie Marshes Shown as an Example

1. Introduction

The aim of the study was to develop a system and to present the capabilities of using GIS tools in monitoring the geographic environment. GIS tools and a digital map enable the application of an environmental policy of sustainable use of a regional area (Gaździcki 2010). Therefore, there is a need to visualise the processes which take place in the environment and to adapt the spatial data resources to the regulations which arise from the INSPIRE Directive of the European Union.

Geographical space can be described with the Geographic Information System (GIS). It consists of software, hardware, data, algorithms, procedures for processing information and accessibility, as well as the people who use the system and the legal, technological and organisational procedures (Gotlib et al. 2007). According to Gaździcki (1990, 2004), GIS is a system used for acquiring, collecting, verifying, analysing and transferring spatial data and making them available; in a broad sense, it embraces methods, technical means, hardware and software, spatial database, organisation, resources and people interested in its operation. GIS is commonly applied in such studies as “Environmental Protection Programmes”, “Environmental Impact Reports” and in numerous reports and documents regarding spatial planning, thematic tasks, modelling of natural phenomena and other management-associated actions.

GIS projects related to the geographic environment require that considerable spatial data resources for the analysed area should be accumulated. Acquisition of the necessary data requires time and considerable financial resources. Organisational units of different institutions accumulate data only for themselves and use them to carry out analyses and processes. In effect, such units have considerable bodies of spatial data and knowledge about them is usually limited to

their direct users. A problem appears of copying information or data accumulated by a unit, which may not be unified or arranged.

In order to create the system for the Nietlickie Marshes, the data must be first tested with respect to their compliance with the INSPIRE (*Infrastructure for Spatial Information in Europe 2007*) Directive. The directive is transposed by the Spatial Information Infrastructure Act (2010). The Act lays down the principles which apply to spatial data and metadata, services, inter-operability, common use of data as well as cooperation and coordination with respect to spatial information infrastructure. The project focuses on harmonisation of data from different sources. The actions taken include unification of formats and systems of coordinates as well as carrying out preparatory work aimed to arranging attributes. Due to a broad range of preparatory work necessary to create a GIS system, knowledge of techniques and tools is also necessary. Carrying out the project also involves selection of the means of execution and designating of testing methods as well as carrying out spatial analyses.

To conclude, creating a system and subsequent analysis of the natural environment must involve accumulation and processing of coherent and unified spatial data and making it available. The subject has been taken up as it is necessary for Poland to take actions aimed at developing the principles of creating, using and cooperation with respect to spatial information infrastructure. The principles apply, *inter alia*, to achieving individual goals of environmental protection (ISO 14001) and to using land, understood to denote physical and biological use of land, including the area of water bodies. The aim is to ensure the availability of knowledge about natural and anthropogenic objects, which are situated within the space delimited by the borders of Poland (SII 2010). Global projects which deal with matters of the natural environment include GMES (*Global Monitoring for Environment and Security*), which provides access to strategic information about the condition and safety of the environment.

2. Study area

According to Łochyński (2010), there are 2470 protected areas, which require protection plans or protection assignment plans to be developed (thematic maps with the use of GIS), including as many as 1368 nature reserves, e.g. the Nietlickie Marshes.

The Nietlickie Marshes cover an area of 3107.6 ha and lie within the East-Baltic Lake District and are situated between Lakes Niegocin and Śniardwy in the province of Warmia and Mazury, in the communes of Miłki (1744.9 ha) and Orzysz (1362.7 ha). According to the “Register of Nature Reserves in the Province of Warmia and Mazury” of April 2011, the Nietlickie Bagno nature reserve was established by Regulation No. 32 of the Governor of the Province of Warmia and Mazury of 26 May 2003 (Official Journal of the Governor of the Province of Warmia and Mazury No. 72, 30 May 2003, item 1069) and it covers the area of 1132.91 ha, with a buffer zone of 1080.341 ha around its borders.

