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GEOINFORMATICA POLONICA
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JOANNA BAC-BRONOWICZ[1]

ACCURACY OF THE EXISTING GEO-INFORMATION SOURCES RELATED TO POINT DATA USED IN DIGITAL CARTOGRAPHIC MODELS

Key words:

georeference point data, distribution of natural elements, accuracy of geoinformation, climate, geographic information system

Abstract

In the models created on the basis of georeference data in GIS systems, spatial data quality should be precisely given to avoid exposing the users to inaccurate results of geographic analyses. It is important to provide precise information in database about conformance quality level as well as information about the accuracy of data visualization so that the user would be warned when trying to use data of low accuracy. Quality is used to determine fitness for use. Thematic accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships have to be known to make a spatial decision based on cartographic model. It concerns mainly information which is the basis for making decisions, sometimes quick, and made in critical situations. In the present paper, the parameters which describe environment and features of agricultural production are the examples of various accuracy of existing sources.

DOKŁADNOŚĆ GEOINFORMACJI UZYSKIWANEJ Z MODELI KARTOGRAFICZNYCH STWORZONYCH NA PODSTAWIE INFORMACJI PUNKTOWEJ

Słowa kluczowe:

georeferencyjne dane punktowe, rozkład przestrzenny elementów przyrodniczych, dokładność geoinformacji, klimat, system informacji geograficznej

Abstrakt

W modelach tworzonych na bazie danych georeferencyjnych w systemach informacji geograficznej jakość danych przestrzennych powinna być określana szczegółowo. Przy wykorzystywaniu geoinformacji muszą być brane pod uwagę elementy dotyczące jakości danych i uzyskanych na ich podstawie modeli kartograficznych (ich poziomu jakości). Jakość jest stosowana do ustalenia przydatności zbioru danych lub informacji do użycia w określonym celu. Dokładność

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tematyczna atrybutów ilościowych i poprawność atrybutów nieilościowych oraz klasyfikacja obiektów i ich związków musi być także określona przed wydawaniem decyzji na podstawie modeli kartograficznych. Pozwala to na uniknięcie, przez użytkowników, nieścisłych wyników analiz geograficznych. W tym artykule pokazano problem różnodokładnych i niejednakowo reprezentatywnych danych na przykładzie elementów środowiska przyrodniczego mierzonych punktowo, warunkujących produkcję rolniczą.

1. Introduction

Since there is a need to work out new or process the old plans, there is a necessity to begin with defining potential dangers, indicate possible places where they may appear and estimate potential results. Studying the methods that evaluate danger is going to be easier when critical situations which can appear in administrative district, province, country or region, are worked out. The author of a model is responsible for the choice of data and, what follows, the accuracy of final information which can be read from the cartographic model. It is especially important in the times of quickly created systems of spatial information which accelerated and simplified acquiring information and its transfer. Due to those systems, the big sets of data can be quickly and simply integrated.

Self-reliability of GIS users is often noticed in the early stages of modeling particularly in linking data from different sources, times of measurement, accuracy, measurement's scale and initial maps' scale (Zhang, Goodchild 2002, In Elements 1995). It seems that during the early stages of GIS construction, the help of various specialists is needed as well as the help of cartographers in the final phase of users' work. Geomatics Scientists should become a sort of "an interface" in GIS when it comes to data harmonization or integration, modeling and visualization (Konecny 2004, Kowalski at al. 2010). In order not to draw wrong conclusions about spatial data distribution, not only the knowledge of narrow specialization's definitions is needed but first and foremost geoinformatic knowledge consisting of geographic and cartographic knowledge as well as computer science. All users of GIS may become specialists in cartography since they can use competent tools for modeling data and their visualization. We should not be surprised that they also want to become the authors of maps which are an effective and final part of studies being the outcome of long, complicated and expensive research. That's why the natural range of cartographers' activities is changing. Cartographers should become an "interface" in GIS when it comes to data choice and visualization as well.

When creating cartographic models on the basis of average values of parameters which describe the environment, one should pay attention especially to initial data and data taken from databases which have too generalized or invalid content. Such data are often the only available values which are entered into systems of geographic information. The models of such phenomena distribution are often interpolated on the basis of generally accepted set of criteria for the entire area, and then particular values are attributed to the basic fields in the studied area.

Compiling maps which will be used for making decisions while creating different types of systems, which take into account the needs at the central and regional level, requires especially careful choice of data, the way of their processing, and the presentation of the results. The correctness and usefulness of the results of cartographic modeling extremely depend on authenticity, accuracy and representativeness of data. Creating the models of distribution of phenomena should be carefully thought over. The most important aspect is to find reliable data. We should also check not only the reliability of data but also the aim they were prepared for. Then, the aim of the model's creation should be set along with the required accuracy, time and expenses (Pravda, 2004). Computer programs that do not allow for the verification of the correctness of modeling should not be used, as we cannot be sure that the effect of modeling will be consistent with the reality. The complex model can give us completely different view on the reality than the one that is individually worked out for each set of data. Complex studies usually concern natural disasters, communication, economy, environment protection etc. They are created by groups of people who are specialized in a specific subject and often do not accept the influence of information gathered by other governments, nor the components which define the complexity of a phenomenon or a process. We think of different kinds of additional information like, for instance, indicating terrains which will be first flooded if the water level rises. Information concerning the probability of flood danger is essential while solving various theoretical and practical problems. This kind of information can be found in different maps concerning a variety of issues connected with environment protection. Linking data from DTM, connected with the average height of water level and the height of terrains near the rivers, is the most popular way of modeling. It takes into account the slant of terrain. Even if the model is created correctly but it does not meet all the above mentioned factors, it is not going to be useful. Specialists who deal especially with floods will also take into account such important information as historical data. If water had flooded the particular terrains in the past, the same will happen in the future unless the dikes are built. It often turned out that the small accumulation of water in the same place, in which the river narrowed and curved sharply to the left because of, for example, a hold-up caused by trees is enough for all calculations to appear not reliable. Analyzing maps created after floods in previous years lets us predict which terrains will be flooded if the water level in main river rises and the tributaries will not be able to take water away. We are also able to predict which terrains will be cut off during the first, second and the next days of the flood.

The author suggests that the specialists in various spatial phenomena distributions should prepare aids related to the so-called phenomena explaining the distribution of other phenomena. As an example, different kinds of geographic units can be given. What characterizes such units are, among other things, the height above the sea level, drop of terrain, exposition, maximal drop and soil permeability. It seems that while working on some of those issues connected with the distribution of, for instance, climate parameters' values, natural disasters caused by intensive precipitation, flood etc., such help could be used instead of including in the distribution's model all the accessible physiological and topographical data, and to prevent modeling the phenomenon many times on the basis of a few indicating points, especially if one is not a specialist in geography (Bihari, 2000). In a similar way we can differentiate areas which have similar groups of accompanying and affecting the phenomenon distribution factors, for instance, for temperature distribution, the units which are typical of that area's values above the sea and southern or northern slopes. The maps produced using the methods which incorporate topographic factors were found to reflect better the large and small scale variations in the spatial distribution of temperature.

In this paper it is suggested that some characteristics of data which concern the quality of original, initial data and the way of their processing should be entered into the database in order to assure that data obtained from each field which indicates areas of homogeneous conditions, are reliable.

2. Various aspects of initial data reliability for cartographic modeling

While compiling maps it is very important to choose current data, process them, present and make them available. The correctness and usefulness of the process of cartographic modeling directly depend on the reliability, adequacy and also representativeness of the data (Bac-Bronowicz 2003a). These elements may be treated as the assessment of data quality and as a measure for suitability of data for specific applications. Environmental data sets usually have both: temporal and spatial components. Different aspects of accuracy have been presented using as an example the collection of characteristics connected with environment and demographic features. Accessible data are the result of measurements. Accessible sources of data represent different levels of reliability with regard to their spatio-temporal representativeness. Each database has to provide information about the time and date of registered features, and their localization. If the measurements which are used for evaluating phenomena are taken in a net that is not dense enough and without the possibility of their verification, then the responsibility for such a model is huge. In such a case it is crucial to provide metadata which include: the way of gathering data, aims for which the model was constructed and evaluation of data accuracy (Norma PN-EN-ISO 19114).

2.1. Spatial data positional accuracy of indicating elements

Determining the localization of measurement points, lines or areas is a very important element of the preliminary phase of the research. Depending on the type of information it is possible to specify the localization by: localizing an object by coordinates, localizing on the basis of other cartographic sources, or reading from descriptive information in relation to other topographic or thematic objects.

We often meet different illustrations of the same geographic elements. It depends on the sources, their scale, purpose and topicality. Typical set of such illustrations is presented in figure 1. Data come from databases managed by Polish national maps agencies: Topographic Database (TBD;1:10'000), Vector Map (VMAPL2; 1:50'000) the first and the second edition, General Geographic Database (GGD; 1:250'000 – similar EuroRegionalMap).

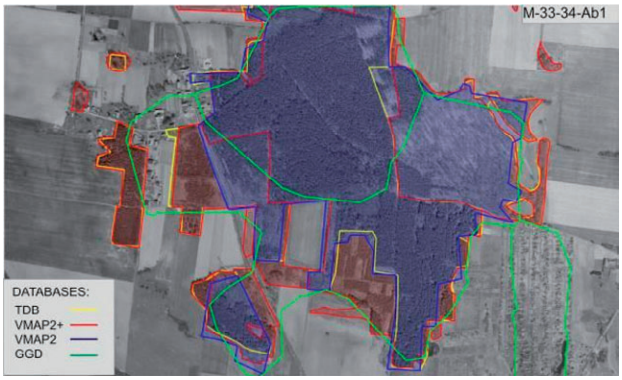

Fig. 1. Visualization of different databases from cartographic resources- "Forest"
Rys. 1. Wizualizacja warstwy "Las" z różnych baz georeferencyjnych

Nowadays, topographic information used for different aims and for different levels of accuracy, comes from maps and geographic databases which are made on the basis of different sources like, for example, topographic maps which were issued many years ago, or from the databases developed basing on an analogue, 1:50 000 scale map. That is why, in many cases, various institutions which create thematic databases and maps must independently update topographic data (Bac-Bronowicz et al. 2007, Głażewski at al.2010, Kowalski et al. 2010). Unfortunately, not all maps have been updated with the use of photomaps.

If the researched area is not covered by uniformed topographic or thematic base of the entire studied area, there is a possibility to use simultaneously different sources in different areas due to Multiresolution Database (MRDB). In order to keep control over the reliability of the sources used, it is important to create additional layer in MRDB which shows the borderlines of various sources together with full information about metadata: the time and the way of data gathering, data resolution and others. The objective of MRDB is not only to propose the rules of development of a multi-resolution reference topographic database for the entire country (Bielecka et al. 2007), but also to develop assumptions and develop the plan of integration of various registers of spatial data. The existing registers are maintained by various state institutions; the co-operation of those registers has been considerably limited. Therefore, MRDB database would allow creating a platform of integration of state registers of spatial data. At the same time, the multi-resolution topographic database should be developed in such a way that it could become the basis for development of governmental thematic databases. The results of those processes are not utilized for the needs of updating the state resources of geodesic and cartographic data. Such an approach often results in multiplication of the same works, i.e. development of many databases, the integration of which is very difficult. On the other hand, developers of thematic databases have access to several topographic databases: VMap, TBD, GGB. However, these are highly differentiated and not mutually related databases.

Topographic maps of Poland which are commonly used have different systems of coordinates and also different ellipsoids of reference. That can cause serious inaccuracy of the model. Despite compatible geographic reference systems in linking data from two neighboring countries, there can be a difference in the reference level. Precise knowledge of the way of localization is essential if we want to link data obtained from maps which include information described by GPS (Fig.2). It is as if we had a checked carpet that has a determined location and in different co-ordinates it had to be moved about 130 meters to preserve its location. If in the basic fields worked out on the basis of gradual separation of geographical co-ordinates, the data of, for example, the land cover were gathered, then the data obtained from reference fields constructed in the same way in a different layout cannot be used for comparisons or for linking the data. While linking data from different sources we should remember that depending on the projection, the basic field of 1 km square which has the same corners' co-ordinates cannot be referred to the same surface. Differences between co-ordinates will be important when the accepted recognition of details in the map, which is 0,3 mm, will correspond with lengths shorter that 130m in terrain, that means that scale must exceed 1:400'000.

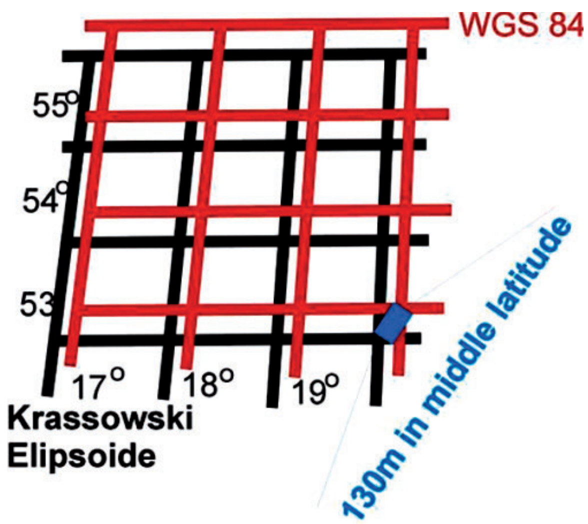

Fig. 2. The point which has determined geographical co-ordinates on ellipsoid WGS-80 about 50 parallel will be found about 130 meters from the point which has the same geographical co-ordinates which are estimated for Krassowsky ellipsoid

Rys. 2. Punkty o jednakowych współrzędnych wyznaczonych na podstawie WGS-80 i z elipsoidy Krassowskiego, na powierzchni rzeczywistej Ziemi są odległe o ok. 130m.

2.2. Representativeness of the place of measurement

Surroundings of a measurement point have a great influence on the value of the measured characteristic, especially in environmental research where attributes depend on external conditions. Phenomena connected with the climate very much depend on the relief and absolute height, for example, the precipitation has a low variation rate within the lowland.

The measured object should be located in the place where technical and environmental conditions are steady. Information about features of the terrain represented by specific stations are included in the measurement reports. These are: plain, seaside-plain, plain and lakes, wide river valley, valley slope, hills, steep slope at a lake, hills and lakes, slope of the plateau, foothills, plateau, large clearing. It means that certain measured values are valid only for the same landscape unit and further "spreading out information" should be conditioned by the analysis of the surroundings. The shape of the terrain where the station is placed, whether convex or concave, has also great an influence on the data.

2.3. Stability of the survey point's localization

The change of the measurement point's location can change the conditions of the observation. If the measured parameter is as variable as precipitation, the change of the altitude of the measuring station during the survey period can alter the value in the database. Stations are moved because of many different reasons. Many stations often changed their location, but the method of the parameter value correction is known for those points. Nevertheless, the information about the change of the measuring point's location should be noted in the database. Changes of the surroundings that occur in time (the construction of new buildings, growth of trees, etc.) should also be taken into consideration. The stability of the survey point localization is especially important when using mean values from long measurement's periods to analyze the changeability of the parameter in time. It concerns also the changeability of the localization of centers of administrative units if, in the analyzed period, there were administrative changes such as an extension of built up areas, change of unit affiliation, fusion of units.

2.4. Representativeness of measurement periods

There are many strange characteristics important in different domains of science, like for example in agriculture and protection of natural environment in the broad sense. For example, for precipitation the following are taken into account: precipitation sums on monthly and annual basis; precipitation sums on daily basis; number of precipitation days; maximal snow depth; downpours and rainfall of high density; hail, snow and thunderstorm data; snow cover water equivalent.

Information concerning given station consists of the list of data related to different climatic periods. The choice of particular period depends on the GIS user's needs. It seems that in some cases it is better to use special elaborations than enter available data into the model, for example, months' or years' average etc. For instance, users should know the limitations resulting from the agro-climatic factors. In the atlas of climatic risk of crop cultivation for plants, the periods of the highest risk are shown and they are described as areas. It helps us to estimate the risk of appearing conditions unfavorable for individual plants, in every unit of the system, and avoid including into the model additional data from few meteorological stations, which are obtained, for example, from such periods as for potatoes (11.03-30.04) or maize (11.07-31.08) in southern part of Poland.

When in the studied area a measurement station does not exist, there is a need to put some information about the determined probability of the climatic conditions analogy, which denotes in what way the next unit would be similar and whether the information could be removed. It would be a kind of meteorological uniformitarianism – the theory that meteorological phenomenon may be explained as a result of existing forces operating in the past.

This example may be chosen for Lower Silesia Region, because the reliability of the parameters depends on taking into consideration suitably long periods of observation. It can be used when the present numbers of monitored points and their distribution are not sufficient but when we have historical, non-continuous up to date data (above 400 measurement points). Although many stations do not exist nowadays, it is possible to divide the monitored territory into micro regions. Subdivision is possible due to historical data bank. Presently there are about 50 monitoring stations left (on average – 1 station for 100 sq. km).

While predicting situations such as heat, frost, tectonic movements, flood, fire in forest, we should also choose periods when those phenomena are the most probable to occur. For example, in the analyses of precipitation, the observations from at least thirty, or better forty years, can be used for detailed comparisons. Observed annual precipitations' sums show the lowest variation in comparison with other precipitation parameters. In case of a shorter period of observations the analyses of data should be more detailed. In extreme cases, maximum daily precipitations can be used.

2.5. Density of measurement network

The phenomena and processes which are interesting for people are often characterized by their continuous occurrence, and that is how their changeability is presented in maps. But not exclusively. The continuation often precedes visualization of abstract features, for example, of non - continuous phenomena such as density of observation networks.

Density of data points, sufficient for creating a continuous model with the determined accuracy representing feature's distribution, should be created based on the existing data bank which is available for GIS users. This statement is especially important in the age of fast development of spatial information systems, which accelerated and simplified gathering and transferring data. Thanks to these systems, existing data files can be easily and quickly integrated into the large data collections. The dense network of stations measuring parameters, whose spatialization depends on topographic conditions, for instance, spread of air pollution, is required especially in mountains and hills, because of a very strong influence of relief. Also, the localization on a northern or southern slope influences measured parameters. The best solution is to place a station in each unit separated by different topographic conditions, so as to make the data representative for the whole area. Existing networks do not meet those conditions.

For example precipitation as meteorological phenomenon not constant in time and space is characterized by local, sometimes big differentiation when it comes to the value of precipitation, its intensity and spatial extent (Bac-Bronowicz, Dancewicz 2005, Observation…2010). The correct interpretation of precipitation data obtained from point measurement creates huge methodological problem while creating cartographic study of precipitation maps. It concerns mainly the differentiated environment such as mountainous terrains or urban areas. Extrapolation of data and information obtained using point measurements in neighboring terrains is crucial when it comes to their further usage. For instance, just to state the fact of precipitation occurrence, the big density of measurement net is not crucial. The situation is different if there is a need to estimate precisely the sum of precipitation or indicate the range of intensive precipitation for example for insurance claims. It happens quite often that active measurement stations do not mark insensitive precipitation while in other part of the city or region the precipitation is quite intensive and it causes big financial damage. A correct estimation of the phenomenon requires having enough measurement data. Opinion given on this basis determines the decisions of refusing or paying compensation. Practical example may be given on the basis of observations in Wrocław, the place of residence of the authors. For research aims the 10-year-period 1963-1972 was chosen. It was the period in which the density of measurement net was the highest – 32 stations. During the 60-year-period the density of the net underwent frequent changes and in 2008, in the analyzed area, there were only 17 stations of institution net (Institute of Meteorology and Water Management, Branch of Wroclaw) and 2 scientific stations. Comparing to the period of 1963-1972 the reduction of net's density reached 1/3 for the whole area and for Wroclaw it reached 50%. Having measurement data from the period of 1963-1972, a few cases of intensive daily precipitation and mean annual sums from the 10-year-period were chosen for further analyses. Precipitation maps made for 32 and 19 stations and with different isohyets interval (10 and 20 mm) underwent further analyses. For the cases characterized by different spatial distribution of precipitation sums, that is - having a few centers of high precipitation sums, the layout of isohyets becomes more irregular and complicated (Fig. 3 and Fig. 4). Apart from the changes in the layout and extent of isohyets (for instance 10 mm) also a clear difference for

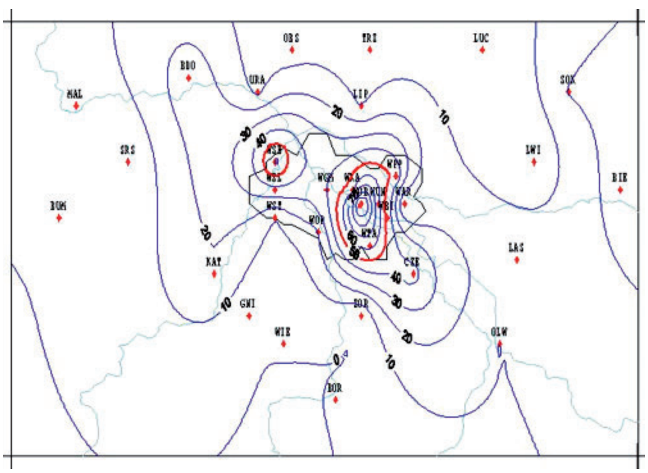

Fig. 3a. Distribution of precipitation - June 1971, on the basis of 32 stations operating in 1971

Rys. 3a. Rozkład opadu atmosferycznego w lipcu 1971 r., wyznaczony na podstawie pomiaru w 32 stacjach istniejących w 1971 r.