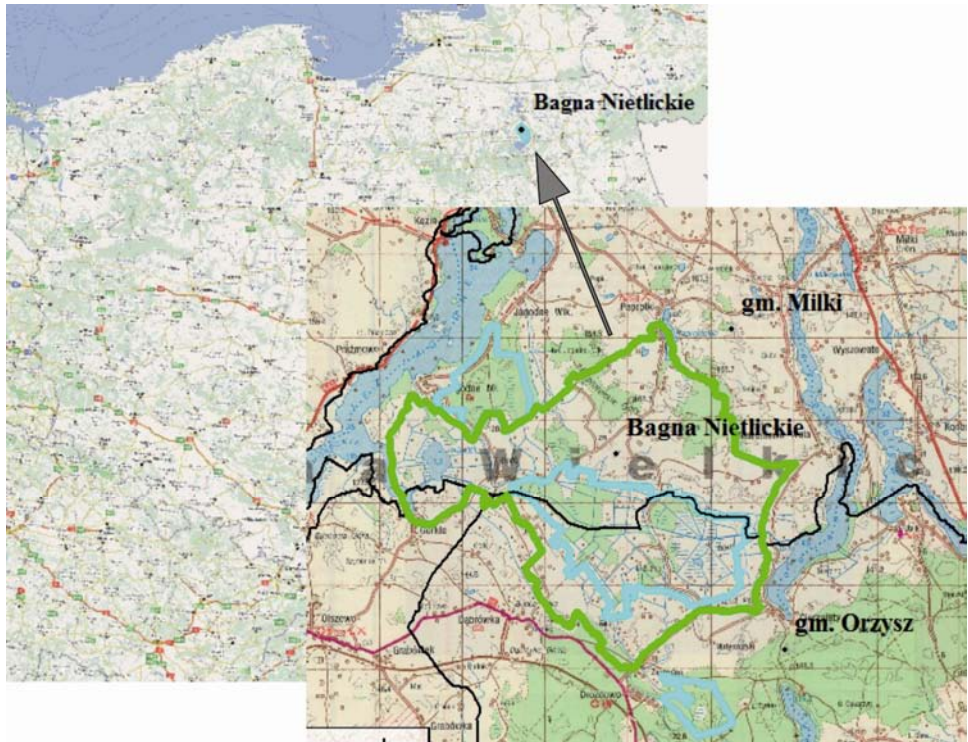


Fig. 1. The position of the Nietlickie Marshes in Poland
Source: Map sections from the Global Mapper

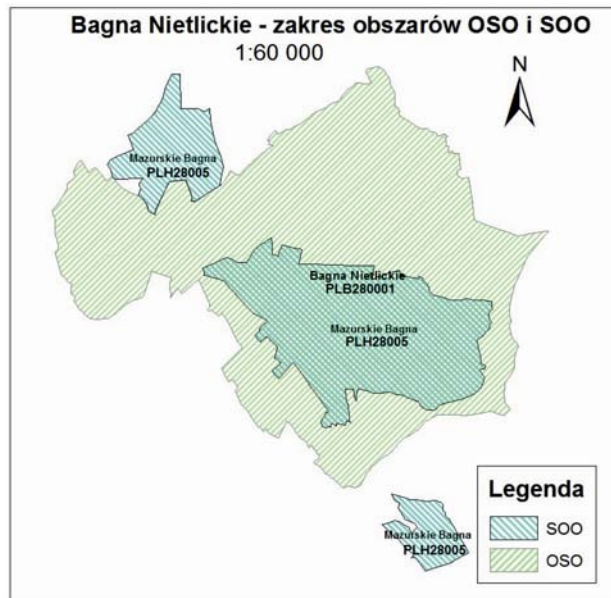


Fig. 2. Digital map of the SBP and SPA area range in the Nietlickie Marshes
Source: Area ranges – SHAPEFILE files

The Nietlickie Marshes include mainly fens and bogs with peat forming vegetation. In the centre of the area there is a nature reserve with the largest and best preserved fen (the result of the drying up of Lake Wąż, which used to occupy the area) and it is one of the largest ecosystems of this kind in Poland which has not yet been degraded. The marshes are endangered now – work carried out by people, for example, draining and drying of marshy areas result in disappearing of such type of land in the Mazurian Lake District and in dramatic changes in hydrographic conditions. The Marshes are also threatened by the area draining by the Wężówka river and by increased activity of beavers, which results in excessive growth of rushes which, in consequence, may result in the disappearance of molinia and hay meadows.

With reference to the data from the Internet website of the General Directorate of Environmental Protection, and furthermore based on the European Ecological Network Nature 2000, which is founded on two EU directives: Bird Directive (2009) and Habitat Directive (1992), the spatial range of the Nietlickie Marshes is delimited by two types of areas, shown in Fig. 2:

- areas of special bird protection (SBP) – area code PLB280001,
- area of special habitat protection (SPA) – area code PLH28005.

Natura 2000 Standard Data Forms (SDF), prepared separately for SBP and SPA, contain identification data, which are shown in Table 1 and Table 2.