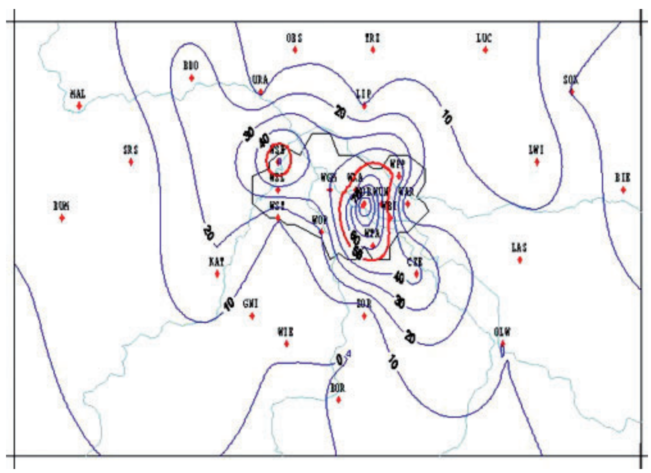

Fig. 3b. The same observation period. Distribution on the basis of 19 stations operating in 2008

Rys. 3b. Ten sam okres obserwacyjny, rozkład wyznaczony na podstawie wartości w 19 stacjach istniejących w 2008 r.

isohyets 50 mm and for higher value isohyets is noticeable. In Fig. 4, two areas of precipitation higher than 50 mm are clearly visible while the lack of "WGM" station results in the fact that two areas of precipitation higher than 50 mm make one big district (Fig. 4). That is why the new problem appears. It turns out that for the terrains situated in the "WGM" station's surroundings, the height of real precipitation level rose from about 40 mm to 60-70 mm. In that case the precipitation reached 50-70% of real precipitation. This value is significant. The small number of measurement stations may cause the vast loss of information concerning the real precipitation quantity in the region and huge generalization of isohyets layout.

The choice of values of isolines must correspond with the range and type of changeability of features and with the values significant for the described processes.

An imprecisely chosen set of isolines may additionally result in the fact that for the non-research areas the values of real precipitation can vary significantly – even by 70 %. For the urban areas the density of the precipitation measurement net should take into account the terrains' surface which has great influence on the spatial precipitation distribution.

The remarks presented above can be used while planning and organizing the precipitation net in urban areas and in works on reorganizing and reducing the existing net. Moreover, they can be used for interpreting precipitation materials while elaborating and editing precipitation maps. From the meteorological point of view, those remarks provide important information about the precipitation course in urban areas.

3. Models on the basis of point data. Reference units and transfer of data

The accuracy of data gathered from the model which was constructed on the basis of spatial information system will depend on the type and size of the reference unit (natural or geometric). Cartographic models created on the basis of data used in operating systems, as well as bases for natural (for example physiographical) or administrative units, can be created during research and analyses, as well as during intervention activities connected with, for example, agricultural needs. The most popular method, such as choropletic maps (especially cartogram), can be very useful when it comes to providing information about the intensity of phenomenon and its spatial layout. The accuracy of information transfer depends on accepted division into classes and accepted reference units. The selection of the reference unit, which is accommodated to the needs, details level and the accuracy of the compilation scale, make a very important point of the construction of the spatial information system.

3.1 Geometric basic units

Geometric basic units of the system can be aggregated in adequate areas on the basis of their localization in certain regions. Such areas will have homogeneous climatic, morphologic and hydrographic conditions. They can be also the basis for the analysis of distribution of other environment-dependent phenomena, such as different types of pollution or soil erosion. Classification can be used to evaluate the usability of areas for different purposes or to predict the outcome of investments and many others. In order to make the transfer of information more reliable, it is important to prepare a system in which the user would get information about the reliability of data gathered in measurement points and referring to the area around the station. The author's proposition of such information transfer from measurement point is presented in Fig. 4.

Because we deal with point data referring to spatial phenomena, this reliability would differ depending on the distance from the station and the topography of terrain. A correct determination of probability distribution is significant in that case.

The most useful parameter to determine homogeneity in the surroundings of a measurement station (apart from the distance of the field from the station) is the difference of height between a measurement station and basic fields, which are placed in the zones of information transfer of the a given station. It was assumed that the influence of height difference on spatial information transfer is the same as the influence of the distance from the station. For instance the probability should have a lin-

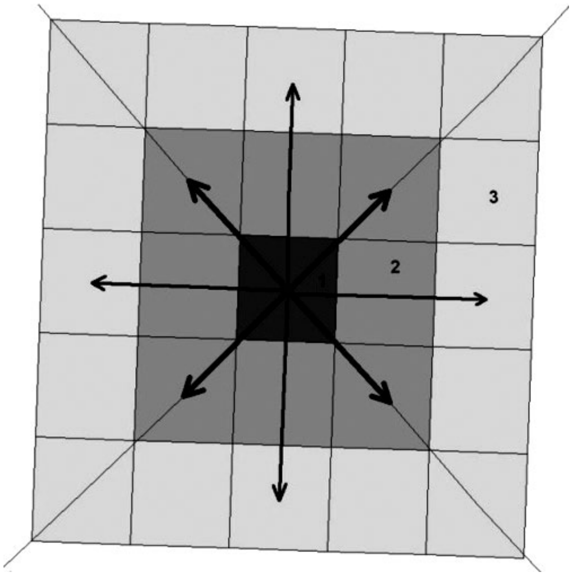

Fig. 4. Transfer of information from basic field which includes data in point to adjacent areas - the zones are of 1 km.
1. – the 1st zone with a measurement station, 2. – the 2nd zone etc.

Rys. 4. Przeniesienie informacji z pola podstawowego zawierającego daną w punkcie do stref sąsiednich – strefy 1 km.
1 – 1. Pierwsza strefa, 2. – druga strefa itd.

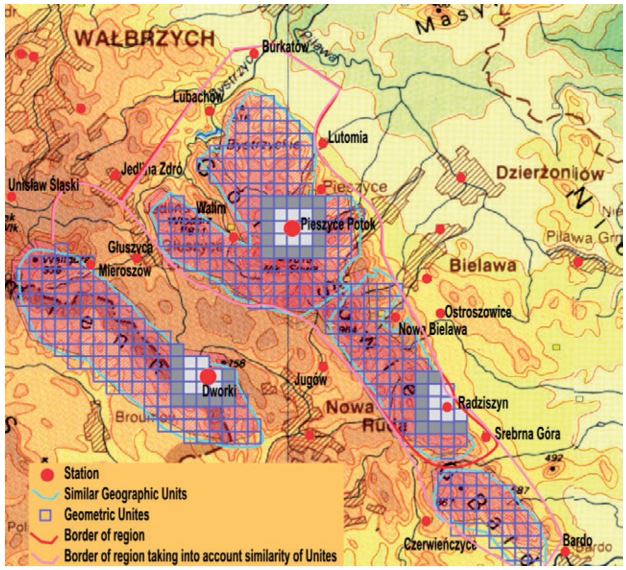

Fig. 5. Indicating continuous information in natural units on the basis of classified geometrical units

Rys. 5. Wyznaczanie informacji ciągłej w jednostkach naturalnych za pomocą pól gridowych

ear distribution up to the 6th zone inclusive. In the 1st zone of information transfer the probability is 100% so probability is 1. In the second zone it diminishes to 0,9 in the 3rd to 0.8, in the 4th one – 0.7, in the 5th one – 0.6 and in the 6th one – 0.5. From the 7th to the 9th one it is 0.4. If we wanted to cover the whole area with the next zones of information transfer, it could be accepted that from the 10th to the 11th zone it would be 0.3, from the 12th to the 15th one – 0.2, from the 16th to the 20th one – 0.1 while in the 30th zone the probability would be 0. Obviously, many other possibilities of ascribing different probability levels to different factors can be accepted. If we have acceptable differences of height for information transfer then, from the tables as in Fig. 6, we can choose those fields which answer the accepted variances. For example, we allow for the differences of information transfer in the zones 1 and 2 to be more or less 20m between the station and elementary field; in 3 and 4 to 30m and in 5.6 and 7 to 40m. In the presented example, only 19 elementary fields will be excluded from qualification of information transfer from the measurement station. Geometric basic units of the system can be aggregated in adequate areas basing on their location in certain regions. Those units can be used for the entire area and for the chosen surface units, which is presented in the next chapter.

3.2. Physiographical basic units

Such areas will consist of homogeneous conditions for example climatic, morphological and hydrographical, they can also be treated as the basis for the analysis of distribution of other environment-dependent phenomena, such as different types of pollution, rainfall or soil erosion. The presented classification can be used to evaluate the utility of areas for different purposes, forecast the outcome of investments and many others.

Table 1. Evaluation of morpho – and hydrological conditions of agriculture in the Lower Silesia Region
Tabela 1. Zakres zmienności wartości określających warunki morfometryczne i hydrologiczne na Dolnym Śląsku

y_1: relief usability index value	y_2: hydr. usability index value	y_3: intensity mean class		homogeneity levels
		A. mean class of intensity	B. levels of homogeneity*	
7.6 — 9.9	7 — 10	5.5 — 7.3	1	high
5.1 — 7.5	5 — 6.9	2.0 — 5.4	2 — 3	medium
2.0 — 5.0	5 — 4.9	1.0 — 1.9	4 — 6	low
		* (range of classes)		

Physiogeographic units by Kondracki (Kondracki 2000) are the example of the units determined on the basis of similar topographic conditions. The course of borders of those units results from similar relief, slope, exposition, altitude, geomorphological structure, etc. The author claims that using those units as basic fields in order to determine the distribution of climatic elements can increase the correctness of their spatial distribution.

Adopting those units as basic ones in climatic modeling raises the liability of received results (Fig.5). The size of the areas determines the scale of the accuracy of the studied climatic regions if we add information about the probability of the occurrence of estimated value, as described earlier.

The construction of, for example, a precipitation model on the basis of historical data may increase the reliability of information. This conclusion seems to be pertinent especially when we interpolate a model from the existing data, using the linear function between distanced monitored stations (Bac-Bronowicz 2003b).

3.3. Administrative basic units

A different picture of spatial distribution structure of values density in the maps presented in Fig. 6, results from adopting class aggregation for administrative basic units.

The elaboration was made in the Lower Silesia Region (LSR). Natural conditions in that area are diverse because there are various physiographic lands such as lowlands, river valleys or mountains. Typology, which will be the basis to present conditioning of precipitation, includes 165 communes (Applications… 2010, Jadczyszyn 2001, Klimczak 2003, Klimczak 2008,).

The method of defining the collection of types connected with natural condition of agricultural production in the LSR is the same as described of the paper Krzywicka-Blum, Bac-Bronowicz 1997. First of all the authors analyzed the range of indices and constructed the "thematic scale" of four features to create the base (Tab.1).

The level of usability for agriculture of factors such as: "relief" and "water conditions" has been determined for arable grounds or grasslands, according to the class of soil suitability. The division is presented in Fig.6. The values related to precipitation were taken from the map of precipitation regions, where variously classified sub–areas were divided into zones of determined degree of assignment probability._

As the main factors for delimitations of precipitation regions the following values were chosen: mean level of intensity during the periods: V + VI, VII + VIII and IV – IX, height above sea level (from 122 m = 1 class to 1216 m — 8 class) and the number of stations in each part of studied area (Atlas .. 2008).

As the result of taxonomical procedure the authors distinguished 7 types of natural conditions connected with agriculture (Fig. 6).

What we can see above is the method of including individual administrative units into precipitation regions whose borders were determined using point information.

A different interpretation of the line route or different evaluation of conditions would make the formula-

types:		level of morf.	hydr.	precip.	homog.	values of typol. character.
hȟ	1A	high	high	mean	high	8,9 - 9,2 - 2,0 - 1
h	B	high	mean	low	high	8,1 - 6,9 - 1,0 - 1
hȟ	2A	high	mean	mean	high	8,0 - 6,6 - 2,0 - 1
ȟhȟ	B	mean	mean	mean	mean	6,1 - 7,5 - 4,0 - 3
ȟH♦	C	mean	high	high	mean	6,6 - 9,0 - 5,6 - 2
ȟ	3A	mean	low	low	high	7,2 - 4,4 - 1,0 - 1
♠H♦	B	low	high	high	mean	5,4 - 8,6 - 6,0 - 2

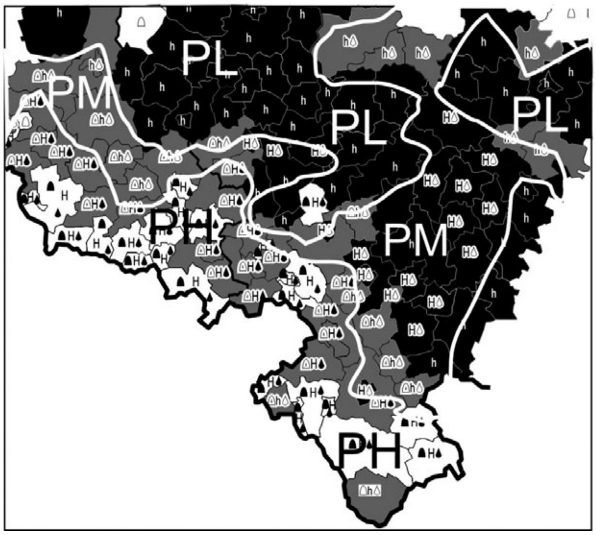

Fig. 6. The types of natural conditions with basic borders of precipitation's regions – Low Precipitation (PL), Medium Precipitation (MP), High Precipitation (HP). The range of presented values is shown in Tab 1.

Rys. 6. Typy warunków naturalnych z informacją wyjściową – region opadowe o wartościach niskich (PL) średnich (MP) i wysokich (HP). Sposób podziału na typy określono w tabeli 1.

tion of other conclusions possible: separating sub-type 2C from the second type made it possible to distinguish specific area with huge quantity of precipitation called Przedgórze Sudeckie. The analysis of that index allows for the observation that there are more green lands than arable lands and forests, and that there are increasing quantity of precipitation and decreasing homogeneity of regions in communes. It does not concern higher parts of the Sudety. In the mountainous areas the changeability of intensity increases and it has a great impact on decreasing advantage of grasslands over forests.

It should be noticed that the regionalization was made very carefully (Pierce, Nowak 1995) after many analyses and after testing a few options. The regionalization was covered by recently established borders of precipitation regions and it turned out that there is no other way to define administrative units. It also shows that inaccuracy can easily appear when joining information from various sources, which is a popular practice when GIS users can analyze different pieces of information quickly and easily even if they do not have knowledge about the analyzed and synthesized subjects.

4. Different aspects of reliability of the results of cartographic modeling

Interpolation is the last stage of the modeling. The final construction of the spatial model depends on the accepted collection of interpolation criteria. Depending on the interpolation method (two-stage, distance-weighted and correlation, surface-raster, propagance) the outcomes may vary (Kravczenko 2003, Ursnul, Czekierda 2003). The results of environmental conditions' values interpolated between basic points require consideration as to the character of the terrain and its relief. Corrections of isolines, regions' borders and reliability zones are introduced as a part of geographic interpolation. As a result, finding regional similarities and determining the borders has a strong biased character and the final result depends on the analysis of as much accessible information as possible that concern the influence of physiogeographic conditions on the provisionally described values. The example of possible interpretations of interdependence of precipitation and height above the sea level is given in the paper by Bac-Bronowicz (2005). It often happens that various indices, such as density, fractal dimension and entropy, are introduced into geographic analyses.

5. Conclusions

After the first years of fascination with GIS technology, the users notice that it is the author who is responsible for a model's quality and reliability. However, legal aspects of data sources are not always clear for practical purpose and goals. The models are useful only when the GIS author knows the theory of the particular knowledge unit and the user is experienced enough to be able to choose a strategy that will be the most useful for that user. The aim is to extract from the model all the new knowledge that is not physically visible.

The phenomena distribution's models do not have to be constructed from the very beginning on the basis of many data. It is sometimes better to refer to specialized elaborations and use GIS for linking information from different layers constructed on the basis of the best knowledge. It works in a similar way with old studies of regionalization on the basis of various thematic maps redrawn on transparent materials. Various kinds of information can be added to such syntheses if we already have partial knowledge on the studied subject. Using the so far analyzed geographic units with borders resulting from the shape and morphology of terrain naturally increases the probability of determining the correct distribution of environmental phenomena. Those areas are homogeneous taking into consideration the relief, slope, exposition, altitude, geomorphologic structure, etc. On that basis it is possible to distinguish morphological barriers which are the main factor of, for example, climatic characteristics distribution. A number of features have a significant impact on the distribution of for example environmental characteristics, and they influence also the localization of borders of geographic units. Adopting those units as basic ones in the models of environment increases the liability of received results. The size of the areas determines the scale of the accuracy of the analyzed climatic regions. When creating multi-resolution bases, the reference units should be created in such a way so that it is possible to divide basic units into correspondingly smaller reference units, when the scale of the study is increasing.

In estimations of the phenomenon's distribution different statistical measurements are used. They do not take spatial localization of phenomena into account. Indices, such as an average, neighborly distance, density, distribution, size, shape, entropy, absolute entropy or fractal dimension, are not useful if we do not take into account the studies over spatial distribution of distinguished subsets.

In that case, it is very useful to use cartographic models which present spatial distribution of those indices. It is also important to recognize the essence of the indices used, choose an adequate algorithm to indicate them, be aware of all advantages and disadvantages of the obtained results in order to interpret them correctly. The presented indices can be used as independent parameters which evaluate spatial structure of the phenomenon. It is also possible to use simultaneously a few indices which enable particularization, extension or explanation of information obtained on the basis of a model.

Easiness of analyses which use databases and applications, various possibilities of modeling and presenting results without specific knowledge, can lead to incorrect conclusions and can cover profits which result from such analyses for the needs of operative activities. In order to recognize the structure of spatial distribution of the set of point, linear or surface objects, it is often necessary to separate local layouts. Their separation takes into account environmental, social and economic factors which are closely related to the studied phenomena. The selection of such factors depends on using models of local structures in special kinds of analyses. Therefore, frequently used factors can be applied as individual parameters, which evaluate the phenomenon. It is also useful to use simultaneously a few indices which enable detailing, extending or explaining the obtained information from the model.

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Streszczenie

Różnego typu wartości mogą być podstawą modeli wybranych elementów przyrodniczych, a określenie ich dokładności umożliwia wiarygodne wielowariantowe modelowanie zjawisk przy użyciu systemów informacji geograficznej. Stworzone modele umożliwiają też aktualizację i rozszerzenie zakresu informacji. W modelach tworzonych na bazie danych georeferencyjnych i statystycznych jakość danych przestrzennych powinna być dokładnie określana. Przy wykorzystywaniu geoinformacji muszą być brane pod uwagę elementy dotyczące jakości danych i uzyskanych na ich podstawie modeli kartograficznych (ich poziomu jakości). Kryterium jakości jest stosowane w pierwszej kolejności do ustalenia przydatności zbioru danych lub informacji do użycia w określonym celu. Dokładność tematyczna atrybutów ilościowych i poprawność atrybutów nieilościowych oraz klasyfikacja obiektów i ich związków musi być precyzyjnie określona przed wydawaniem decyzji na podstawie informacji pozyskanych modeli kartograficznych (Norma PN-EN-ISO 19114). Dotyczy to zarówno wyników w postaci wizualizacji przeprowadzonych analiz geograficznych jak i map wykonywanych przy użyciu systemów informacji geograficznej. Pozwala to na uniknięcie, przez użytkowników systemów geoinformacji , nieścisłych wyników analiz i syntez poszczególnych warstw topograficznych i tematycznych, wykorzystanych do modelowania.

W artykule przeprowadzono ocenę jakości danych przyjmowanych do modelowania i dokładność informacji uzyskiwanych z modeli, zbudowanych na podstawie informacji w punktach. Zmienność warunków przyrodniczych między stacjami pomiarowymi ma charakter bardzo złożony. Artukuł ukazuje problem jakości różno dokładnych i niejednakowo reprezentatywnych danych na przykładzie elementów środowiska przyrodniczego warunkujących produkcję rolniczą. Przeanalizowano następujące elementy jakości danych przestrzennych: dokładność pozycyjna wyrażona przez dokładność współrzędnych obiektów w odpowiednim odwzorowaniu (Rys.1 i 2), reprezentatywność miejsca pomiaru warunkująca możliwość zamiany informacji punktowej na ciągłą w otoczeniu punktu wyznaczającego, niezmienność warunków i miejsca pomiaru determinujące wiarygodność wartości średnich i gęstość sieci pomiarowej (Rys. 3a i b).

Ważnym elementem budowy systemu informacji przestrzennej jest dobór jednostki odniesienia dostosowany do potrzeb oraz szczegółowości i dokładności opracowania. Zdaniem autorki, z przyrodniczego punktu widzenia, przyjęcie jako jednostki podstawowej regionów fizycznogeograficznych (z granicami wynikającymi z ukształtowania i morfologii terenu) podnosi prawdopodobieństwo prawidłowego określenia rozkładu zjawisk przyrodniczych. Jednostki te są podobne pod względem rzeźby terenu, nachylenia, wystawy, wysokości bezwzględniej i względnej, budowy geomorfologicznej i tym podobnych. Na podstawie przebiegu granic takich jednostek można wyróżnić bariery morfologiczne, które są podstawowym czynnikiem rozkładu wielu cech uzależnionych od uwarunkowań topograficznych.

W artykule opisano sposób metody przenoszenia informacji uzyskanych na podstawie standartowych danych np. ze stacji meteorologicznych do różnych powierzchniowych jednostek odniesienia na terenie Dolnego Śląska (Rys. 5 i 6). Taki sposób modelowania, przez kontynu-

alizację danych i informacji, uzyskanych na podstawie danych punktowych, ukierunkowaną podobieństwem uwarunkowań w sąsiedztwie punktu wyznaczającego, może być w konsekwencji źródłem bardziej wiarygodnej informacji uzyskanej z modelu. Przedstawiona metoda traktuje indywidualnie wyznaczenie rozkładu wartości wokół każdego punktu wyznaczającego. Wartości, które są interpolowane w geometrycznych regularnych polach podstawowych typu GRID czy TNT, na podstawie z góry założonego modelu rozkładu wartości, dla całej opracowywanej powierzchni, są wrażliwe na wybór funkcji interpolacyjnej oraz gęstość i rozkład sieci pomiarowej. W artykule zaproponowano przeniesienie informacji w sąsiedztwo punktu wyznaczającego najpierw do jednostek typu grid, z określeniem wiarygodności przeniesienia, a następnie do jednostek naturalnych lub administracyjnych.

Opisany szczegółowy sposób regionalizacji może posłużyć do analizy i oceny przydatności terenów ze względu na wielorakie cele, a także do prognozowania skutków podejmowanych decyzji i optymalizacji rozwiązań. Opracowane rozwiązania metodyczne można zastosować, dla mierzonych punktowo lub wyspowo innych niż zjawisk, zależnych od ukształtowania terenu oraz dla procesów topograficznozależnych występujących na większości obszarów Polski.

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MONITORING OF TIDEWATER GLACIERS ON SVALBARD USING ASTER IMAGES

Key words:

ASTER, glaciers, Svalbard, DEM, classification, texture.

Abstract

The purpose of this study is to describe different methods of using ASTER images (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*) for monitoring of tidewater glaciers on Svalbard, an archipelago in the northern part of Europe. Monitoring of tidewater glaciers is of special importance, especially considering the present climate changes. Changes in the geometry of glacier tongues, negative mass balance and front retreat have been noticed within last twenty years. The author proposes procedures of examining tidewater glaciers characteristics, generation of digital elevation model (DEM) from satellite stereo pairs and automatic delineation of glacier areas in satellite imagery (mapping of glaciers boundaries). The most important morphometric features of all tidewater glaciers derived from satellite images are: glacier area, length of centreline, glacier slope and aspect, extent of crevassed zone close to the active calving front, length of the ice cliff and front position changes. Image texture parameters were also applied to the identification of crevassed areas and to the separation of ice float from glaciers. The surface velocity fields of glacier termini were derived from ASTER image pairs using *feature tracking* methods. The paper aims at the continuation of the work of Hagen *et al*. (1993) focusing on updating different information. The list of proposed methods of satellite data processing is recommended for assessing changes in Svalbard glacier areas in the future, during the next International Polar Year.

MONITORING LODOWCÓW UCHODZĄCYCH DO MORZA NA SVALBARDZIE Z WYKORZYSTANIEM OBRAZÓW SATELITARNYCH ASTER

Słowa kluczowe:

ASTER, lodowce, Svalbard, NMT, klasyfikacja, tekstura.

Abstrakt

Przedmiotem niniejszej pracy jest zaprezentowanie różnych metod wykorzystania obrazów satelitarnych ASTER (Advanced Spaceborne Thermal Emission and Relfection Radiometer) w monitorowaniu lodowców Archipelagu Svalbard

[1] Wojewódzki Ośrodek Dokumentacji Geodezyjnej i Kartograficznej w Katowicach

położonego w północnej części Europy. Monitoring lodowców uchodzących do morza jest istotny w świetle współczesnych zmian klimatu. Od dwudziestu lat notuje się ciągły ubytek powierzchni tych lodowców wskutek topnienia lodowców i recesji klifów. Pozyskanie teledetekcyjnych danych o lodowcach uchodzących do morza obejmowało następujące etapy: analiza ilościowa lodowców współcześnie uchodzących do morza, generowanie numerycznego modelu terenu, automatyczne wyznaczanie obszarów zlodowaconych na obrazach, wyznaczenie basenów glacjalnych (generowanie granic lodowców) oraz wyznaczenie parametrów morfometrycznych takich jak: długość i powierzchnia lodowca, wielkość strefy uszczelinionej czoła lodowca, wystawa, nachylenie, długość klifu czy wielkość recesji. Omówiono także możliwość wykorzystania analizy teksturalnej dla wyznaczania obszarów uszczelinionych na lodowcach oraz do wydzielenia lodu pływającego na powierzchni morza. Wypracowano metody pomiaru rocznych prędkości lodowców na parach obrazów ASTER z wykorzystaniem metody feature tracking. Zebrane dane są uaktualnieniem inwentarza lodowców Svalbardu wydanego w 1993 roku (Hagen et al., 1993). Wypracowane metody przetwarzania danych teledetekcyjnych oraz zebrane dane stanowią podstawę do wyznaczania zmian charakteru zlodowacenia Svalbardu podczas kolejnego Międzynarodowego Roku Polarnego.

1. Introduction

The Svalbard Archipelago is located in the northern part of Europe. The archipelago's area is c.a. 60, 000 km2, and c.a. 45% of the area is covered with glaciers that terminate in the sea (Hagen et al., 1993). One of the main factors that decide on the glacier mass balance is the process of calving, which takes place along ice cliffs. Monitoring of tidewater glaciers is of great importance, considering the present climate changes. Within last twenty years the area of these glaciers has been diminishing due to melting and cliff reterat. Its importance should be stressed, since almost 20% of the Svalbard Archipelago's coastline is made of cliffs of these glaciers. Moreover, the determination of calving intensity – the ice volume transported from the lands to the sea – is crucial for forecasting the eustatic sea leavel rise and additional sweetening of coastal waters by melting icebergs.

Because of the difficulties in taking measurements in the remote and highly inaccessible areas, creating world resources of areas covered with ice has been recently done based on satellite data (GLIMS, 2009; WGMS, 2009). The objective of the present work is the presentation of different methods of using ASTER (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*) satellite images for monitoring the archipelago's glaciers. The methods were then applied to updating the part of the data included in the Svalbard's glacier inventory "Glacier Atlas of Svalbard and Jan Mayen" (Hagen *et al*., 1993). In the studies, forty ASTER images collected in seven summer seasons on Spitsbergen (2000-2006) were used. Additionally, three images from Landsat ETM+ were used. The spatial range of the used images is shown in Fig. 1.

For the analyses, several different GIS tools were used, such as: IDRISI, PCI Geomatica Orthoengine, MaZda, ArcGis and eCognition. The choice of the software was dictated by the possibilities of particular systems as well as their availability (licences) and simplicity of its use.

2. Methods of ASTER images analysis

2.1. Determination of glacier areas

The first stage of the study was a quantitative analysis of glaciers that presently terminate in the sea. The analysis consisted in the visual interpretation of the appearance of glacier fronts based on ASTER satellite data of July and August. The results of the author's work were then compared with the inventory of Svalbard's glaciers compiled by Hagen *et al*. (1993). Based on data from 2000-2006, it was established that presently 163 glaciers terminate in the sea.

The next task was to determine glacier areas in satellite images. Snow and ice are characterized by a high albedo within the visible radiation and near-infrared spectra and by low reflectance factor indices in channels of a length not exceeding 1.5 μm. The works by Błaszczyk, Drzew-

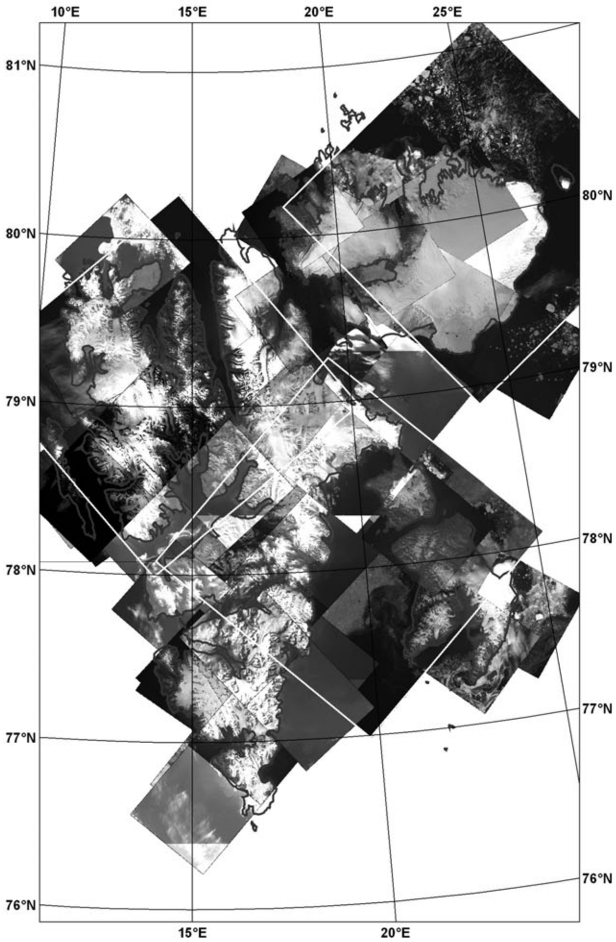
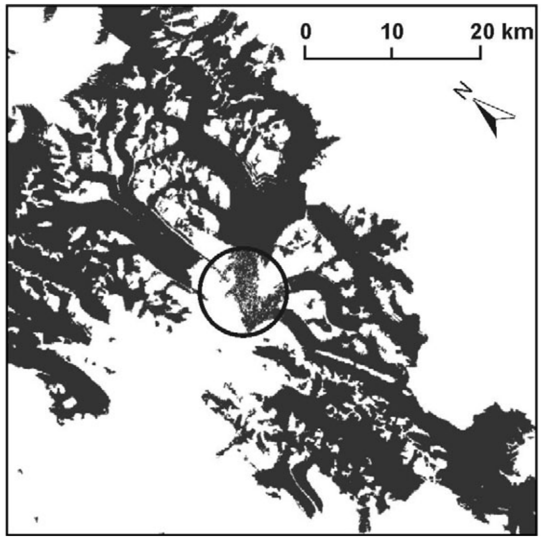


Fig.1. Spatial range of ASTER and Landsat ETM+ images analyzed in the present work; white colour marks the reach of Landsat ETM+ images (explanations in the text).

Rys. 1. Zakres przestrzenny obrazów ASTER oraz Landsat ETM+ analizowanych w niniejszej pracy; białym kolorem zaznaczono zasięg obrazów Landsat ETM+ (wyjaśnienia w tekście).

iecki (2006) present three methods of automatic isolation of glacial areas using VNIR and SWIR channels of ASTER pictures (of resolution of 15 m and 30 m respectively). The most practical way of determining glacier areas used while compiling the inventory was the ratio of A4 and A3 chanells . This method is simple and does not require

a)



b)

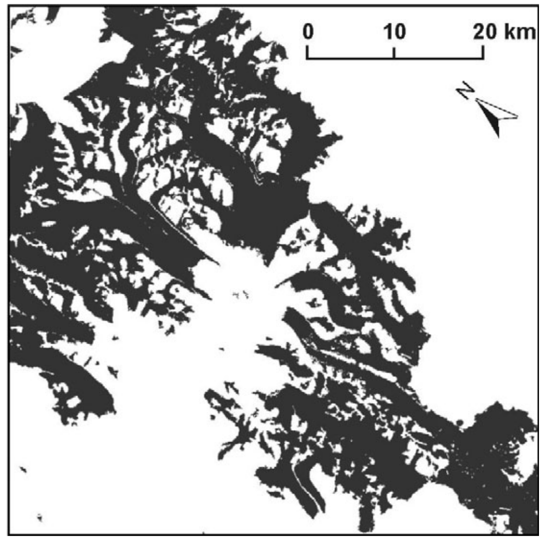


Fig. 2. Ice masks obtained as a result of: a) A4/A3 channels ratio – a circle marks the place of the occurrence of ice floating on the sea surface; b) quotient of *Contrast* texture picture and of A4/A3 channels ratio.

Rys. 2. Maski lodu otrzymane w wyniku: a) dzielenia kanałów A4/A3 – kółkiem zaznaczono miejsce występowania lodu pływającego na powierzchni morza; b) iloczyn obrazu teksturalnego Kontrast z ilorazem kanałów A4/A3.

complicated software; moreover, the selection of threshold values is relatively quick. Additionally, the application of median filter improves noise resulting from the presence of moraine material on the glacier or from pixels occurring in the shade. However, the data obtained from the scene in July, when large patches of snow lie on slopes and in gullies, required corrections (Błaszczyk, Drzewiecki, 2006). An example of a mask obtained as a result of the division of A4 and A3 channels is shown in fig. 2a.

During automatic classification, ice floating on the sea surface emerged (a circle in Fig. 2a), but both types of the isolated areas were characterized by different textures. Texture images made applying MaZda software (Błaszczyk, Drezwiecki, 2006) were used for the separation of the ices floating on the sea surface from the glacier surface. The map of "Contrast" characteristics made in MaZda software underwent the process of thresholding and then the obtained picture was multiplied by the ice mask obtained without taking into account texture parameters. An example of the obtained picture of glacier range is shown in Fig. 2b.

2.2. Digital Elevation Model

ASTER stereoscopic pictures enable to generation of the digital elevation model (DEM). A detailed description of making DEM out of ASTER images as well as the accuracy assessment of generating DEM within areas covered with glaciers was shown in the work by Błaszczyk (2007). The analyses lead to the conclusion that the preparation of correct DEM based on ASTER satellite images in polar areas poses some difficulty. Due to the lack of clear situational details there are some problems related to unambiguous identification of ground control points in this areas. According to the author, the lowest values of mean square error and the smallest areas of altitude gross errors characterized ASTER DEM of resolution of 60 and 120 m.

High values of altitude errors for ASTER DEM generated by the author caused distortions of pictures in the areas of steep slopes and in the scene edges in the process of orthorectification. Yet, on relatively flat glaciers the orthorectification of scenes did not introduce almost any changes. Therefore, for the needs of working out a new inventory of glaciers the idea of orthorectification of satellite images was given up. Yet, ASTER DEM of relatively low resolution (120 m) proved very helpful for the determination of glacial basin boundaries. Such a model is deprived of many terrain details, but it shows better accuracy due to error averaging within a large area. On relatively flat glacier areas such accuracy proved to be satisfactory for compiling maps of terrain aspect and for the determination of drainage basin boundaries applying the *watershade* procedure, used in hydrology. The next thing that facilitated the deliniation of glacier on flat accumulation areas was a 3D visualization of data in the ArcScene software. The ASTER picture projected on DEM with vertical scale exaggerattion helps in the assessment of the glacier flow direction and in the determination of boundaries between individual glacial basins, especially in the regions of flat accumulation areas (Fig. 3).

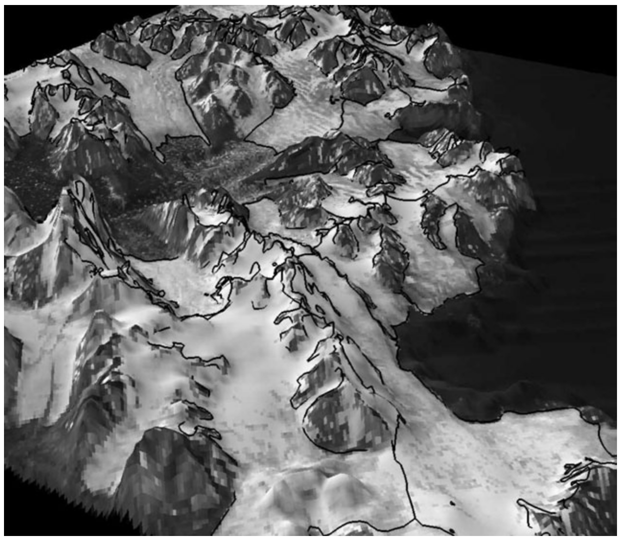


Fig. 3. The boundaries of glaciers basins determined employing automatic methods (black vector) against the background of ASTER channel 3; vertical scale exaggerated 5x.

Rys. 3. Przebieg granic basenów wyznaczonych metodami automatycznymi (czarny wektor) na tle kanału 3 ASTER; widok perspektywiczny – przewyższenie 5- krotne.

It should be added that in spite of a rich collection of optical sensors there is still a problem in measuring changes in glacier volumes from satellite altitudes with an accuracy required in glaciology. The changes in the thickness of glaciers on Svalbard range between decimeters and several meters per year. The ASTER DEM accuracy assumed by the distributor is at a level of 10-50 m, therefore it excludes the possibility of its application to the assessment of glacier thickness changes.

2.3. Determination of glacier movement velocity based on satellite pictures

To create a dynamic classification of glaciers, and later to establish the intensity if calving, it was necessary to know mean annual movement velocities of typical glaciers on Svalbard. One of the newest technologies of glacier velocity measurement is the feature tracking method, which bases on the technique of picture cross-correlation. The method consists in determining glacier surface velocity by detection (sensing) and tracking unique features on the glacier surface (e.g. crevasses) on two pictures obtained in a given time interval (Massom, Lubim, 2006). The measurements with the application of the feature tracking method are small in number on Svalbard (Dowdeswell, Benham, 2003; Lefauconneir *et al*., 1994, Kääb *et al*., 2005; Rolstad *et al*., 1997) and are related only to four glaciers characterized by fast flow and visible crevassed areas within their whole surface. That is why the author decided to determine glacier front velocities applying the method discussed above to glaciers of different dynamic conditions.

The method of co-referencing of ASTER images based on a dozen or so tie points (situational details located at the sea level) was applied to carry out geometrical calibration. The mean square error of the scene matching with the application of affine transformation of the 1st order ranged between 5 to 15 m. Dowdswell and Benham (2003) estimate the impact of geometric orientation on the error in determining glacier velocities between 7.5 to 15 m. They emphasize, however, that the estimation of this value is difficult. In her studies the author takes into account also the error in photointerpretation and assumes that the error in the determination of glacier velocities is $\pm$ 30 m. An example of velocities determined for Austre Terellbreen glacier is shown in Fig. 4.

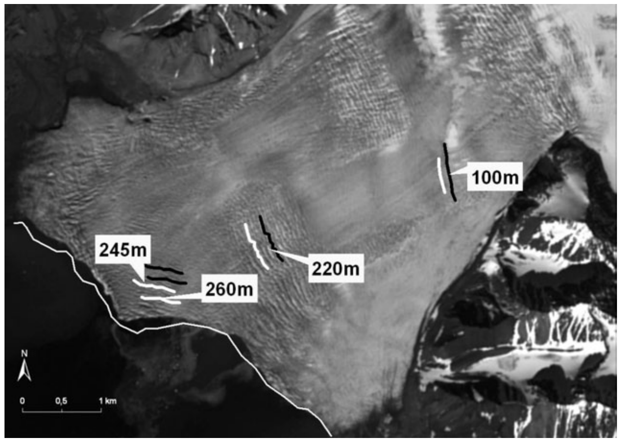


Fig. 4. Austre Terellbreen glacier velocities (m/year) determined based on the measurement of crevasse movement; background: an ASTER scene of 2006; black lines – positions of crevasses in 2005; white line – positions of crevasses in 2006; the figure shows also the position of the front in 2005.

Rys. 4. Prędkości lodowca Austre Torellbreen (m/rok) wyznaczone na podstawie pomiaru przemieszczeń szczelin; podkład – scena ASTER z 2006 roku; linie czarne – pozycja szczelin w roku 2005; linie białe – pozycja szczelin w roku 2006; na rysunku widoczna także pozycja czoła w roku 2005.

The pictures covering the period of many years give a possibility of measuring changes of glacier cliff lengths as well as the size of the front retreat or advance. The white line in Fig. 4 shows the position of the front in 2005 against the background of a picture taken in 2006. The collected remote sensing data enabled the measurement of the retreat for 40 glaciers and for the velocity of 27 glaciers.

2.4. Methods of determination of crevassed zones

The basis for the dynamic classification of glaciers on Svalbard was the examination of the relationship between glacier velocities and the degree of crevassing in glacier fronts. The more crevasses in a front and the wider the crevassed area, the higher potential velocity of a glacier front and the higher calving intensity, because the calving intensity is related to glacier movement velocities (Jania, 1998; Van der Veen, 1996).

The methods of delineation of crevassed zones in glaciers were presented in the work by Błaszczyk, Drzewiecki (2006). The most effective method was automatic distinguishing of crevassed zones applying eCognition software. A textural picture produced earlier with the application of MaZda software was used for the segmentation process. To sum up this stage of the study, it may be stated that the segmentation process is too complex and too time consuming due to a large number of steps necessary to be taken in order to achieve desired effects, i.e. crevassed area deliniation for 40 ASTER scenes collected in different periods of time, in different lightning conditions and in different stages of ablation season advancement. This method may be recommended in Landsat pictures, because of their aera, which is nine times bigger than the aera of ASTER pictures. Therefore, in the further studies, the data related to crevassed zones were obtained form ASTER pictures by manual digitalization.

The collected data related to velocities and crevassing of glacier fronts allowed for working out the method of glacier classification in relation to the size of crevassed zone in the glacier front. Glaciers were classified in four velocity groups: stagnant, slow, fast and surging glaciers, as well as fast ice streams.

3. Results and conclusions

The result of the methodical studies is a set of methods of collecting morphometric data related to tidewater glaciers, with the application of satellite pictures, which is illustrated by the block diagram below (fig. 5). The choice of a given method may depend on the character of a given scene, on the number of glaciers in the picture, and on the pace of snow melting in a given year.