Table 1

Identification data for the area of special bird protection (SBP)

Site name – Nietlickie Marshes	special bird protection area (SBP) KOD PLB280001
Area [ha]	4 080.8
Altitude (m above sea level)	116-118
Administrative region	Olsztyn – 3% Ełk – 97%
	Species mentioned in the directive annexes
Birds	<i>Botaurus stellaris</i> , <i>Ciconia nigra</i> , <i>Ciconia ciconia</i> , <i>Circus aeruginosus</i> , <i>Circus pygargus</i> , <i>Aquila pomarina</i> , <i>Porzana porzana</i> , <i>Porzana parva</i> , <i>Crex crex</i> , <i>Grus grus</i> , <i>Chlidonias Niger</i> , <i>Dendrocopos leucotos</i> , <i>Luscinia svecica</i> , <i>Acrocephalus paludicola</i> , <i>Sylvia nisoria</i> , <i>Lanius collurio</i> , <i>Tetrao tetrix tetrix</i> , <i>Rallus aquaticus</i>
General characterisation of the site	Coniferous forest – 14% Broadleaved forest – 2% Mixed forest – 1% Meadows and bush habitats (overall) – 35% Agricultural habitats (overall) – 36% Peat land, marshes, shore vegetation, swamps – 10% Inland waters (standing and running) – 2%
Ownership	Property of the State Treasury, administered by the National Forests and the Mazurian Landscape Park

Source: Table based on the Standard Data Form for areas which meet the criteria of sites of community importance (SCI) (<http://natura2000.gdos.gov.pl/>)

Table 2

Identification data of special habitat protection areas (SOO)

Site name – Mazurian Marshes	special site protection area (SPA) KOD PLH28005
Area [ha]	1 569.3
Administrative region	Elk – 100%
Types of habitats	Old river beds and natural eutrophic water bodies Molinia meadows of variable humidity Lowland and mountainous meadows used extensively Bogs with peat forming vegetation Poor fens and swamps Oak-hornbeam forests (<i>Galio-Carpinetum</i> , <i>Tilio-Carpinetum</i>) Marsh and bog forests
Species mentioned in the directive annexes	
Birds	<i>Botaurus stellaris</i> , <i>Ciconia nigra</i> , <i>Ciconia ciconia</i> , <i>Circus aeruginosus</i> , <i>Circus pygargus</i> , <i>Aquila pomarina</i> , <i>Porzana porzana</i> , <i>Porzana parva</i> , <i>Crex crex</i> , <i>Grus grus</i> , <i>Chlidonias Niger</i> , <i>Dendrocopos leucotos</i> , <i>Luscinia svecica</i> , <i>Sylvia nisoria</i> , <i>Lanius collurio</i> , <i>Tetrao tetrix tetrix</i> ,
Mammals	<i>Castor fiber</i> , <i>Lutra lutra</i> , <i>Myotis daubentonii</i> , <i>Nyctalus noctula</i> <i>Pipistrellus nathusii</i>
Amphibians and reptiles	<i>Triturus cristatus</i> , <i>Bombina bombina</i> , <i>Bufo bufo</i> , <i>Bufo calamita</i> , <i>Bufo viridis</i> , <i>Hyla arborea</i> , <i>Pelobates fuscus</i> , <i>Rana arvalis</i> , <i>Rana esculenta</i> , <i>Rana temporaria</i> , <i>Triturus vulgaris</i> , <i>Anguis fragilis</i> , <i>Lacerta agilis</i> , <i>Lacerta viridis</i>
Invertebrates	<i>Leucorrhinia pectoralis</i> , <i>Lycaena dispar</i>
Plants	<i>Drepanocladus vernicosus</i> , <i>Liparis loeselii</i>
General characteristics of the area	Coniferous forests – 20% Broadleaved forests – 5% Mixed forests – 17% Meadows and bush habitats (overall) – 27% Agricultural habitats (overall) – 7% Peat land, marshes, shore vegetation, swamps – 24%
Ownership	Most of the area is owned by the State Treasury, administered by the National Forests, Forest District Giżycko

Source: Table based on the Standard Data Form for areas which meet the criteria of sites of community importance (<http://natura2000.gdos.gov.pl/>)

3. Materials and methods

The aim of the study was to develop a system and to present the capabilities of using GIS tools in monitoring the geographic environment of the Nietlickie Marshes. Materials obtained from the following sources and concerning the reserve were used in the study:

- 1) Topographic maps in the scale of 1: 100 000, 1: 50 000 in the PUWG-1992 system (N-34-80-A, N-34-80-B).
- 2) DEM data (.hgt files) obtained from the Shuttle Radar Topography Mission – SRTM-3. The 2000 mission of the Endeavour space shuttle devoted to interferometric radar scanning of the Earth surface; its aim was to provide data for developing digital terrain models (DTM).
- 3) SRTM-3 in approximate resolution of 3'' ($\Delta x = 60$ m and $\Delta y = 90$ m) for the area of Poland, are specified in the geographic coordinates of the reference system WGS-84. They are divided into segments, with each one covering a section of the Earth's surface with the dimensions of $1^\circ \times 1^\circ$ (Michalak 2004).
- 4) ASTER (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*), was launched from the Vandenberg Air Force Base, California, USA, with Terra as part of the NASA' Earth Observing System. ASTER collects data which can be used in different areas of earth science, for example, about changes that are taking place in vegetation.
ASTER GDEM has a resolution of 1", vertical accuracy is estimated at 20 m, and horizontal accuracy – at 30 m, it is made available in the GeoTiff format in the WGS84 system.
- 5) Graphic and descriptive data: commune borders, grid of coordinates 92 (file types: jpg, dgn, dxf, .txt).
- 6) Spatial data diagram from the Regional Directorate of Environmental Protection in Olsztyn, files in the .shp format: borders and forms of environmental protection, nature groups, other borders.
- 7) Graphic data in .jpg files (provided by Ms K. Glińska-Lewczuk), which were drawn in and exported from the Bentley Microstation programme: location of piezometers, hydroisobates, location of measurement points, types of ecosystems and infrastructure, map of forms of protection, touristic infrastructure, tree stands map, forest habitat types, map of actual vegetation, map of potential vegetation, map of plant species distribution, valuable animal species, location of threats.

Due to a broad range of preparations necessary to construct and present the capabilities of GIS tools in working out environmental data resources, the following method should be applied:

1. Develop a technology for constructing a system which meets the formal and legal requirements and select GIS tools.
2. Test the data with respect to compliance with the INSPIRE requirements. This stage focuses on harmonisation of data from different sources. Actions involve:
 - unification of formats,
 - unification of systems of coordinates,
 - arranging attributes.
3. Show examples of analyses and capabilities of the tools.

4. Work aimed at creating a GIS system for the Nietlickie Marshes

4.1. Legal grounds

International organisations which deal with geographical information have formally organised methods of using spatial data. Commonly accepted ISO 19100 standards have been developed as well as European standards accepted in Poland, including OpenGIS standards as well as the INSPIRE directive. Those documents, as well as instructions and current regulations, provide the basis for designing geoinformation systems devoted, for example, to environmental protection. They include:

- The Spatial Information Infrastructure of 4 March 2010.
- Regulation of the Minister of Environment of 12 May 2005 on preparing a draft plan of protection for a national park, a nature reserve and a landscape park, making alterations in the plan and protecting resources, creations and components of nature.

„§ 13. *Thematic maps, (...) are prepared in a digital form, using a spatial information system (GIS), in the national system of spatial reference (...)*”

- Regulation of the Minister of Environment of 30 March 2005 on the manner and scope of developing a draft protection plan for a Nature 2000 site.

§ 4. *Developing a draft plan includes:*

(...) 7) *developing thematic maps based on the national geodetic and cartographic resources or linked to points of the national geodetic grid, (...)*

- Regulation of the Minister of Environment of 17 February 2010 on developing a draft protection plan for a Nature 2000 site (J. of Laws No. 34, item 186).

§ 3. *The scope of work necessary to develop a draft protection plan for a site includes:*

(...) 9) *preparing documentation of a draft plan of protection assignments in an electronic form, developed in the form of a textual description, tabular specifications, graphic presentations, maps, databases, including digital information layers (...).*

4.2. Selection of design tools

Presentation of the GIS tools capabilities will require actions aimed at developing a system for the Nietlickie Marshes area. Tools for developing the design (Fig. 3) should be selected at the planning stage.

Object-oriented technology of creating information systems was chosen for execution of the GIS system project. A GIS software package – ArcGis Desktop 10 – developed by ESRI, was selected. Auxiliary database software (Access, MySQL) as well as data combining and transformation software (Safe Software Feature Manipulation Engine) was also used. The preparatory work involved acquisition of additional data, for which Geoxa Serwer and GlobalMapper software was used.



Fig. 3. Examples of GIS (information processing) software
Source: prepared by the author

4.3. Developing data structure in accordance with the INSPIRE requirements

Identification data for special areas in Table 1 and 2 in the system being developed should be presented in accordance with the Standard for GIS data in environmental protection. The aim of the standard was to develop guidelines, which provide an opportunity to create unified spatial data for the entire country, which cover the natural environment and environmental protection. Only after being transformed at the central level (analysis, interpretation, generalisation) can the databases become material conforming with the INSPIRE directive.

Currently, the GIS data standard (version 3.03.01) applies; this study takes into account data subjects contained in Directive 2007/2/EC of the European Parliament and the Council (INSPIRE) of 2007 (the data subjects are presented in appendixes I – IIP to the Spatial Information Infrastructure Act of 2010). The GIS data standard for nature protection is a proposition of architecture of a comprehensive GIS system, which is to manage environmental data. The standard defines a system of coordinates in which spatial data are accumulated, as well as the data format; it also defines structures of object classes, dictionaries and symbols with which information on maps should be presented.