Collecting of ASTER images

Delineation of glaciers boundaries in a picture
1. A4/A3 channels ratio
2. picture thresholding

Making a texture picture to isolate
ice floating on the sea surface (A3 channel)

Distinction between glacier and ice
floating on the sea surface

Collection of tie points
and of ground control points

Conversion of glacier mask from vector into raster

Generation of Digital Elevation Model
(DEM ASTER)

Digitalization of crevassed zones in glaciers

Delineation of tidewater glacier basins

Generating DEM derivatives:
aspect; drainage basins

Determination of morphometric
parameters of crevassed zones: length, width, area

Determination of morphometric parameters of tidewater glaciers: length, width, area

IDRISI MAZDA PCI Geomatica ArcGis

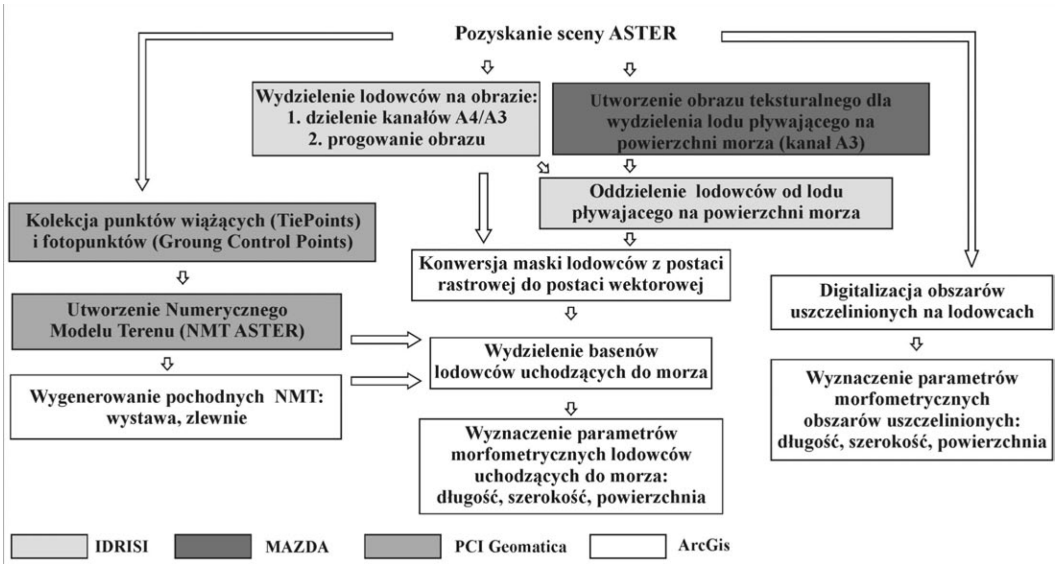


Fig. 5. **Block diagram showing methods of obtaining morphometric data of tidewater glaciers. Grey shades mark the applied software.**

Rys. 5. **Schemat blokowy przedstawiający metody pozyskiwania danych morfometrycznych lodowców uchodzących do morza. Odcieniami szarości zaznaczono użyte oprogramowanie.**

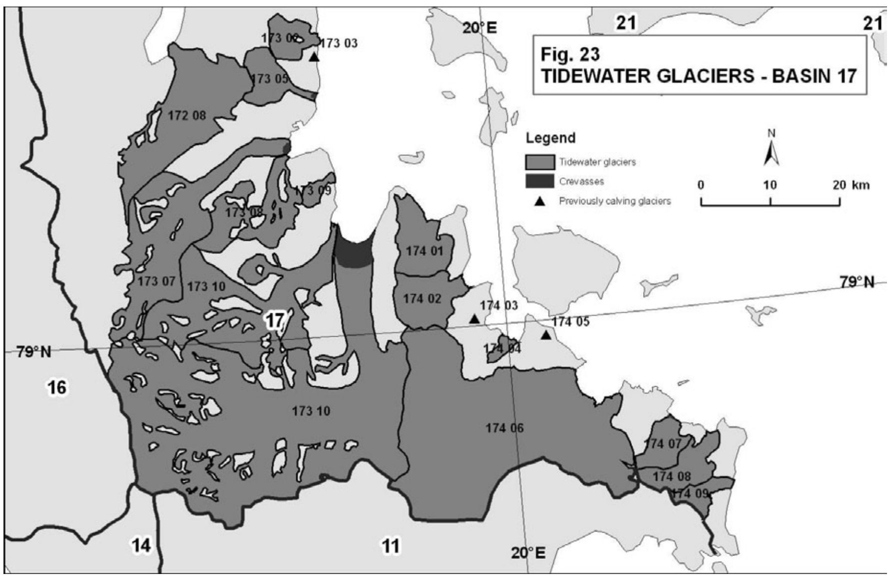


Fig. 6. **An example of covering of one of the Regions (Basin 17) with tidewater glaciers; glacier crevassed areas and glaciers that retreated to the land in the previous century are also marked on the maps (Błaszczyk** ***et al*****., 2009).**

Rys. 6. **Przykład pokrycia jednego z regionów (Basen 17) Spitsbergenu lodowcami uchodzącymi do morza; na mapach zaznaczono również strefy uszczelinienia lodowców oraz lodowce, które wycofały się na ląd w ubiegłym wieku (Błaszczyk et al., 2009).**

Based on the above flowchart, the author worked out an updated digital inventory of glaciers for the whole area of Svalbard (Błaszczyk *et al*., 2009; fig. 6). Spatial data were supplemented with attribute data, such as the length and size of the glacier area as well as of the front crevassing, cliff lengths, size of the front recession, and others. Working out the method of glacier classification made possible the determination of calving intensity, i.e. the amount of ice that breaks off from glacier cliffs into the sea each year. For Svalbard, this value is estimated to c.a. 7.5 ± 1.5 km^3/year. The comparison of the obtained results with the data of the earlier inventory (Hagen *et al*. , 1993) showed that ice cliff lengths on Svalbard decreased by 16.5% in the second half of the previous century.

Summing up, the analysis of remote sensing satellite images proved useful to obtain data related to tidewater glacier characteristics.

The most important conclusions are as follows:

- satellite pictures obtained from the ASTER scanner make a good source of information on the size of ice area and boundaries of particular glacial basins, if clouding permits their acquisition in the second part of the ablation season. The most practical way of delineation of ice surfaces in ASTER picture is by dividing A4/A3 channels;
- during automatic classification, ice floating on the sea surface and glaciers are isolated in the pictures. Texture picture executed applying MaZda software proved useful to isolate floating ice from glaciers;
- the accuracy of digital elevation model (DEM) worked out based on stereoscopic channel of ASTER satellite images are sufficient for the determination of glacial basin boundaries;
- the method of movement measurement (feature tracking) applied by the author to ASTER pictures make a valuable source of current surface velocities of glacier fronts on Svalbard. Although the obtained velocities are burdened with an error of ± 30 m/year they provide us with useful information about glacier movements (or lack of movements) within a period of one year, and in the case of a few glaciers, within the period of several years;

The volume of Svalbard's glaciers is small in comparison to Greenland, however it is foreseen that climate changes will have an effect on this part of the Arctic much sooner than on other Polar regions (Bevan *et al*.; 2007). In this light, the results of the research done during the 4th International Polar Year 2007-2008 (IPY, http://www.ipy.org), have acquired special meaning. The presented studies and analyses, as well as methods worked out in order to acquire data by processing remote sensing data sources, make a basis for commencing long-term studies and for comparing the character of Svalbard's glaciers in 25 or 50 years' time, which is one of the tasks of cyclically repeated IPY.

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Streszczenie

Przedmiotem niniejszej pracy jest zaprezentowanie różnych metod wykorzystania obrazów satelitarnych ASTER (*Advanced Spaceborne Thermal Emission and Reflection Radiometer*) w monitorowaniu lodowców Archipelagu Svalbard położonego w północnej części Europy. Monitoring lodowców uchodzących do morza jest istotny w świetle współczesnych zmian klimatu. Od dwudziestu lat notuje się ciągły ubytek powierzchni tych lodowców wskutek topnienia lodowców i recesji klifów. Pozyskanie teledetekcyjnych danych o lodowcach uchodzących do morza obejmowało następujące etapy: analiza ilościowa lodowców współcześnie uchodzących do morza, generowanie numerycznego modelu terenu, automatyczne wyznaczanie obszarów zlodowaconych na obrazach, wyznaczenie basenów glacjalnych (generowanie granic lodowców) oraz wyznaczenie parametrów morfometrycznych takich jak: długość i powierzchnia lodowca, wielkość strefy uszczelinionej czoła lodowca, wystawa, nachylenie, długość klifu czy wielkość recesji. Omówiono także możliwość wykorzystania analizy teksturalnej dla wyznaczania obszarów uszczelinionych na lodowcach oraz do wydzielenia lodu pływającego na powierzchni morza. Wypracowano metody pomiaru rocznych prędkości lodowców na parach obrazów ASTER z wykorzystaniem metody *feature tracking*. Zebrane dane są uaktualnieniem inwentarza lodowców Svalbardu wydanego w 1993 roku (Hagen *et al*., 1993). Wypracowane metody przetwarzania danych teledetekcyjnych oraz zebrane dane stanowią podstawę do wyznaczania zmian charakteru zlodowacenia Svalbardu podczas kolejnego Międzynarodowego Roku Polarnego.

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ZBIGNIEW KASINA[1]

THE ANALYSIS OF THE EFFECTIVENESS OF THE MULTIPLES ATTENUATION BY MEANS OF KARHUNEN-LOEVE (K-L) TRANSFORM - MODEL STUDY[2]

Key words:

geophysics, seismic method, processing, K-L transform, multiples attenuation

Abstract

In the paper the analysis of the effectiveness of multiples attenuation using Karhunen-Loeve (K-L) transform is presented for the case of model data. The K-L transform was performed by means of the *Eigenimage Filter* procedure in the ProMAX seismic data processing system. The model traces of CDP gathers were generated with the application of the ProMAX process named *The Synthetic Trace Generation*. The influence of the K-L filter parameters on the effectiveness of multiples was estimated for the case of primaries and multiples interference. Several values of moveout differentiation between primaries and multiples were considered. The different values of the NMO stretch parameter and receiver interval as well as different phase characteristics of the signals were taken into consideration during model calculations.

ANALIZA SKUTECZNOŚCI TŁUMIENIA FAL WIELOKROTNYCH ZA POMOCĄ TRANSFORMACJI KARHUNENA-LOEVEGO (K-L) - STUDIUM MODELOWE

Słowa kluczowe:

geofizyka, metoda sejsmiczna, przetwarzanie, transformacja K-L, tłumienie fal wielokrotnych

Abstrakt

W pracy przedstawiono analizę efektywności tłumienia fal wielokrotnych za pomocą filtracji Karhunena-Loevego (K-L), realizowanej z wykorzystaniem procedury *Eigenimage Filter* sejsmicznego systemu przetwarzania ProMAX. Trasy modelowe kolekcji CDP były generowane za pomocą procedury *The Synthetic Trace Generation* w systemie ProMAX. Oszacowano wpływ parametrów filtracji K-L na skuteczność usuwania fal wielokrotnych w przypadku interferencji fal jednokrotnych i wielokrotnych. Rozważono kilka wartości zróżnicowania krzywizny kinematycznej między falami jednokrot-

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nymi i wielokrotnymi. W trakcie obliczeń modelowych uwzględniono różne wartości parametru osłabiania zniekształceń spowodowanych wprowadzaniem poprawek kinematycznych (*NMO stretch*), różne wartości interwału pomiarowego, jak również różne charakterystyki fazowe sygnałów

Introduction

The most common seismic tools used to attenuate multiples during seismic data processing are still F-K transform and Radon transform (Weglein 1999, Kasina 2001a). The analysis of the effectiveness of the discussed transforms has been the subject of many publications (e.g. Kasina 2001 b, c).

The last applications of the K-L transform were proposed mainly for the purpose of surface waves removing (Lu 1999, Bitri & Grandjean 2004) and as an effective tool for the selection and analysis of dispersive waves (Kritski et al. 2007). But in the much earlier publications this tool was proposed (Jones & Levy 1987, Al-Yahya 1991) as an alternative way of multiple attenuation. That direction of the K-L transform application was analyzed lately using the field data of seismic records and CDP gathers used in the velocity analysis (Kasina 2010). In the case of seismic records a satisfying result of multiple suppression was obtained for the eigenimage range 0% - 4% and 0% - 5% although the too low level of the primaries in the analyzed area for great arrival times caused the problem of the identification of the primaries at the background of noise. The analysis of the wave field of supergathers after K-L filtering made possible the formulation of several conclusions referring to the effectiveness of multiple suppression. One of the most important conclusions - used in the present paper - confirmed that the application of the ProMAX process named *Eigenvector Filter* in the *Subtract Eigenimage of zone* mode (subtraction of reconstructed multiples) generates a risk of weakening the primaries in the process of multiple suppression lower than the *Output Eigen-filtered zone* mode.

In the present paper the analysis of the effectiveness of multiples attenuation using Karhunen-Loeve (K-L) transform is undertaken for the case of model data. The K-L transform was performed by means of the *Eigenimage Filter* procedure in the ProMAX seismic data processing system. The model traces of CDP gathers were generated with the application of the ProMAX process named *The Synthetic Trace Generation*. The model data used were generally the same as in the analysis of multiples attenuation effectiveness presented by the author for the case of F-K and Radon filtering (Kasina 2001a). This creates the background for the comparison of the effectiveness all of these three methods in the next paper.

1. The theoretical aspects of K-L filtering

The starting point of K-L transform is a creation of the covariance matrix $\hat{C}$. Each element C_{ij} of that matrix has a the form of a submatrix:

$$C_{ij} = \begin{bmatrix} a_{i1}a_{j1} & a_{i1}a_{j2} & \ldots a_{i1}a_{jN} \\ a_{i2}a_{j1} & a_{i2}a_{j2} & \ldots a_{i2}a_{jN} \\ \vdots & & \ddots \\ a_{1N}a_{j1} & a_{i3}a_{j2} & ..a_{iN}a_{jN} \end{bmatrix} \tag{1}$$

where a_{kl} is the lth sample of the kth trace. Each submatrix contains elements of crosscore-lation function for different lags. In the special case of the full K-L transform only the main diagonal elements of C_{ij} matrix are nonzero. Since the main diagonal elements are the zero-lag crosscorelations, using them alone enhances horizontally correlated events only.

In the spectral decomposition of matrix $\hat{C}$ we are looking for the matrices $\hat{R}$ and $\hat{\Lambda}$ from the matrix equation:

$$\hat{C} = \hat{R}\,\hat{\Lambda}\,\hat{R}^T \tag{2}$$

where $\hat{R}$ is the matrix of eigenvectors of covariance matrix, $\hat{\Lambda}$ is the matrix of eigenvalues of the covariance matrix. The rows of matrix $\hat{\Lambda}$ are the normalized eigenvectors of a covariance matrix and the matrix $\hat{\Lambda}$ is identical with the matrix $\hat{B}$ used for the reconstruction (Jones & Levy 1987). The K-L filtering relies on the modification of $\hat{\Lambda}$ matrix through the selection of its eigenvalues to obtain the matrix $\hat{\Psi}$. The $\hat{B}$ and $\hat{\Psi}$ matrices are used to reconstruction defined by the relation:

$$\hat{X} = \hat{B}\,\hat{\Psi} \tag{3}$$

The multiple suppression by means of K-L filtering may be effectively realized in the following steps:
- application of normal moveout corrections (NMO) to the data (with the multiples velocity) achieving the flattening of the multiple arrivals;
- realization of the K-L transform in which the energy of multiples is associated with the several greatest eigenvalues (mainly with the first principal component) ordered from the greatest to the least value;
- reconstruction of the NMO corrected multiples using only several principal components;
- removal of the NMO corrections and subtraction of the reconstructed multiples from the input data.

2. The K-L filtering in the ProMAX seismic data processing system

The K-L filtering in the ProMAX seismic data processing system may be realized by means of the process named *Eigenvector Filter*. That process decomposes the input set of data considered as a matrix into eigenimages through the use of eigenvectors. The sum of all eigenimages reconstructs the original data traces. The choice of eigenimages to be used in the reconstruction allows us to include or exclude different types of seismic events or noise. That choice may be treated as some type of a bandpass filtering over the eigenimage range. The eigenvalues and eigenvectors defined in the process of the decomposition of the covariance matrix of input traces are arranged from the greatest value to the least one. Typically, the flatter events are reconstructed using the low number eigenimages, the dipping events using the middle eigenimages, and the more random components using the higher number eigenimages. The eigenimage range 0 - 10% means the range of eigenvalues from the first value (the greatest one) to the value with the number defined by the product (10% * the number of traces in data gather).

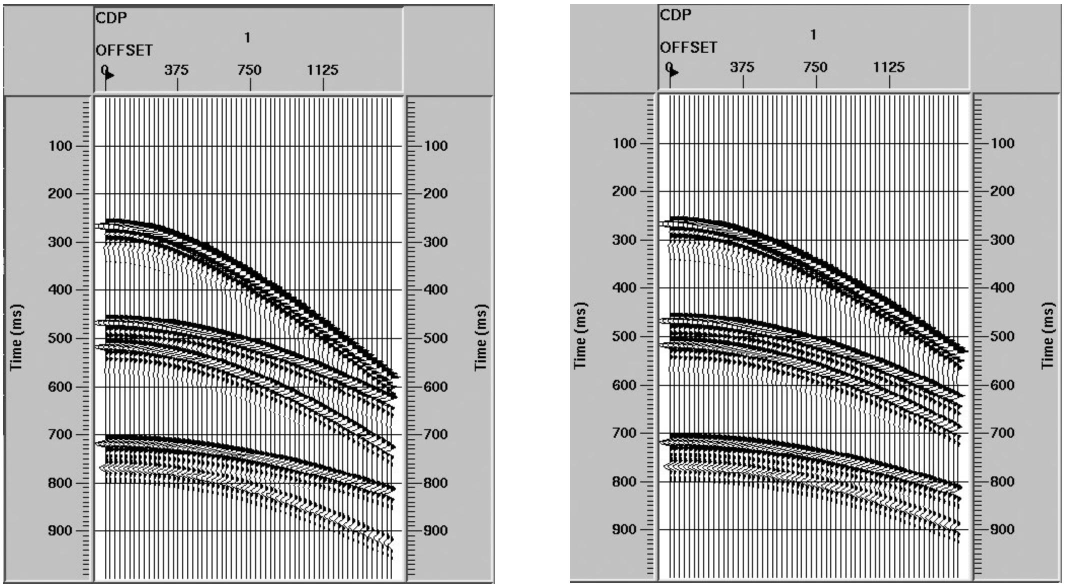
3. The model data used in the analysis

The synthetic traces used in the analysis were generated by means of the ProMAX process named *Synthetic Trace Generation*. For the case of the reflected waves the model with three horizontal reflectors was considered and the traces of CDP gather were generated assuming 60 traces with the receiver interval 25 m and 50 m. The multiples propagating between the surface and the first reflector were introduced and their arrival times were close to primaries arrival times. Three variants of moveout differentiation between primaries and multiples were taken into consideration. The main parameters of the *Synthetic Trace Generation* process applied during calculations are presented in Table. 1 and include:
- arrival time for zero offset (t_0);
- type of wave (primaries or multiples);
- velocity (V) determining the moveout;
- the length of the wavelet (L);
- the bandbass (Δf) of Ormsby signal defined by a set of four frequencies;
- maximum amplitude of the signal (A);
- the dip of the reflectors (φ).

For the majority of the model calculations the Ormsby signal with zero-phase characteristic was used and the value of NMO stretch equal 800. The composition of synthetic CDP gather traces (with minimum-phase primaries and multiples) for the assumed seismogeological model with multiples velocity 2850 m/s and 3200 m/s are presented in Fig. 1.

4. The analysis of the effectiveness of the multiples attenuation by means of Karhunen-Loeve (K-L) transform

As mentioned in the introduction, the main applications of the K-L filtering in the last publications were limited to the analysis or attenuation of the coherent noise



a) b)

Fig. 1. Composition of synthetic CDP gather traces (with minimum-phase primaries and multiples) for the assumed seismogeological model with multiples velocity: a) 2850 m/s), b) 3200 m/s

Fig. 1. Zestawienie syntetycznych tras kolekcji CDP (z falami jednokrotnymi i wielokrotnymi w wersji minimalnofazowej) dla założonego modelu sejsmogeologicznego z prędkością fal wielokrotnych: a) 2850 m/s), b) 3200 m/s

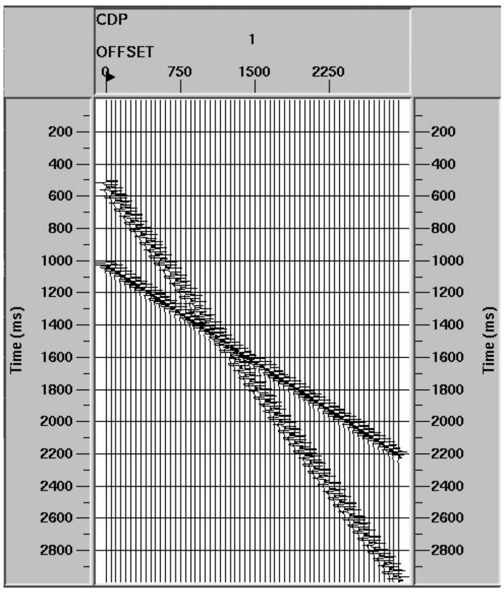
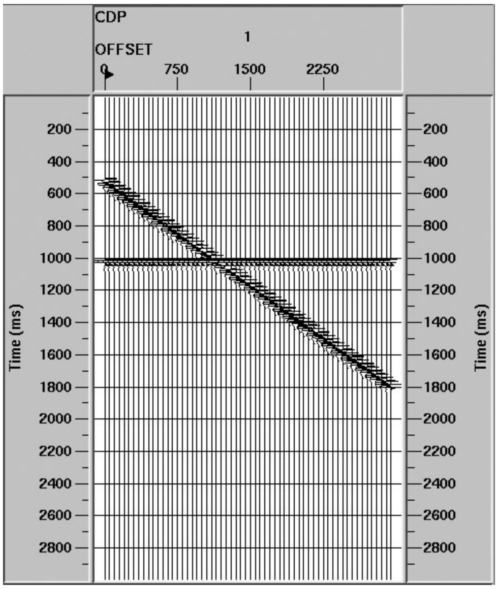
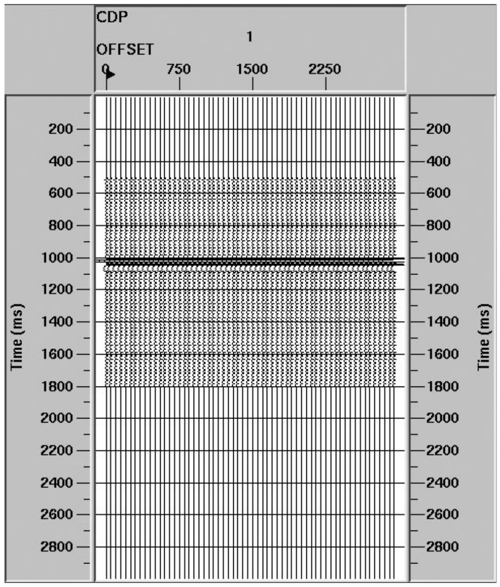


Fig. 2. The wave field of the CDP gather traces of two waves with linear phase axes with the apparent velocities 1200 m/s and 2500 m/s

Fig. 2. Pole falowe kolekcji tras CDP z dwiema falami o liniowych osiach fazowych z prędkościami pozornymi 1200 m/s and 2500 m/s



a)



b)

Fig. 3. The wave field from Fig. 1 after LMO corrections (a) with the velocity 1200 m/s and the result (b) of its K-L filtering (*Output Eigen-filtered zone* variant) for the eigenimage range 0% - 0%

Fig. 3. Pole falowe z fig. 1 po zastosowaniu poprawek LMO (a) z prędkością 1200 m/s oraz wynik (b) jego filtracji K-L (wariant *Output Eigen-filtered zone*) dla zakresu obrazów własnych 0% - 0%

with linear phase axes. Therefore in the first step of the model calculation the effectiveness of the ProMAX procedure named *Eigenvector Filter* was investigated using the simple model of two interfering waves with linear phase axes (Fig. 2). Treating one of the waves as coherent noise, the LMO corrections were introduced to obtain the horizontal phase axis of that wave (Fig. 3a). In the next step the *Eigenvector Filter* was used in the variant named *Output Eigen-filtered zone* (the reconstruction of the noise) for the eigenimage range 0% - 0%. The resulting coherent noise is obtained with a low level of the background noise (Fig. 3b) confirming the effectiveness of the process in the discussed case.

For the purpose of the multiples attenuation the NMO corrections must be introduced with the velocity of the multiples and the *Design Gate* must be defined. The CDP gather from Fig. 1a after NMO corrections (with the value 800% of NMO stretch) defined with multiples velocity and the *Design Gate* used for the eigenvector and eigenvalues calculations are presented in Fig. 4. The result of multiple suppression obtained using the S*ubtract Eigenimage of zone* variant for the eigenimage range: 0% - 0 %, 0% - 2%, 0% - 3% is illustrated in Fig. 5. It may be noticed that the result are very similar for the eigenimage range 0% - 0 %, 0% - 1 % and 0% - 2 %. The attenuation of the multiples is noticeable but not so strong. For the eigenimage range 0% - 3% the visible distortions of deeper reflections are introduced for smaller offsets. The same result was obtained for the case of the multiples velocity 3000 m/s and 3200 m/s (Fig. 6). If we change the phase characteristic of the signal from minimum-phase to zero-phase we can obtain deeper reflections without serious distortions (Fig. 7). But multiples attenuation is still weak.

To explain the source of such weak attenuation of the multiples the case of single multiples at the time 500 ms was analyzed. The wave field from Fig. 1a after the selection of the only multiple at the time of 500 ms is

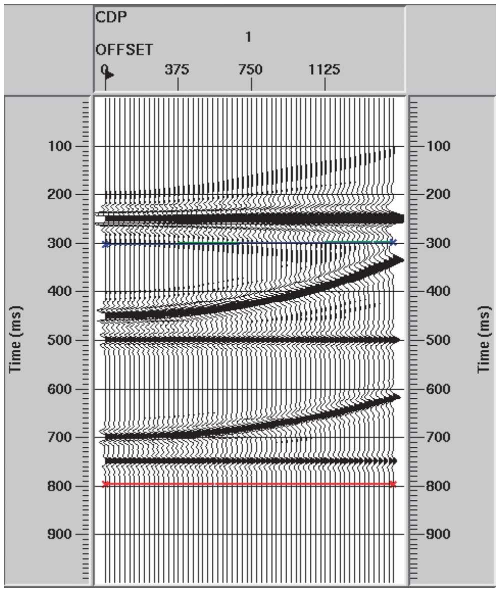
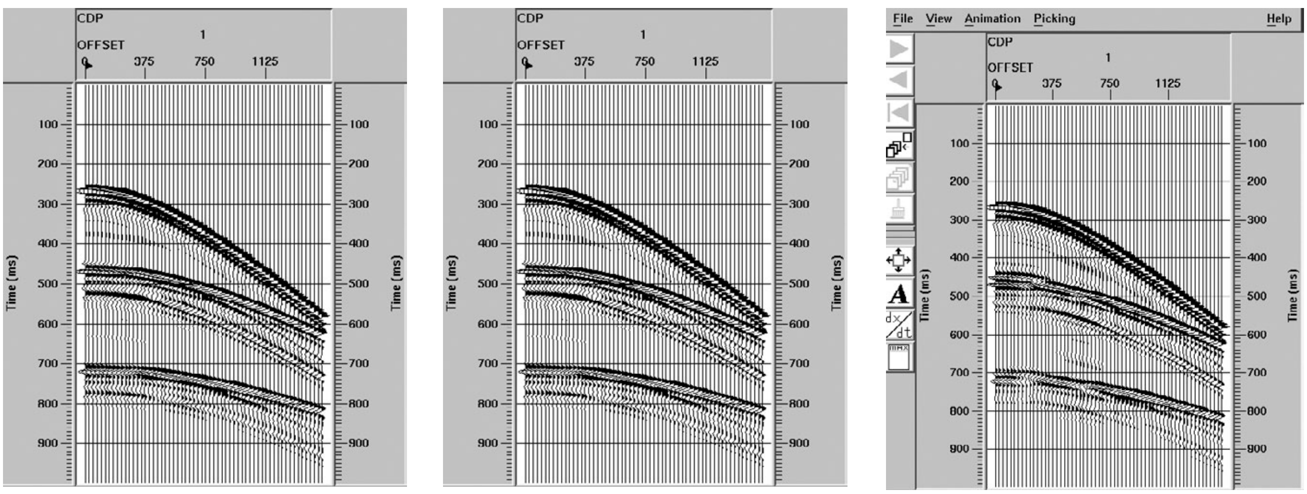


Fig. 4. The CDP gather from Fig. 4a after NMO corrections defined with multiples velocity; *Design Gate* **is marked using blue and red lines**

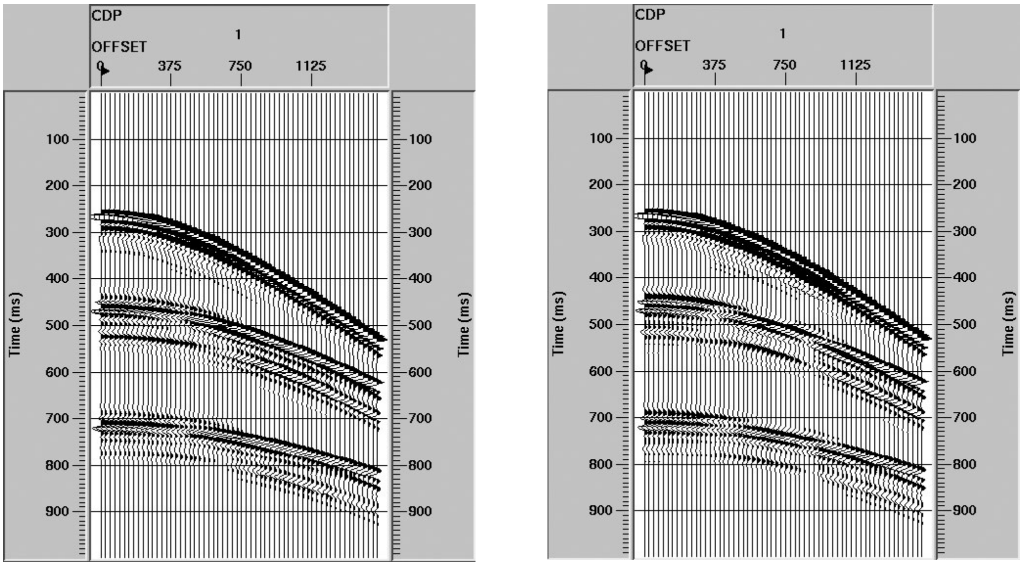
Fig. 4. Kolekcja CDP z fig. 4a po wprowadzeniu poprawek kinematycznych określonych z zastosowaniem prędkości fal wielokrotnych; okno projektowania (*Design Gate***) zaznaczono linią niebieską i czerwoną**



a) b) c)

Fig. 5. The result of multiple suppression in CDP gather from Fig. 1a obtained for the eigenimage range: a) 0% - 0 %, b) 0% - 2%, c) 0% - 3%

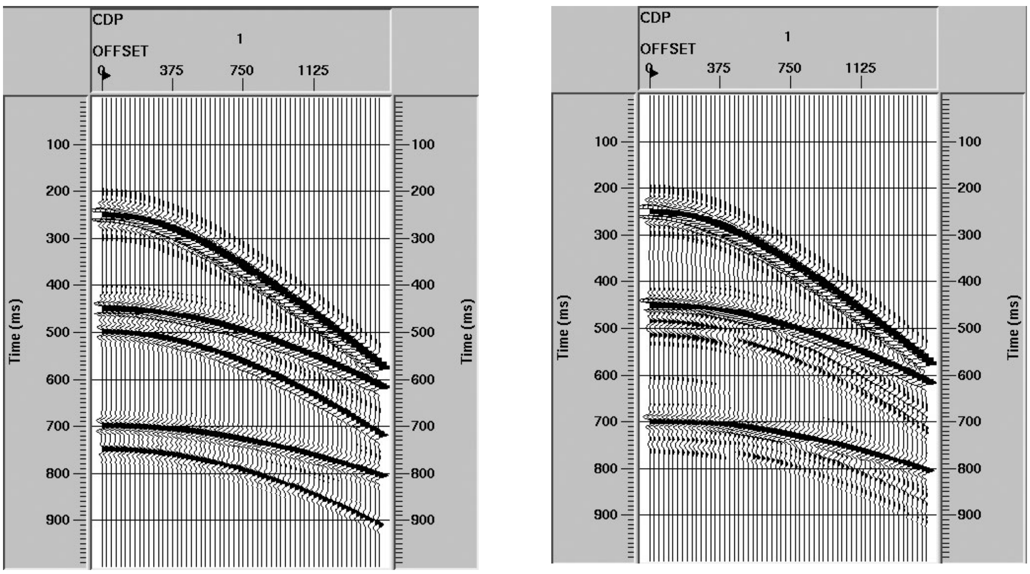
Fig. 5. Wynik tłumienia fal wielokrotnych w kolekcji CDP z fig. 1a uzyskany dla zakresu obrazów własnych: a) 0% - 0 %, b) 0% - 2%, c) 0% - 3%



a) b)

Fig. 6. The result of multiple suppression in CDP gather from Fig. 1b obtained for the eigenimage range: a) 0% - 0 %, b) 0% - 3%

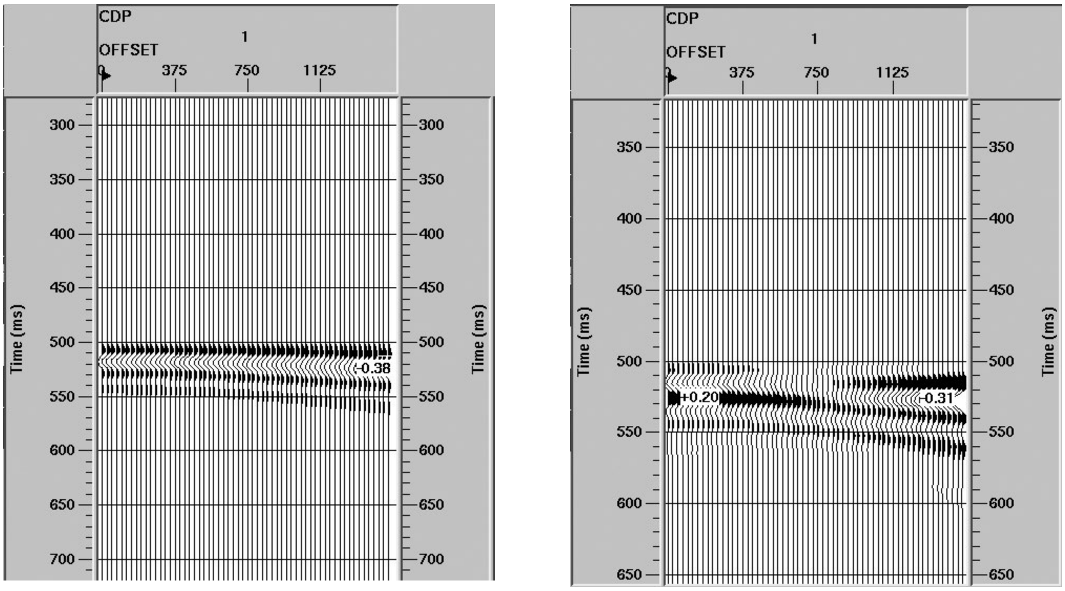
Fig. 6. Wynik tłumienia fal wielokrotnych w kolekcji CDP z fig. 1b uzyskany dla zakresu obrazów własnych: a) 0% - 0 %, b) 0% - 3%



a) b)

Fig. 7. Composition of synthetic CDP gather traces (with zero-phase primaries and multiples) for the assumed seismogeological model with multiples velocity 2850 m/s (a) and the result of multiple suppression (b) obtained for the eigenimage range 0% - 0 %

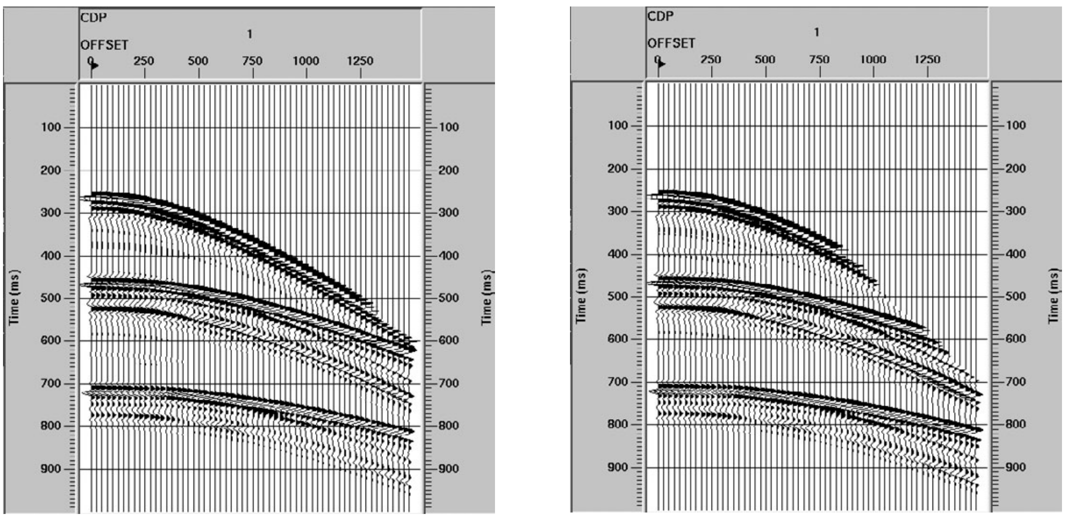
Fig. 7. a) Zestawienie syntetycznych tras kolekcji CDP (z zero-fazowymi sygnałami fal jednokrotnych i wielokrotnych) dla założonego modelu z falami wielokrotnymi o prędkości 2850 m/s (a) oraz wynik tłumienia fal wielokrotnych (b) uzyskany dla zakresu obrazów własnych 0% - 0 %



a) b)

Fig. 8. The wave field from Fig. 1a after the selection of the only multiple at the time of 500 ms: a) after NMO, b) after K-L filtering using the S*ubtract Eigenimage of zone* mode for the the eigenimage range 0% - 2 %

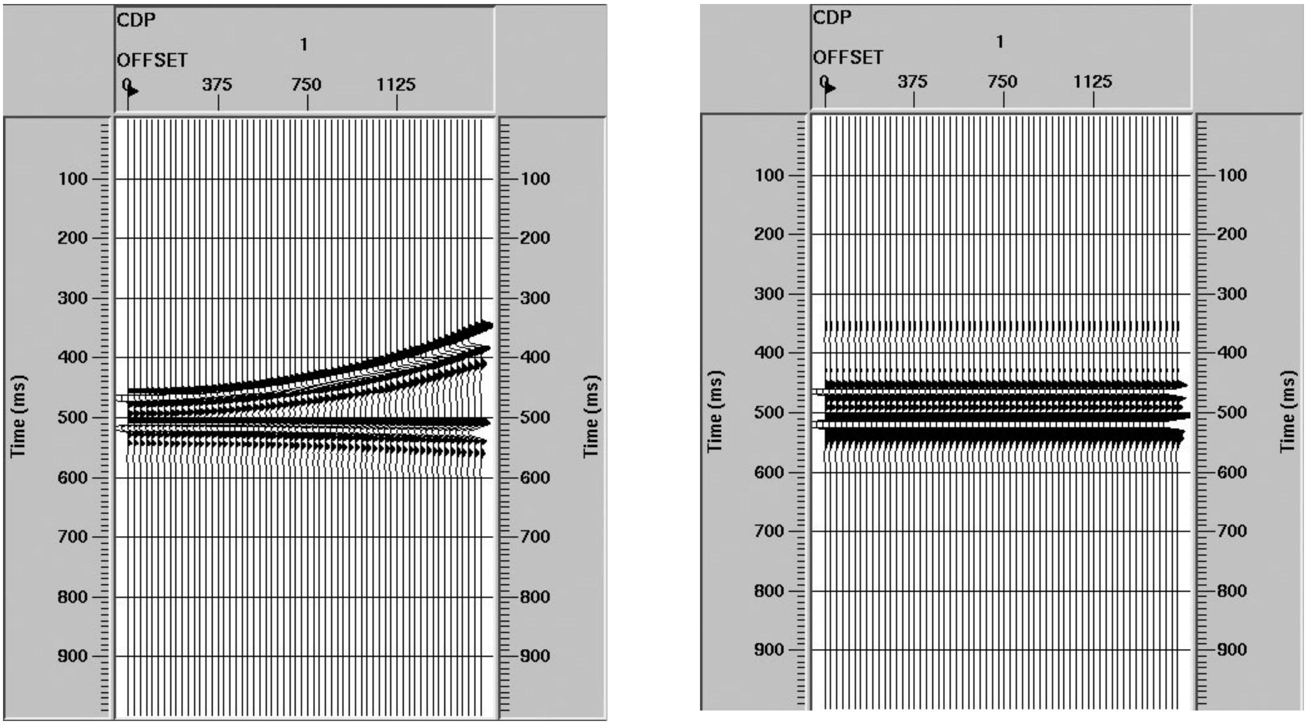
Fig. 8. Pole falowe z fig. 1a po zachowaniu jedynie fali dwukrotnej na czasie 500 ms: a) po wprowadzeniu poprawki kinematycznej, b) po filtracji K-L w wariancie S*ubtract Eigenimage of zone* z wykorzystaniem zakresu obrazów własnych 0% - 2 %



a) b)

Fig. 9. The result of multiple suppression in CDP gather from Fig. 1a obtained for the eigenimage range 0% - 0 % for different values of NMO stretch: a) 100%, b) 50%

Fig. 9. Wynik tłumienia fal wielokrotnych w kolekcji CDP z fig. 1a uzyskany dla zakresu obrazów własnych 0% - 0 % dla różnych wartości parametru *NMO stretch*: a) 100%, b) 50%



a) b)

Fig. 10. The wave field from Fig. 1a after the selection of the only primary wave at the time of 450 ms and the multiple at the time 500 ms: a) after NMO, b) after K-L filtering using the *Output Eigen-filtered zone* **mode for the the eigenimage range 0% - 2 %**

Fig. 10. Pole falowe z fig. 1a po zachowaniu jedynie fali jednokrotnej na czasie 450 ms oraz fali dwukrotnie odbitej na czasie 500 ms: a) po wprowadzeniu poprawki kinematycznej, b) po filtracji K-L w wariancie *Output Eigen-filtered zone* **z wykorzystaniem zakresu obrazów własnych 0% - 2 %**