Detailed structures of spatial data for the system have been developed with class diagrams in the UM notation as conceptual schemas. A fragment of drawing 4 presents only those data diagrams which are necessary in order to develop a system for the Nietlickie Marshes area.

An example of description of object classes according to GIS standards (class of habitats of mammal species and class of boundaries of ecological habitats) is shown in Fig. 5a and 5b.

The main classes of objects present in the area of the Nietlickie Marshes were specified based on the diagram of spatial data, provided on the website of the Regional Directorate of Environmental Protection in Olsztyn, using the catalogue of classes available in the GIS data standard for nature protection. Each class was assigned attributes which arise from the requirements contained in the standard and from the requirements of users of an environmental protection unit. Data types for the attributes were defined and relationships of classes were created. Different types of relationships between object classes were proposed: links, generalisations, total aggregations.

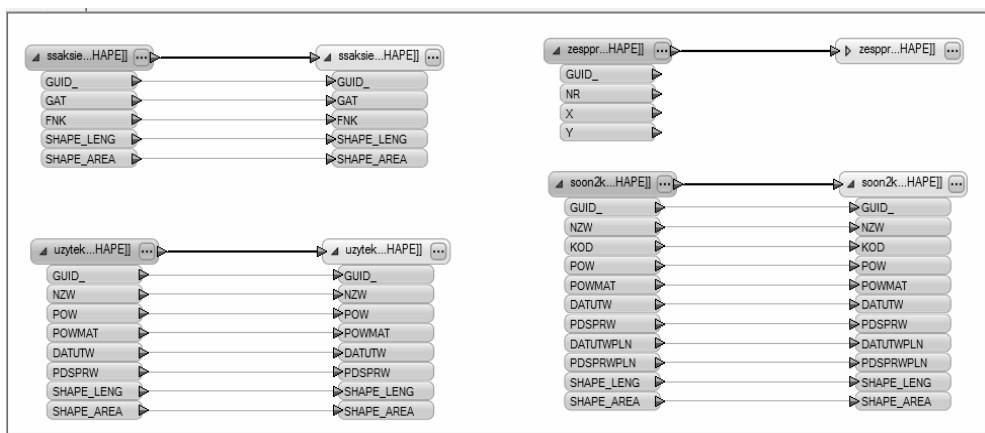


Fig. 4. Links of examples of object classes in the Nietlickie Marshes, presented in accordance with the standard: habitats of mammal species, boundaries of ecological habitats

Source: FME Studies, data from the diagram of the Regional Directorate of Environmental Protection

a)

Siedliska gatunków ssaków							Geometria	Poligon
ssaksied_ajt								
Nazwa pola	Typ danych	Dozw. PUSTE	Domena / Format	Precyzja	Skala	Długość	Opis	
guid_	GUID	Nie					Identyfikator unikatowy globalnie GUID (np. {530F3B5C-0156-49F4-B536-89AC1BE75C8B}) siedliska gatunku	
gat	Short	Nie	gatssk	3			Gatunek ssaka	
fnk	Short	Nie	fnksdl	1			Funkcja siedliska (dopuszczalna wartość domeny to 'zerowisko')	
Uwaga: Do bazy danych należy wprowadzać jedynie obszary wykorzystywane przez gatunki ssaków jako żerowiska								

b)

Granice użytków ekologicznych							Geometria	Polilinia
uzytekol_ajt								
Nazwa pola	Typ danych	Dozw. PUSTE	Domena / Format	Precyzja	Skala	Długość	Opis	
guid_	GUID	Nie					Identyfikator unikatowy globalnie GUID (np. {530F3B5C-0156-49F4-B536-89AC1BE75C8B}) formy ochrony przyrody (identyfikator musi mieć jednakową wartość w klasie obiektów uzytekol_pft, uzytekol_ajt, uzytekol_ajt dla tej samej formy ochrony przyrody)	
zrdopsgm	Short	Nie	zrdopsgm	1			Źródło opisu granic	

Fig. 5. a and b Classes of objects from Fig 4, described in the GIS data standard for nature protection

Sources: GIS data standard for nature protection (Łochyński, Guzik 2009)

4.4. Harmonisation of data from different sources

Acquisition of data from different sources is associated with the need to unify systems of coordinates and data formats. It is a labour-consuming process as it requires generation of data in the appropriate system of coordinates, i.e. transformation to an adopted format of data to SHAPEFILE files and the PUWG-92 system (Gaździcki 2004).

It consists of several stages:

- graphic preparation of map sublayers and fitting in rasters (topographic maps) and creating raster catalogues,
- object vectorisation (.jpg files with location data for piezometers, measurement points, etc.),
- overlaying a vector drawing (map of protection forms, tourist infrastructure, map of tree stands, types of forest habitats, map of actual vegetation, map of potential vegetation, map of plant vegetation distribution, valuable animal species, threat locations),
- generating SHAPEFILE files in the ArcCatalog (for point, linear and planar objects),
- loading data to the rheobase (file formats: .jpg, .shp, .dgn, .dwg).