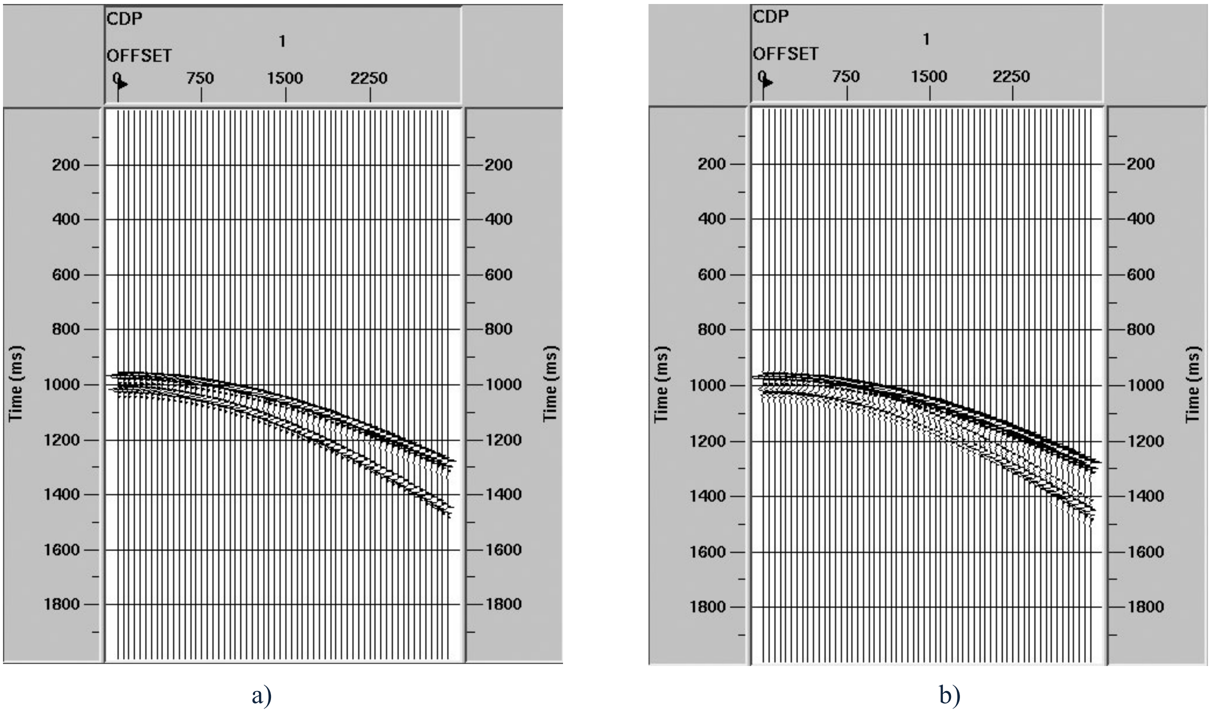


Fig. 11. Composition of synthetic CDP gather traces (60 traces with a receiver interval of 50 m) for the assumed seismogeological model with the primary wave at the time of 950 ms and the multiple (velocity 2850 m/s) at the time of 1000 ms: a) before K-L filtering, b) after K-L filtering using the S*ubtract Eigenimage of zone* **mode for the the eigenimage range 0% - 2 %**

Fig. 11. a) Zestawienie syntetycznych tras kolekcji CDP (60 tras z interwałem pomiarowym 50 m) dla założonego modelu sejsmogeologicznego z falą jednokrotnie odbitą na czasie 950 ms i falą dwukrotnie odbitą (prędkość 2800 m/s) na czasie 1000 ms: a) przed filtracją K-L, b) po filtracji K-L z zastosowaniem wariantu S*ubtract Eigenimage of zone* **dla zakresu obrazów własnych 0% - 2 %**

presented in Fig. 8 after NMO corrections and after K-L filtering using the S*ubtract Eigenimage of zone* mode for the eigenimage range 0% - 2 %. We can see that even after subtracting reconstructed multiples from the NMO corrected input traces the amplitudes of the traces are still comparable with amplitudes of input traces. The decreasing of the NMO stretch from 800% to 100% and 50% did not improve the result of the multiples attenuation (Fig. 9) for the gather traces from Fig. 1a. When we consider the filtering of the single multiples together with the primary wave after NMO corrections (Fig. 10a) we obtain as a result a multiphase wave pattern at the times corresponding to the multiples and the primary wave (Fig. 10b). Increasing the maximum offsets from 1500 m to 3000 m did not improve the effect of multiples attenuation (Fig. 11).

5. Conclusions

The results of the calculations confirmed that K-L filtering are far less effective tool of multiples attenuation for the discussed models with reflected waves (hiperbolic phase axes) than for the model with coherent linear noise. The introduction of the lower values of NMO stretch parameter and the greater maximum offsets did not improve the result of the multiples attenuation. A little improvement was noticed for the zero-phase signals in comparison with minimum phase signals.

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Streszczenie

W pracy przedstawiono analizę efektywności tłumienia fal wielokrotnych za pomocą filtracji Karhunena-Loevego (K-L), realizowanej z wykorzystaniem procedury *Eigenimage Filter* sejsmicznego systemu przetwarzania ProMAX. Trasy modelowe kolekcji CDP były generowane za pomocą procedury *The Synthetic Trace Generation* w systemie ProMAX. Oszacowano wpływ parametrów filtracji K-L na skuteczność usuwania fal wielokrotnych w przypadku interferencji fal jednokrotnych i wielokrotnych. Rozważono kilka wartości zróżnicowania krzywizny kinematycznej między falami jednokrotnymi i wielokrotnymi. W trakcie obliczeń modelowych uwzględniono różne wartości parametru osłabiania zniekształceń spowodowanych wprowadzaniem poprawek kinematycznych (*NMO stretch*), różne wartości interwału pomiarowego, jak również różne charakterystyki fazowe sygnałów.

Wyniki obliczeń potwierdziły, że filtracja K-L jest znacznie mniej efektywnym narzędziem tłumienia refleksów wielokrotnych dla rozważanych modeli z falami odbitymi (hiperboliczne osie fazowe) niż dla modelu z koherentnym szumem liniowym. Wprowadzenie mniejszych wartości parametru usuwania zniekształceń spowodowanych wprowadzaniem poprawki kinematycznej (*NMO stretch*) oraz większych maksymalnych offsetów nie poprawiło wyniku osłabiania fal wielokrotnych. Niewielką poprawę zauważono dla sygnałów zero-fazowych w porównaniu z sygnałami minimalno-fazowymi.

GEOINFORMATICA POLONICA
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POSSIBILITIES OF USING TERRA ASTER SATELLITE IMAGE FOR DRAWING UP MAPS OF SOIL FERTILITY OF FALLOW FARMLANDS

Key words:

remote sensing, satellite images, Terra Aster, fallow farmlands, soil properties

Abstract

Remote sensing data is applied in soil cartography to setting soil boundaries. It most often concerns bare soil surfaces, but it is also possible to determine spatial variation of the soil through the analysis the vegetation variability. It relates particularly to areas covered with natural vegetation. The area of fallow farmlands in Poland covers c.a. 1 million hectares. The goal of the study was to use the quantitative relationship between the TEB resources in the soil within the fallow farmlands and the spectral reflectance from their surface as registered by satellite images (Terra Aster) to draw maps of the soil fertility. On the basis of this relationship the resources of TEB were estimated and maps showing soil fertility in three categories were prepared. These maps were then compared with soil-agricultural maps pointing at resemblances and differences of the three fertility classes' boundaries and complexes of agricultural usefulness of the soil, taking the kind of the soil into consideration.

MOŻLIWOŚCI WYKORZYSTANIA OBRAZÓW SATELITARNYCH TERRA ASTER DO OPRACOWANIA MAP ŻYZNOŚCI GLEB NIEUŻYTKÓW POROLNYCH

Słowa kluczowe:

teledetekcja, obrazy satelitarne, nieużytki porolne, właściwości gleb, suma zasad

1. Introduction

Remote sensing data, i.e. satellite images and aerial photographs, may be helpful in verifying the content of soil maps (Karolyuk et al. 1994). Most studies related to the possibilities of using remote sensing in soil cartography have focused on soils not covered with vegetation (Ben-Dor, 2002). Cierniewski and Królewicz (1997) claimed that by using aerial photographs as well as SPOT and Landsat satellite images it is possible to determine the reach of hydromorphic soils, yet it is not possible to determine the boundaries of grey-brown podzolic soil.

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Apart form the analysis of images and photographs of soil surfaces not covered with vegetation one may also gain information related to soils using remote sensing data in an indirect way, namely by analysing crust vegetation (Barnes 1996), taking into account the close relationship between the two components of natural environment: soil and vegetation. According to Vink (1968; after Ciołkosz 1999), in soil studies the second most important element for photointerpretartion is vegetation, going just after topographic characteristics. The use of aerial photographs and satellite images enables relatively cheap and quick collection of environmental data related to vast areas. According to Peña-Barragán et al. (2004), replacing traditional methods of field inspection by remote sensing methods reduces the costs by 75%.

Fertilisation and mechanical methods of plant cultivation applied to arable lands and grasslands limit the influence of natural soil properties on the plant growth. That is why the relationship between soil and vegetation that can be seen in remote sensing data is better visible in natural vegetation (Ciołkosz 1999), which is similar to the vegetation of fallow farmlands. The course of succession and the development of vegetation on fields lying fallow largely depend on soil conditions. On fallow farmlands of better soil conditions the vegetation is lush and produces greater mass. Soils of more granulometric composition create more favourable conditions for the plant development. In earlier studies Piekarczyk (2009) determined the relationship between some characteristics of fallow farmlands covered with vegetation in the second stage of succession and spectral data obtained from images from the Terra Aster satellite. The closest relationship occurred between the values of the vegetation index calculated based on reflectance factor indices within the range of the near and medium infrared and TEB resources in soil. TEB resources, constituting the total content of exchangeable base cations of calcium, magnesium, potassium and sodium (measured in cmol(+)/m^2 /soil profile thickness) in soil, make up a synthetic measure of sorption volume, basic microelements resources as well as soil reaction, and indirectly characterise soil fertility.

The most detailed source of information about soil environment is soil-agricultural maps. They are, however, not strictly speaking soil maps, since apart from information related to genetics and natural sciences (soil types, graining) they first of all show the division of agricultural production space into complexes of farmland usefulness. This kind of functional interpretation of soil characteristic together with the number of observations not meeting the standards of observation density for a given map scale (Buol et al., 2003; Hazelton and Murphy, 2007) as well as ignoring remote sensing data in field works and analyses, result in limited reliability of the picture of habitat and soil conditions as presented on those maps (Kuźnicki et al., 1979; Borowiec, 1985).

The aim of the studies was to determine the possibilities of using Terra Aster satellite images for drawing maps of soil fertility of fallow farmlands based on the relationships between the values of reflectance factor index obtained from satellite images and soil characteristic values obtained while doing field and laboratory research.

2. Materials and methods

The research was done on four fallow farmlands situated within the village of Kunowice (O1) in the community of Słubice, in the village of Bielice (O3) in the community of Torzyn, and in the villages of Sułów ()2) and Starków (O4) in the community of Rzepin. The farmlands had been excluded from agricultural production for five years and the vegetation succession there was in its second stage. A Terra Aster satellite image registered on 24 April 2005 was used. Spatial references were given to this imaged based on a topographic map at scale 1:10,000. The choice of images from the Aster sensor is dictated by a great number of satellite scenes (2311) available for the territory of Poland within the years 2000-2009, including 979 with cloudiness not exceeding 50% (Suchecka, 2010). In the studies three sensor channels of visible and near-infrared spectrum (VNIR) were used: Ast1 (520-600nm), Ast2 (630-690 nm), and Ast3 (760-860 nm), as well as of short-wave infrared spectrum (SWIR): Ast8 (2295-2365 nm). The DN (Digital Numbers) values of picture pixels were transformed into the form of standarized reflectance factor index (SRFI) at the level of the Earth surface, taking atmospheric correction into account. Next, dividing the values of the reflectance index factor from Ast3 channel by the values of the same index factor from Ast8 channel, the vegetation Ast3/Ast8 factor index was calculated (Almeida and Souza Filho, 2004). Maps of boundaries of arable lands deprived of vegetation and of fallow farmlands for the area of the community of Rzepin covered by satellite images were prepared based on the differentiation between the values of reflectance factor indices in first three spectral channels (Ast1, Adt2, Ast3).

The description of the method of determining the relationship between spectral reflectance and TEB resources is included in the work by Piekarczyk (2009).

3. Results

Fig. 1 shows fragments of a Terra Aster satellite image in infrared spectrum (Ast3) registered on 24 April 2005, covering areas of four examined fallow farmlands. The analysed areas exhibit clearly visible differentiation of pixel brightness reflecting the variability of reflectance factor index, which mirrors the variability of vegetation cover.

In this spectral channel, light pixels express higher values of reflectance factor index and for farmlands they correspond to surfaces covered with a vegetation of a large biomass, growing on relatively cohesive soils, which on a soil-agricultural map cover the areas of clay graining (gl) or light clayey sand (pgl). Darker pixels were related to lower values of reflectance factor index and to the occurrence of vegetation of turf grasslands character, which occurs on soils originated from loose sands (pl) or weak clayey sands (ps). When the discussed satellite picture was registered, the vegetation on better soils was better developed than the vegetation on poor soils.

Fig. 2 shows maps of spatial differentiation of TEB resources in soil within the examined fallow farmlands. What was used to calculate TEB resources values for each pixel was the relationship between the soil characteristic and the vegetation Ast3/Ast8 factor index, calculated

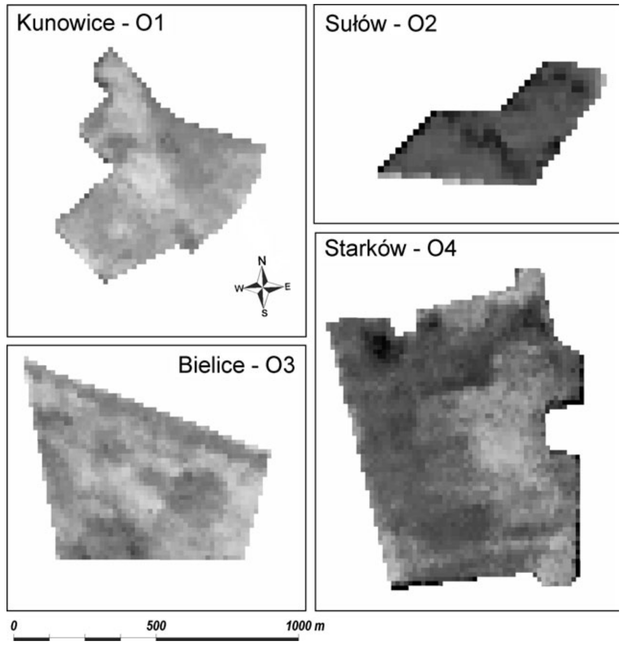

Fig. 1. Analysed fallow farmlands in an ASTER satellite image (fallow farmlands boundaries are outlined in black).

Rys. 1. Analizowane nieużytki porolne na obrazie satelitarnym ASTER (granice nieużytków obwiedziono linią koloru czarnego).

based on reflectance factor index values from channels 3 and 8 of the Aster sensor (Piekarczyk, 2009).

The calculated values of TEB resources ranged between 5,400 and 324,000 cmol(+)/m^2/50cm. The highest mean values of TEB resource were obtained for O2 fallow farmland (34 000 cmol(+)/m^2/50cm), and the lowest ones for O3 fallow farmland (8 495 cmol(+)/m^2/50cm). Based on the analysis of soil and habitat conditions within the areas of the analysed fallow farmlands, three conventional categories of TEB resources - trophicness of soils - were established (Table 1)

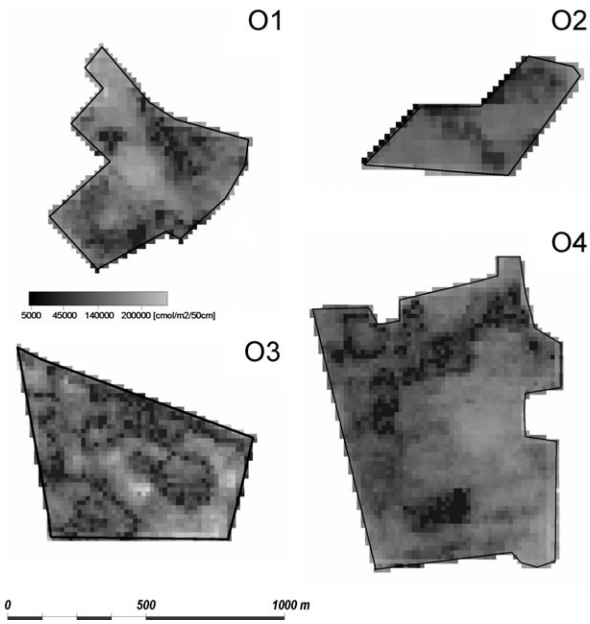

Fig. 2. Spatial distribution of TEB resources in soil within the analysed fallow farmlands.
Rys. 2. Rozkład przestrzenny zasobów TEB w glebie w obrębie analizowanych nieużytków porolnych.

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Table 1. Trophic categories of soils based on TEB resources.
Tab 1. Kategorie troficzności gleb w oparciu o zasoby TEB.

Fertility class	Soil type	Draining conditions	TEB resources ($me*m^{-2}$)
1	poorly developed soils	extremely excessive	< 7,5000
	rusty soils	excessive	
	sandy grey-brown podzolic soils	excessive	
2	typical seepage grey-brown podzolic soils (of low or medium erosion)	slightly excessive or optimal	7,500 – 45,000
	very light and light proper deluvial soils	optimal	
3	typical grey-brown podzolic soils of low or high erosion	excessive	> 45,000
	proper black earths made of full glacial sands or sands lying shallow on clays	unsatisfactory	
	medium deluvial soils	optimal	

As the main root mass of plants reaches 50 cm, the TEB resources values at a depth of 50 cm were used to determine trophicness categories of habitat. The analysis of TEB resources in the examined soil profiles showed that for values lower than 7,500 cmol(+)/m^2/50cm the soils were overgrown with vegetation of turf grassland character and of very small biomass. They are rusty or poorly developed soils of loose sand graining, reaching down to 1 km or more, and of excessive draining. The soils of the second trophicness category were grey-brown podzolic soils, sometimes with slightly marked by gleyic processes, or low or medium stage of erosion, as well as proper light deluvial soils. TEB resources ranged from 7,500 to 45,000 cmol(+)/m^2/50cm, and draining conditions were close to optimum. The third trophicness category was composed of medium or highly eroded grey-brown podzolic soils (with clays lying shallow) of excessive draining, and soils of the most favourable draining conditions, i.e. proper black earths made of glacial sands lying shallow or medium deep on clays, as well as medium-grained deluvial soils. In the last of the categories just mentioned, TEB resources exceeded 45,000 cmol(+)/m^2/50cm.

Fig. 3 shows maps of spatial distribution of three classes of TEB resources with fragments of soil-agri-

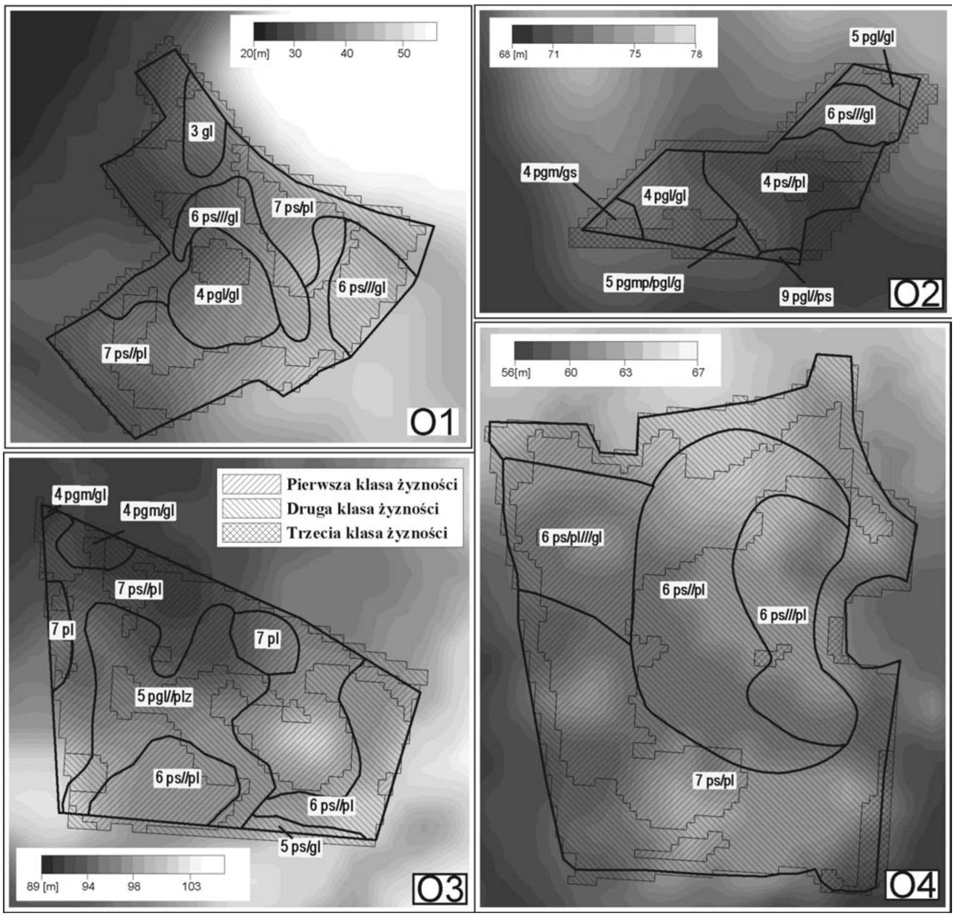

Fig. 3. Maps of topographic profile and maps of spatial distribution of TEB resources with fragments of soil-agricultural maps of the analyzed fallow farmlands included.

Ryc. 3. Mapy rzeźby terenu i mapy rozkładu przestrzennego zasobów TEB z nałożonymi na nie fragmentami map glebowo-rolniczych analizowanych nieużytków porolnych.