The effect of combining data from different sources and of different formats is presented in Fig. 6; those are thematic layers, grouped according to sources from which they were acquired (printout from the ArcMap application).

The GIS system development process should also employ auxiliary tools, such as: Geoxa (Fig. 7) and Global Mapper (Fig. 8) in order to determine the usability of such materials as: data provided by WMS and WFS services as well as satellite data.

WMS (*Web Map Service*) – is a standard of making raster data (maps) available on the Internet.

WFS (*Web Feature Service*) – is a standard of making vector data available on the Internet.

4.5. Testing the system for the Nietlickie Marshes

Using the layer files, it is possible to prepare sample thematic maps in the ArcMap application: map of distribution of SBP or SPA objects. Data accumulated in the base can be used to present the processes and phenomena in the geographical environment and to present spatial analyses between the phenomena.

For example, one can analyse in Fig. 9 where black grouse occurs (yellow elongated area – sites of winter rest) and the area where it occurs (dark green – marshy ecosystems) and whether there are cranes in the area (yellow circles).

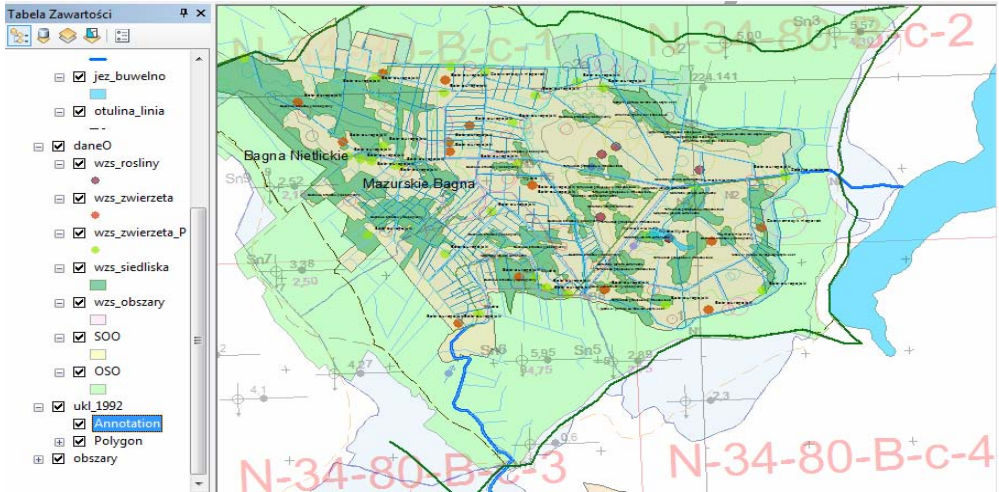


Fig. 6. Thematic layers – data integration from different sources and formats
 Source: Map in Esri program in the ArcMap application, prepared by the author

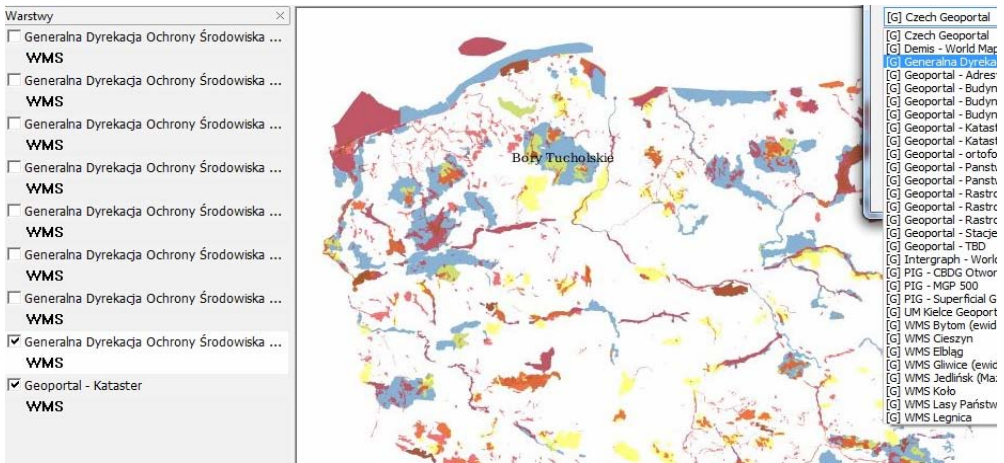


Fig. 7. WMS servers of the General Directorate of Environmental Protection – image from the Geoxa server (blue – special bird protection areas, red – special protection areas)
 Source: prepared by the author