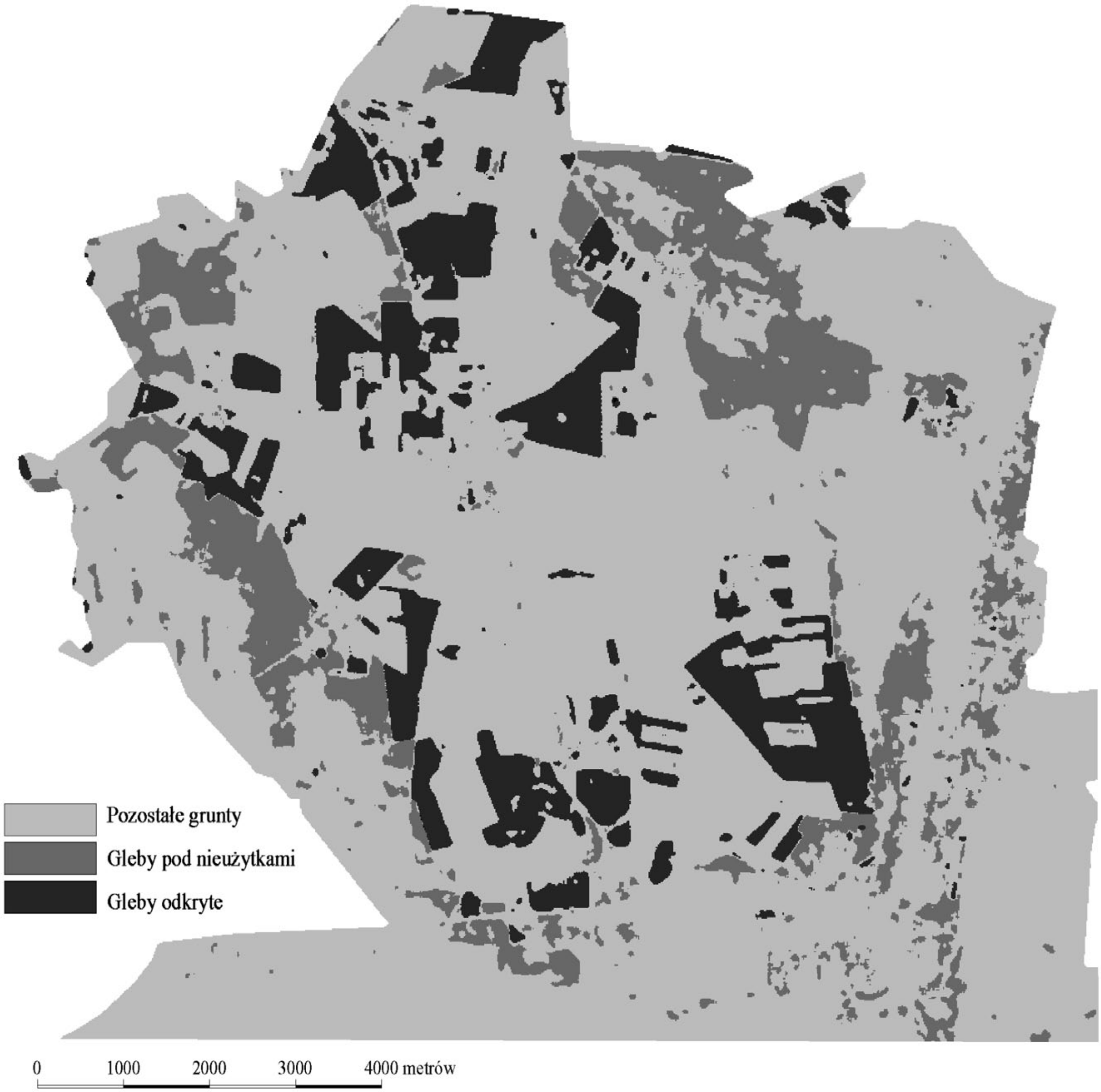

Fig. 4. The area of lands not covered with vegetation and of fallow farmlands in the community of Rzepin, within the analysed image from the Terra Aster satellite of 24 April 2005.

Ryc. 4. Areał gruntów niepokrytych roślinnością oraz gruntów zajętych przez nieużytki porolne w gminie Rzepin na analizowanym obrazie satelity Terra Aster z 24 kwietnia 2005 roku.

cultural maps drawn against the topographic profile. On schematic maps showing the topographic profile one may asses the diversity of land configuration, which is crucial for draining conditions and toposequential structure of soil cover in catenal systems, depending on these conditions. The highest diversity of the configuration was seen on O1 fallow farmland, where delevelling reached 20 m. On the remaining fallow farmlands the diversity of the configuration was lower and delevelling did not exceed 8 m. In the conditions of wavy bottom moraine, the diversity of soil cover corresponds to the diversity of draining conditions in catenal systems (Kaźmierowski 2001).

Therefore, one may expect a relationship between the shape of the boundaries in soil maps and the land configuration, taking at the same time into consideration primary materials and draining conditions that form microclimate. The diversification of grey shades within the areas marked in the soil-agricultural map illustrates the diversity of the terrain and proves that the outlined soils are located in different places of catenanes or they contain whole catenanes. An example of such an inaccuracy can be on outline marked in Fig. 3 with a symbol of 5pgl/plz on O3 fallow farmland and the outline in the south part of O4 fallow farmland marked as 7ps/pl. The interpretation of the soil cover diversity based on characteristics most closely correlated with the biomass of natural vegetation and indirectly with natural adaptation of vegetation complexes to soil condition, which together with the application of geostatistical and remote sensing techniques enables outlining naturally distinguished soil patches of specified morphological structure, water regime and soil characteristics. Distinguishing such natural soil units is possible by interpreting remote sensing data related to soils covered with natural or seminatural vegetation appearing in a form of systems of different soil fertility categories. The largest area of relatively best soils belonging to the third conventional class of TEB resources occurred on O2 fallow farmland. Also the soil-agricultural map shows the higher agricultural usefulness of the soil in this fallow farmland (Fig. 3), however the boundary lines do not correspond to the TEB resources classification based on spectral characteristic of vegetation. The highest degree of TEB resources diversification occurs on O1 and O3 fallow farmlands. Similar diversification occurs on soil-agricultural maps. The applied division of TEB resources is not taxonomic; it is schematic and serves mainly to characterise the diversity of habitat conditions within the area of the examined fallow farmlands.

Using the relationship between TEB resources of fallow farmland soils and spectral reflectance from its surfaces enables the improvement of effectiveness of using remote sensing data, broadening the classic interpretation of uncovered soils. Fig. 4 shows the location of soils not covered with vegetation and of fallow farmlands within the area of the community of Rzepin, covered with the analysed images from the Terra Aster satellite of 24 April 2005. The area of fallow farmlands was 420 ha and the area of lands not covered with vegetation was c.a. 385 ha. By applying remote sensing data in order to determine soil characteristics (in the context of improving soil maps and making fertility maps) within the area of uncovered lands and fallow farmlands, based on the quoted example, the effectiveness of using satellite data may be doubled.

4. Conclusions

The results of the studies prove that satellite images of fallow farmlands surfaces may be useful while assessing habitat conditions and verifying soil maps. The diversity of vegetation occurring on lands excluded from agricultural production accurately reflects the variability of their soil cover. Thanks to this, boundaries between soils of different trophicness can be determined on the satellite images of fallow farmlands. Images obtained at the beginning of vegetation period (April) are of highest usefulness, since the vegetation of fallow farmlands produces the greatest green mass. Then the spectral contrast between the surfaces covered with vegetation growing on cohesive soils and grassland vegetation is most striking.

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Streszczenie

Materiały teledetekcyjne stosuje się w kartografii gleboznawczej do wyznaczania zasięgu konturów glebowych. Najczęściej dotyczy to powierzchni glebowych nie pokrytych roślinnością, ale możliwe jest również określenie przestrzennego zróżnicowania gleb poprzez analizę zmienności roślinności, która na nich się znajduje. Dotyczy to szczególnie powierzchni pokrytych roślinnością naturalną. Do takich powierzchni można zaliczyć nieużytki porolne, których areał w Polsce wynosił około 1 mln ha. W pracy zaprezentowano wykorzystanie zależności ilościowej między wielkością zasobów sumy zasad (TEB) gleb pod nieużytkami porolnymi a odbiciem spektralnym od ich powierzchni zarejestrowanym na obrazie satelitarnym do tworzenia map żyzności gleb. Na podstawie wspomnianej zależności oszacowano zasoby TEB w obrębie badanych nieużytków. Następnie wykonano mapy przedstawiające żyzność gleb w trzech kategoriach. Mapy żyzności porównano z mapami glebowo-rolniczymi wskazując na podobieństwa i różnice zasięgów klas żyzności i kompleksów rolniczej przydatności gleb uwzględniając gatunek gleby.

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AN ANALYSIS OF GEOGRAPHICAL DATA ACCURACY ON MAPS

Key words:

accuracy, precision, map content, point marks, principal point of mark, cartometrics, geographical map classification, geodesic maps, topographic maps, base map

Abstract

Accuracy of geographical data is a key issue as regards any graphic representation aspiring to be called a map. The paper discusses the term *accuracy* in its geometrical sense of points location on a map. The term *accuracy* is very often treated as equivalent to and synonymous with the term *precision*. However, this is a mistake since *accuracy* overrides *precision.* Map content is a result of graphic representation of geographical data by means of appropriate symbols. The shape, size and location of the symbols should correspond to the postulates that result from the isomorphism of form and position. A feature point associated with the geographical location of each symbol is its *principal point*. The ability to determine it is crucial to the accuracy of the measurements of linear values, angles and areas made on a map. The values that characterize the accuracy of points location on the map and the resultant reliability of measurements on the map are cartometrics.

Another problem dealt with in the paper is a classification of maps published in the O-2 technical instruction of GUGiK (Main Office of Geodesy and Cartography). It is not hard to notice that contemporary geographical maps are made using digital technologies and are therefore often called *digital maps,* which finds no reflection in the classification presented in the O-2 Instruction . If the maps concerned were made using classical methods and the result was only an analogue copy, we can consider it generally correct. However, contemporary digital technologies, beside the content criterion, should also take into account. classification conditions such as geodata collection and processing, primary source of geodata – source map, secondary map.

Accordingly, contemporary map classification should include two map classes such as *geodesic maps* and *topographic maps* and a sub-class of *thematic maps*.

Geodesic maps are defined according to content and accuracy in the K-1 Instruction of GUGiK. In this case, a land surveyor cannot change anything on the map without prior field measurements. In the case of *topographic* and *thematic maps*, on the other hand, a geographer makes visualisations of the results of his studies which gives rise to some questions about the precision of such procedures. Determination of professional competences could make it clear that a land surveyor has a right to authorize a geodesic map while a geographer-cartographer can make a topographic map.

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ANALIZA DOKŁADNOŚCI DANYCH GEOGRAFICZNYCH NA MAPACH

Słowa kluczowe:

dokładność, precyzja, treść mapy, znaki punktowe, punkt główny znaku, kartometryczność, klasyfikacja map geograficznych, mapy geodezyjne, mapy topograficzne, mapa zasadnicza

Accuracy is a concept which the Polish Language Dictionary derives from the word '*accurate – doing something or done with due diligence and attention to detail'* (Bralczyk 2007). This very general definition points to some significant features of a surveyor's and a cartographer's work such as *diligence* and *attention to detail*. Dictionaries of synonyms, on the other hand, associate *accuracy* with *precision* which is an incorrect and yet a very common practice in colloquial language. In the present paper accuracy is considered in its geometrical sense as location of points in the terrain and on the map.

When it comes to analyzing geographical data on the map, *accuracy* and *precision* are not equivalent terms. *Accuracy* appears to override *precision*. According to Leśniok(1979, page116):

„**Precision** is a degree of perfection of the measurement tool and methods. **Accuracy** is a degree of perfection of the measurement that is achieved owing to the precision applied. Precision is thus a constant feature characteristic of tools and methods while accuracy can be calculated given the known precision and observation results."

If we consider cartometrics to be a fundamental feature of a map, the map, as a graphic representation of geographic data will be evaluated with respect to geometric accuracy of the location of particular elements that make up its content. Moreover, cartometrics are closely linked with the process of map content generalization as a result of mathematical modelling of geographical space.

Other aspects of the problem include accuracy in terms of map content correspondence to the current conditions in the given area. However, this issue is not discussed in the paper. It entails other map features such as topicality and reliability.

Map content is a result of graphic presentation of geodata – symbolization. It is an extremely complex process dependent on semiotic and isomorphic relations which literature on the subject calls, quite appropriately, 'the language of a map'(Ratajski 1989). This kind of symbolization differs from any other data representation in that the symbols-marks of particular objects and phenomena have a geographical location – this entails the problem of a feature point, the so-called *principal point of a symbol.* The precision with which particular point, line and area symbols are located on a map contributes to its geometric accuracy.

Point symbols are graphic representations of the objects whose dimensions on the map scale do not exceed *0,5×0,5 mm.* For example: a geodetic control point, a well, a monument, a windmill, a transformer, a small industrial unit, a watchtower. The symbols only mark the presence of an object on a map and show its location. They do not represent its shape or dimensions. The location of an object on a map and in the terrain should be associated with a point of the symbol which is called a *principal point*.

Depending on the shape of the symbol, the principal point is situated in the following places:

a) symmetrically-shaped symbols - in their centers (triangle, circle, square, rectangle), e.g.: a well, a geodetic control point ,a water mill.
b) broad based figure- shaped symbols – in the centre of the base , e.g.: a chimney, a monument, a weather station, a brick windmill,
c) symbols with a right angle at the base – the right triangle vertex, e.g.: a cross, a wind turbine, a wooden windmill, a single tree,
d) symbols which are combinations of several figures – in the centre of the lower figure, e.g.: a brick chapel, a petrol station, a transformer, a tower-like object (Fig. 1).

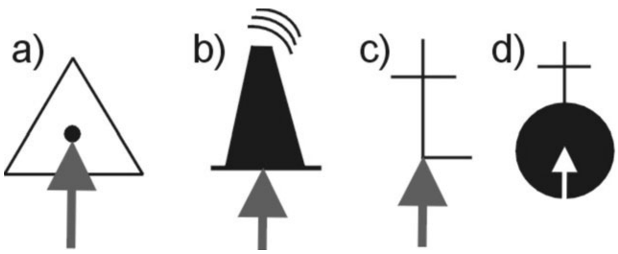

Fig. 1. Location of feature point of the symbol and indication of actual location of the object, benchmark.

Ryc. 1. Położenie punktu głównego znaku umownego i wskazanie na rzeczywiste położenie obiektu, punkt pomiarowy.

The principal point of a symbol is crucial as regards the expected accuracy of measurements and reliability of results. If the length of a segment or a direction are not determined on the basis of this point the measurement will be burdened not with a measurement error but with a mistake.

Measurements on analogue maps are made using a graphic method in many ways, with various measuring tools characterized by specific precision of measurement and reading (Dorożyński 2006). The results of linear, angular and area measurements are sufficiently reliable provided the map sheet has not been exceedingly deformed – mostly due to shrinkage. If the shrinkage is more than 0,2%, appropriate corrections should be introduced into graphically calculated areas of geometric figures. (Leśniok 1979, p. 252).

The basis for analyzing map accuracy are the criteria provided by the appropriate technical instructions of the Main Office for Geodesy and Cartography (GUGiK). Meeting the criteria ensures compatibility of geodata, is an attribute of professionalism and determines the quality of a particular data handling. According to the criteria, the expected accuracy of objects location on analogue maps with the scales 1: 10 000 and 1: 5 000 should correspond to the following values:

1) mean error of geodetic control points and mathematic control points location entered onto a map should not exceed ±*0,1 mm* and maximum error should not be more than ±*0,15 mm*

2) accuracy of situation details location should not exceed ±*0,5 mm*, while in mountainous areas with thick forestation it should not be more than ±*0,75 mm* – terrain situation objects with clear contours which do not change over many years and are permanently fixed to the ground, e.g. boundary signs, technical buildings and facilities including bridges, viaducts, tunnels, retaining walls, etc, surface elements of installations and street details with regard to the closest grid points,

3) accuracy of other situation points location should not be greater than ± *1,0 mm*.

Accuracy of geodetic control points on topographic maps based on other topographic maps at larger scales should not exceed ±*0,15 mm*, while mean accuracy of location of all situation details relative to their location on basic materials should not be more than ±*0,3 mm*[2].

Thus for cartometrics purposes total precision of location of situation details on topographic maps based on other maps is assumed to be the value calculated by taking into account the precision of the first principle map ±*0,5 mm* and the admissible difference of location on the map being made ±*0,3 mm*. The root sum square of the values is ±*0,6 mm* after rounding.

Hence, in the calculations of theoretical accuracy of measurements on a topographic map using graphic methods it can be assumed that the precision of situation details location is ***±0,6 mm*** and it will be treated as a **basic criterion of the cartometrics of situation elements.**

On the other hand, the cartometrics of the elements of relief represented by means of contour lines are determined by mean errors in contour lines elevation with respect to vertical control points and cannot exceed:

1) 1/3 of contour vertical interval value in the terrain with slope incline of up to 2°,
2) 2/3 of contour vertical interval value in the terrain with slope incline between 2° to 6°,
3) One contour vertical interval value in the terrain with slope incline greater than 6°,
4) while depicting relief of the terrain with thick forestation or emphasizing characteristic features of the ter-

[2] Instrukcja Techniczna K-2, GUGiK Warszawa 1980 (Technical Instruction,Main Office for Geodesy and Cartography)

rain, errors by one and a half times greater are admissible in contour line location[3].

On topographic maps at 1: 5 000 and 1: 10 000 scales, the elevations of geodetic control points determined by means of geometric leveling are described with the accuracy of 0,01 m , while elevations of points determined using other methods are described with the accuracy of 0,1 m. On the other hand, elevation of points on maps at 1: 25 000 and 1: 50 000 scales is described with the accuracy of 0,1 m, while maps at 1: 200 000 and 1: 500 000 scales use the accuracy of 1 m.

While measuring a length of a section on a map, it is possible to compute theoretical (*a priori*) accuracy which is also called expected accuracy. The value of this parameter is computed basing on the precision of the measuring equipment, measuring methods and precision of the point location on the map.

The values that characterize measurement components are as follows:

1) maximum graphic precision is $\pm 0,1\ mm$ – it expresses the ability of the human eye to assess the length of small sections and in the case of measurements on the map means the greatest possible precision with which the measuring point is identified,

2) precision of point identification using caliper $m_C = \pm 0,1\ mm$, and gauge graduation $m_L = \pm 0,2\ mm$,

3) precision of point location on map $m_{pp} = \pm 0,6\ mm$ – it characterizes mean error of a graphic symbol location on a topographic map.

The theoretical accuracy of the measurement of a section length on the map computed according to the Gaussian law of error is $m^T_D = \pm 0,9\ mm$. while internal consistency criterion is $3 \times m^T_D = \pm 2,7\ mm$ (borderline error).

The theoretical accuracy of a section length measurement on a map to the map scale illustrates the degree of reliability of the information about a given linear value obtained in this way. Some examples have been presented in Table 1.

[3] Instrukcje techniczne GUGiK: K – 2 (1980), O – 1 (1988). Technical Instruction,Main Office for Geodesy and Cartography)

Table1.Theoretical accuracy of a length measurement on map and internal consistency criterion at map scale

Tabela 1. Dokładność teoretyczna pomiaru długości na mapie i kryterium zgodności wewnętrznej w skali mapy

Map scale	Theoretical accuracy $m^T_D = \pm 0,9\ mm$	Consistency criterion $3 \times m^T_D = \pm 2,7\ mm$
1:25 000	±22 m	±66 m
1: 50 000	±45 m	±135 m
1: 100 000	±90 m	±270 m
1: 200 000	±180 m	±540 m

While measuring a length using a gauge it is necessary to pay attention to the metrics of the millimeter gauge and the metrics of the map.. The expected reliability of the measurement will be achieved when the so called *matching* of the units of measurement on the map and the gauge is checked. The procedure is the same as in the case of examining shrinkage. For example – the kilometer grid spaces on a map at 1: 25 000 scale should be 40,0 mm, while the gauge graduation shows a value that is different from the multiplied space size. This means that either the map or the gauge is not metric. Then a coefficient must be calculated to correct the results of the measurements.

Modern geographic maps are made using digital technologies and the term *digital maps* is often heard and yet they have not been included in the classification of maps presented in the O-2 Instruction of the Main Office for Geodesy and Cartography. The Instruction uses map content as the basic classification criterion and distinguishes two classes of maps: *general geographic maps* and *thematic maps*, including *the base map*

(Fig. 2, Fig. 3). However, modern classification of maps should take into account the latest technologies of geodata handling which involves the problem of original databases, source maps and a possibility of generating secondary map content. Therefore, beside the content criterion, the classification should also take into account the method of geodata acquisition and processing – from source map to secondary map..