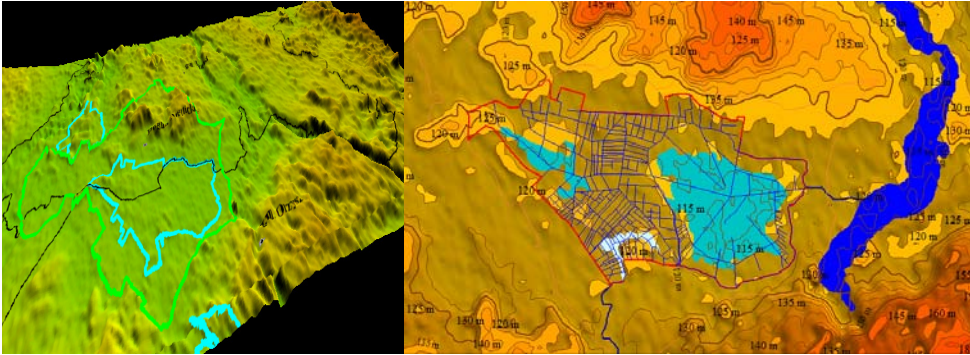


Fig. 8. NMT based on SRTM-3 data and contour presentation of the Nietlickie Marshes area (images from the Global Mapper programme)
Source: prepared by the author

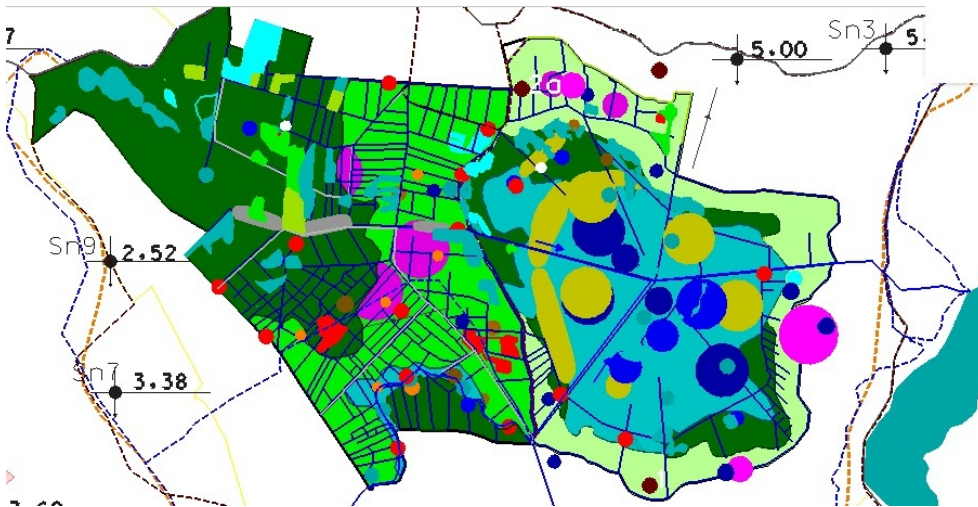


Fig. 9. Graphic data – .dgn from .jpg files
Source: prepared by the author

Fig. 10 shows an analysis in which the vector layer which shows flowing water bodies was selected from the project. The selection criteria was that the ditches' width should not be lower than 1 m.

Whereas Fig. 11 shows a selection of layers: flowing water bodies and beaver dams. The selection criteria was that the ditches' width should not be lower than 1 m and that there should be a beaver dam near it.

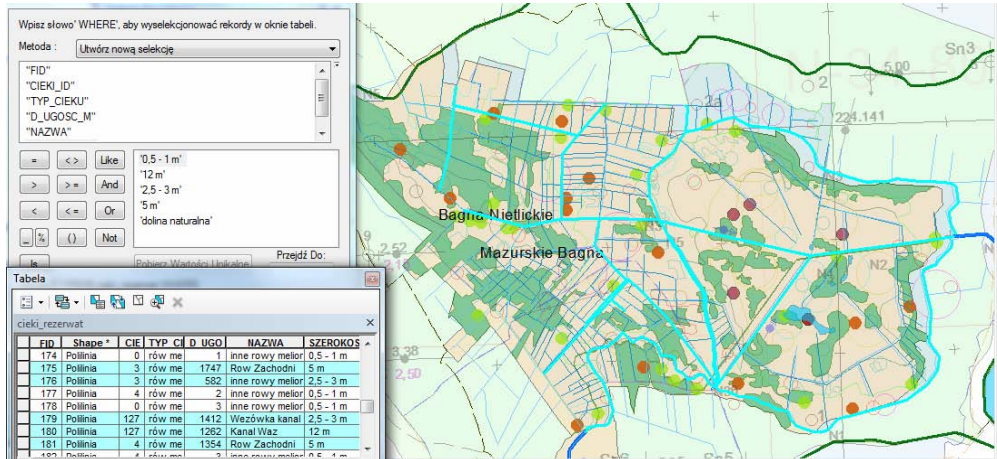


Fig. 10. Example of ditch choice from the ArcMap programme
 Source: prepared by the author

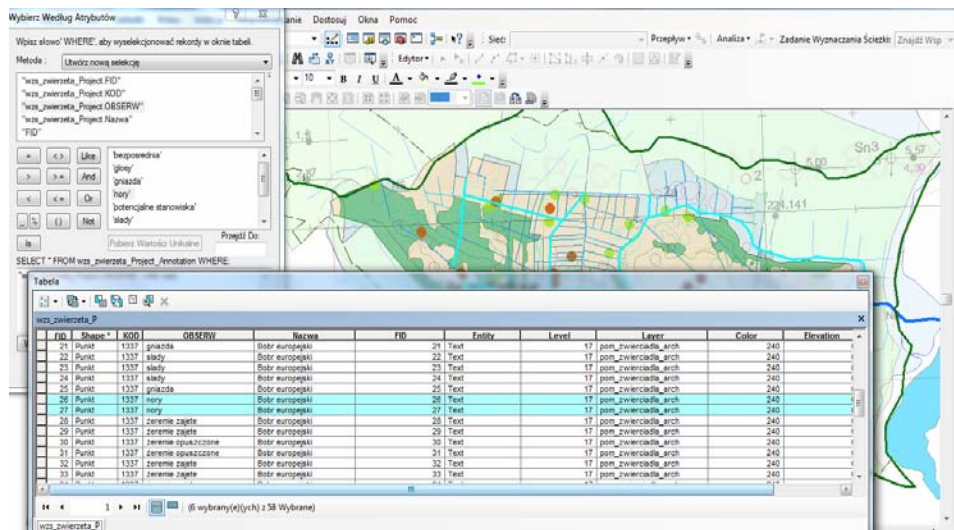


Fig. 11. Example of selection of occurrence of a flowing water body and a beaver's dam
 Source: prepared by the author

Another analysis concerns a situation when a river floods an area up to a distance of 10 m. Fig. 12 shows that a dam of a Eurasian beaver could be flooded.

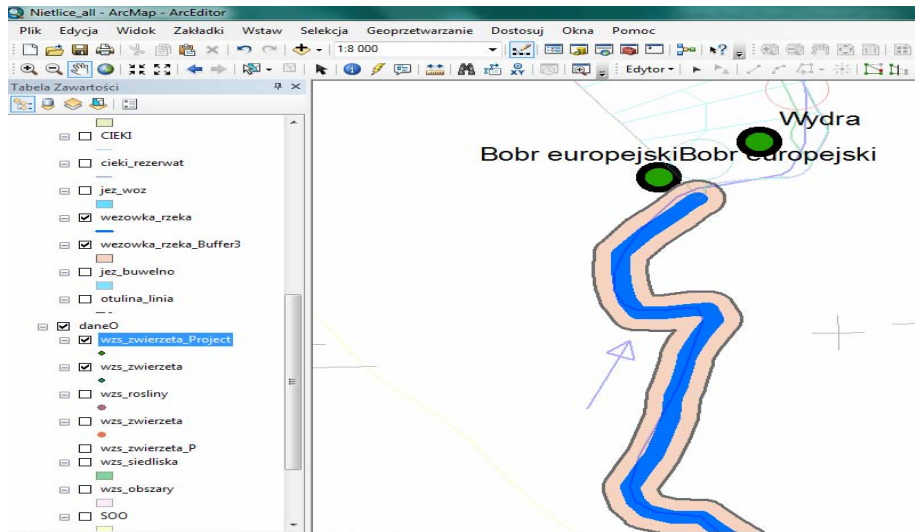


Fig. 12. Assuming a buffer of flooding an area of up to 10 m by the Węzówka River
Source: prepared by the author

5. Summary

It was mentioned in the introduction that taking up the issue of using GIS tools is caused by the need to create spatial data infrastructure.

Analysing the available materials and legal regulations and reviewing existing geodetic software shows developing the GIS system is very labour consuming. The test system for the Nietlickie Marshes required time-consuming analyses to determine the usability of input materials and their preparation. This shows that a system has to be developed so that options available in GIS tools can be used. Meanwhile, according to the Act (SII 2010), developing spatial information infrastructure in Poland will contribute to improvement of policies and to streamlining of actions which require knowledge about the space delimited by the national borders. These issues require urgent consultation with many existing and potential specialists.

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Web Site WWW:

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SRTM-3 for the area of Europe: <ftp://edcftp.cr.usgs.gov/pub/data/srtm/Eurasia/>

The General Directorate for Environmental Protection: <http://olsztyn.rdos.gov.pl/>

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