In view of the above, the current classification needs to be corrected to include two map classes: *geodesic maps*

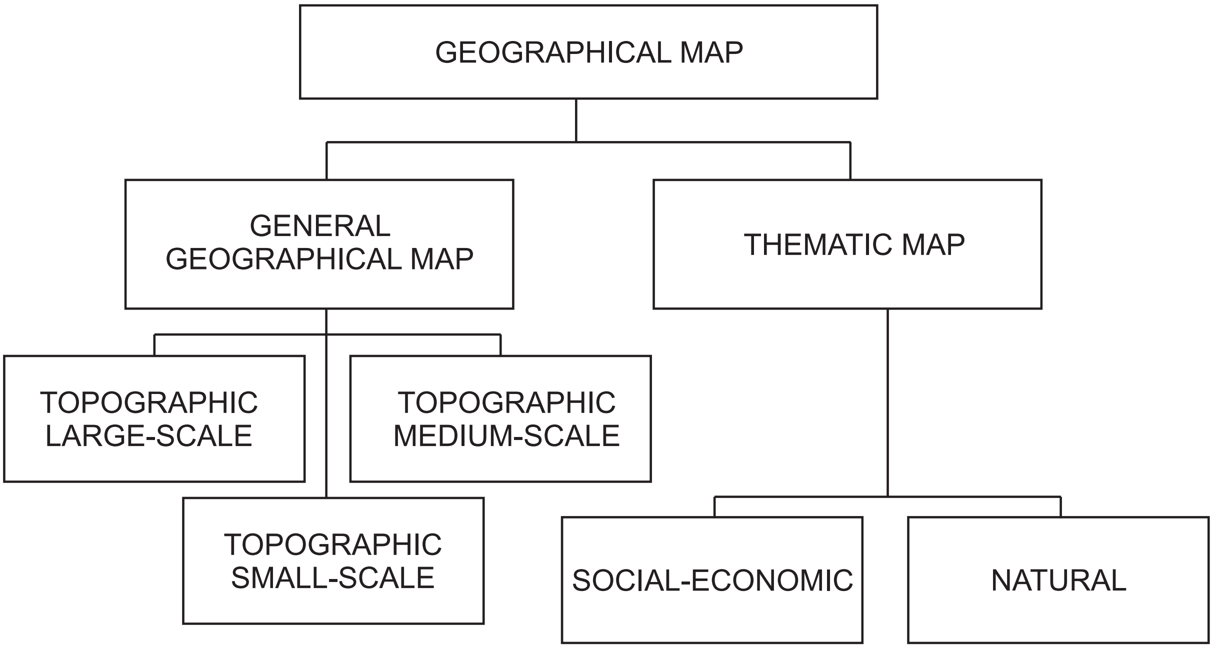

Fig. 2. Geographic map classification according to The O-2 Technical Instruction.
Ryc. 2. Dotychczasowa klasyfikacja map geograficznych wg Instrukcji Technicznej O-2.

and *topographic maps (source maps)* and a subclass of *thematic maps(secondary maps)* (Fig. 4).

Geodesic maps are made by land surveyors basing on direct field surveys and numerically processed *base maps* at 1: 500, 1: 1 000, 1: 2 000, 1: 5 000 scales. *Base maps* are source(original) maps for the subclass of *thematic maps.*

Topographic maps (large-,medium- and small-scale ones), are made by land surveyors and geographers by digital updating of the existing topographic maps basing on aerial and satellite photography or land surveys. *Topographic maps* are also source maps for the subclass of *thematic maps.*

When such a classification is used, it is possible to clearly define professional competences of the specialists who make the maps and determine the quality of source maps which should be signed with their names since maps are public so the information about their authors should also be public.

Geodesic map are defined with respect to their content and accuracy of object location in the K-1 Technical Instruction Mapa zasadnicza(Base Map), the Main Office for Geodesy and Cartography, 1998. A land surveyor cannot change anything on the map without prior surveys. On the other hand, it is mainly a geographer who makes graphic visualizations of the results of his studies on *topographic maps* and, especially, *on thematic maps* which gives rise to some questions about the precision of the operations. Is the location of all the terrain covering elements equally precise? Is it possible to update the topographic map content basing on GPS data and unprocessed aerial pictures? What is graphic measurement precision and what are the accuracies of linear ,angular and area measurements on topographic maps?

Conclusion

1. Accuracy of a map is a term which has many aspects and is not equivalent to precision,

2. Digital form of maps is a contemporary form of geodata but it should meet the geometric criteria specified

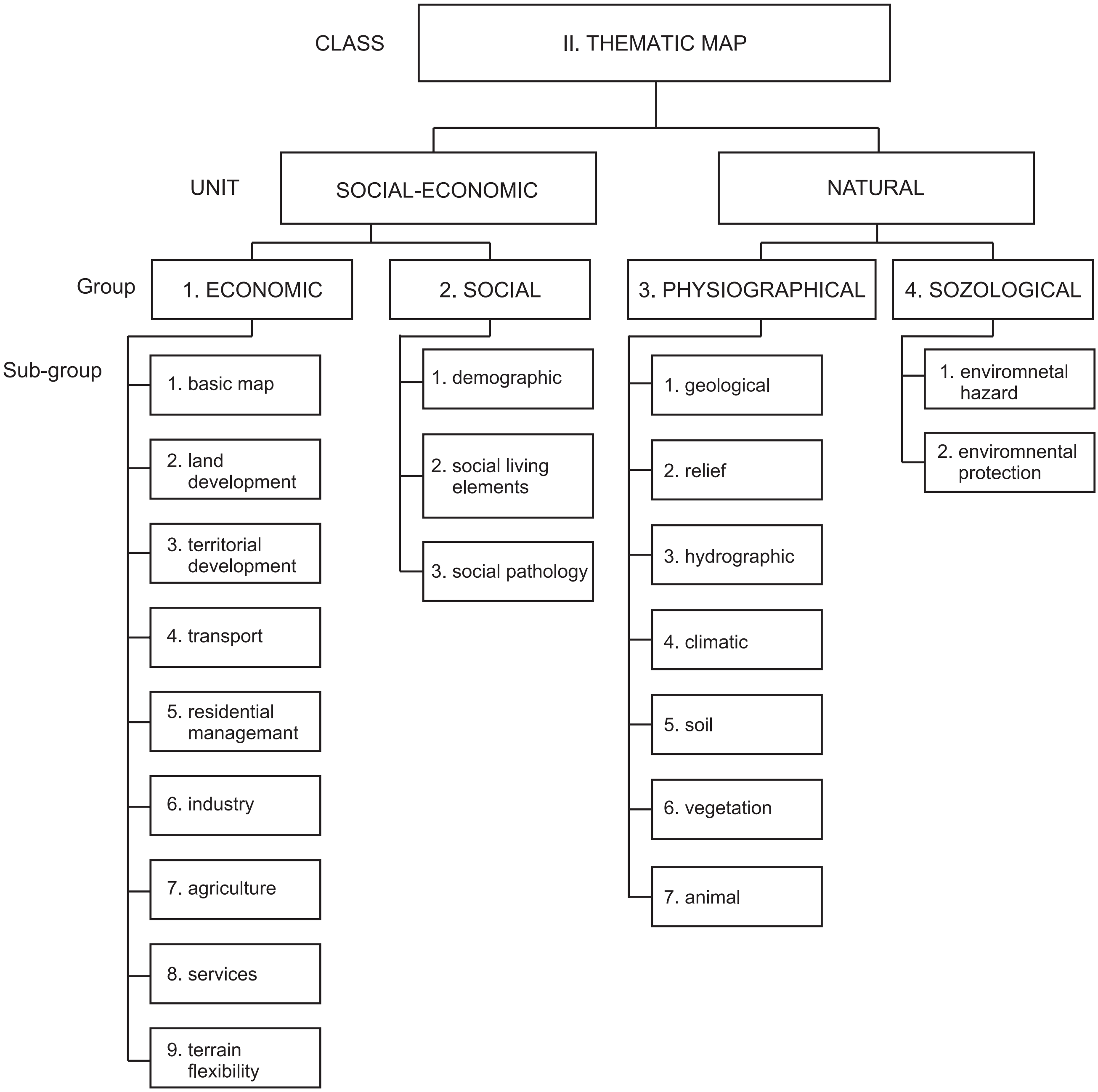

Fig. 3. Thematic map classification according to The O-2 Technical Instruction.
Ryc. 3. Dotychczasowa klasyfikacja map tematycznych wg Instrukcji Technicznej O-2.

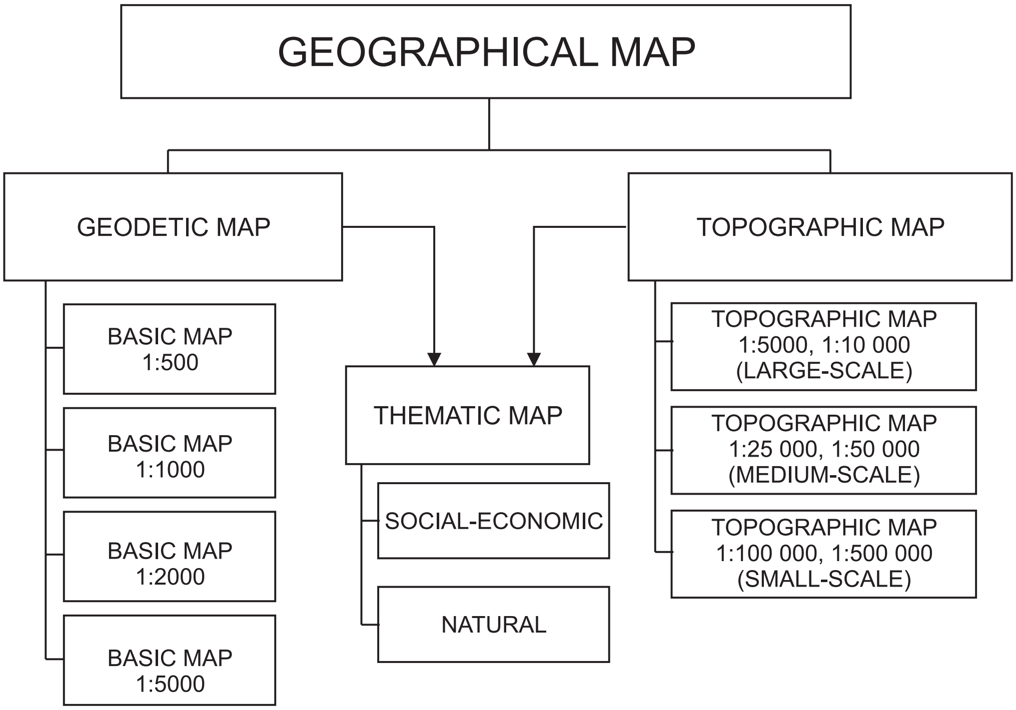

Fig. 4. Suggested modification of geographic map classification.
Ryc. 4. Proponowana modyfikacja klasyfikacji map geograficznych.

in the appropriate technical instructions of the Main Office for Geodesy and Cartography GUGiK,

3. Geodata published in the form of analogue or digital maps should be provided with information about the authors, which would guarantee professional performance and the highest geometric quality of the work.

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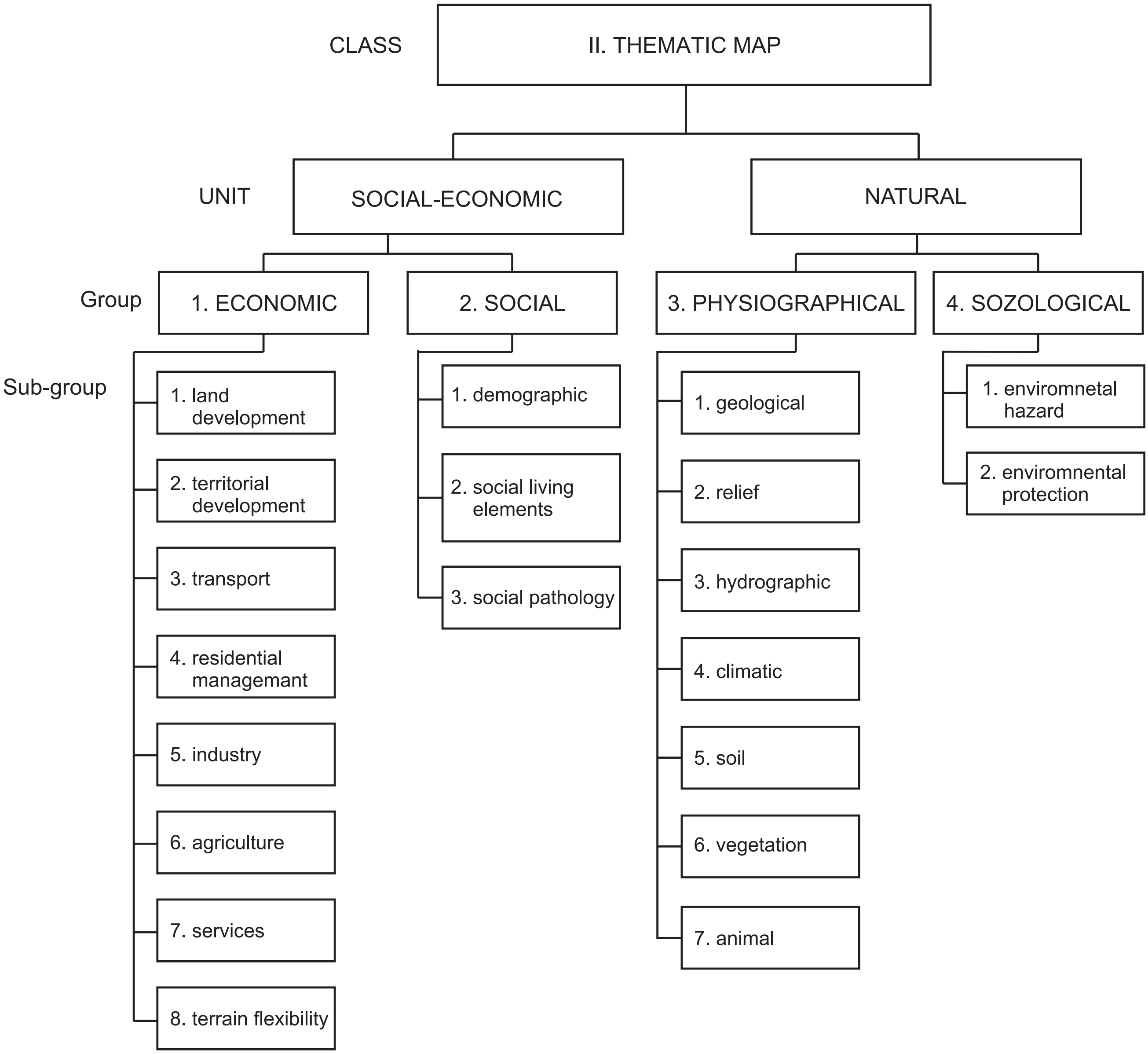

Fig. 5. Suggested modification of thematic map classification.
Ryc. 5. Proponowana modyfikacja klasyfikacji map tematycznych.

Streszczenie

Dokładność danych geograficznych jest kluczowym zagadnieniem każdego opracowania graficznego aspirującego do pojęcia mapa. W niniejszym opracowaniu przedmiotem rozważań będzie *dokładność* w sensie geometrycznym położenia punktów na mapie. Bardzo często pojęcie *dokładność* jest traktowane równoważnie i zamiennie z pojęciem *precyzja* – okazuje się, że tak nie jest, bowiem *dokładność* jest nadrzędna w stosunku do *precyzji*. Treść mapy jest rezultatem graficznego opracowania danych geograficznych i ich prezentacja za pomocą odpowiednich symboli. Kształt wielkość oraz położenie owych symboli powinny być zgodne z postulatami wynikającymi między innymi z izomorfizmu postaci i położenia. Punktem charakterystycznym kojarzonym z położeniem geograficznym każdego symbolu jest jego *punkt główny*. Umiejętność jego określenia ma istotne znaczenie z punktu widzenia poprawności wykonywanych na mapie pomiarów wielkości liniowych, kątów i pól powierzchni. Natomiast wielkości charakteryzujące dokładność położenia punktów na mapie oraz wynikająca z tego określona wiarygodność wyników pomiarów na mapie to kartometryczność mapy.

Drugi problem niniejszego opracowania dotyczy klasyfikacji map zamieszczonej w Instrukcji technicznej O-2 GUGiK. Nie trudno o stwierdzenie, że współczesne mapy geograficzne są opracowywane z wykorzystaniem technologii numerycznych, stąd też często mówi się o *mapach numerycznych* – co nie ma odniesienia do klasyfikacji przedstawionej w Instrukcji O-2. Jeżeli dotyczyło to map opracowywanych klasycznie i skutek tego był tylko analogowy, to w dużej ogólności można uznać to za poprawne. Jednakże, współczesne technologie numeryczne wraz z kryterium treści powinny również uwzględniać takie uwarunkowania klasyfikacji, jak: sposób pozyskania i opracowania danych geograficznych (geodanych), zbiór pierwotny geodanych – mapa źródłowa, mapa wtórna.

W związku z powyższym współczesna klasyfikacja map powinna uwzględniać dwie klasy map: *mapy geodezyjne* i *mapy topograficzne* oraz podklasę *mapy tematyczne*.

Mapy geodezyjne co do swojej treści i dokładności są zdefiniowane w Instrukcji K-1 GUGiK. W tym przypadku geodeta bez pomiaru w terenie nic na takiej mapie nie zmieni. Natomiast na *mapach topograficznych*, a tym bardziej na *mapach tematycznych* najczęściej geograf dokonuje wizualizacji wyników swoich badań i wtedy powstają pytania o precyzję tych procedur. Ustalenie kompetencji merytorycznych służyłoby przejrzystości w ustalaniu uprawnień autorskich opracowania mapy geodezyjnej przez geodetę i mapy topograficznej przez geografa-kartografa.

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AN INTERDISCIPLINARY APPROACH TO THE ENVIRONMENTAL AND SPATIAL INFORMATION SYSTEM BUILT FOR COASTAL WATERS. VISTULA LAGOON CASE STUDY

Key words:

Vistula Lagoon, environmental and spatial information system, mathematical modeling, satellite remote sensing, WEB map services.

Abstract

An interdisciplinary approach to geoinformation system built for assessment of ecological vulnerability of coastal water ecosystems and for sustainable development of ecologically valuable areas is presented. The example of such approach is shown for Vistula Lagoon test area where the project "System of the environmental and spatial information as the background for the sustainable management of the Vistula Lagoon ecosystem (VISLA)" is carried out in the framework of the Polish Norwegian Research Fund.

The main problem causing permanent disturbances in ecological equilibrium of the ecosystem is excessive phytoplankton primary production. The reasons for this phenomenon are spatially variable processes of phosphorus and nitrogen transport from watershed and bottom sediments. The factors influencing spatial distribution of these pollutants are hydrodynamics, meteorological and biogeochemical processes. An interdisciplinary research of these biological phenomena using remote sensing technology and mathematical modeling can facilitate control, prognosis and more appropriate actions aiming at water quality improvement.

INTERDYSCYPLINARNE PODEJŚCIE DO TWORZENIA SYSTEMU INFORMACJI ŚRODOWISKOWO--PRZESTRZENNEJ WÓD PRZYBRZEŻNYCH NA PRZYKŁADZIE ZALEWU WIŚLANEGO

Słowa kluczowe:

Zalew Wiślany, system informacji środowiskowo-przestrzennej, równowaga ekologiczna, modelowanie matematyczne, teledetekcja satelitarna, serwisy mapowe, eutrofizacja, fitoplankton

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1. Introduction

Carrying out investment or reclamation activities in coastal water ecosystem areas of great ecological and economic significance such as the Vistula Lagoon requires a precise and repeatable diagnosis of the area condition as well as the construction of a system of monitoring and ensuring ecological security of the area using remote sensing technology and mathematical modeling. The VISLA project aims at providing a modern tool for managing the natural resources and space of the Vistula Lagoon.

The Vistula Lagoon is a unique part of the Baltic Sea in ecological terms. It is a wide (an area of 838 km^2, 328 km^2 of which lie in the Polish part) and shallow lagoon (an average depth of 2,6 m). As is the case with most Baltic lagoons, its hydrological regime depends on the inflow of sea water. As much as 80% of the water flows into the Lagoon from the Sea through the Pilawa Strait, 17% is river water and only 3% of water comes from atmospheric precipitation. Water is exchanged with the Baltic Sea roughly 7 times a year. The main problem causing permanent disturbances in the ecological equilibrium of the ecosystem is excessive phytoplankton primary production and especially the regular blooms of blue-green algae (Cyanobacteria). Despite the favourable water balance which facilitates organic suspension transport to the Baltic Sea, the Lagoon waters constantly receive loads of biogenes and bacterial pollutants as a result of poor wastewater management policy in the catchment area and resuspension of phosphorus from the bottom sediments that have been deposited there over the years. The Lagoon can be defined as a shallow water area with turbid water (visibility below 0,5 m) and trophic state indices that signify hypertrophicity or high trophicity. A significant factor that contributes to high turbidity of water is the wind that not only causes the suspension to shift horizontally but also makes it rise from the bottom and mix with water. As a result, biodiversity deteriorates and production of ecological systems other than phytoplankton decreases. Ichthyofauna is especially affected together with submerged vegetation which is regarded as a natural 'repository' of biogenes and which almost completely disappears. Blue-green algae and bacteria as well as inorganic and organic substances that come from sewage cause toxicity which practically excludes the Lagoon from recreational use.

The Vistula Lagoon has recently become an object of special interest due to some navigation problems, environmental protection(Nature2000) and poor quality of water. Any future actions will have to affect all the components of the ecosystem of the lagoon and they will look differently in particular zones of the reservoir. Below there are some examples of actions that can be taken in the Lagoon's ecological system and whose effects can be predicted only after taking into account some complex interactions between abiotic and biological components of the ecosystem in spatial configuration which are part of the designed model:

- there is a plan to dig a channel through the Vistula Spit and deepen the water lane from Elbląg: disturbing the bottom, additional exchange of water with the sea.
- further trend to pollute the Lagoon water: extra charge of biogenes and toxins.
- improvement in wastewater management in the catchment area: decrease in pollutant inflow, role of „internal eutrophisation".
- reclamation activities such as bottom dredging biomanipulation, phytoplankton acquisition: affecting biogeochemical and trophic systems (bottom-up and top-down techniques).
- effects of climate changes: longer periods with high temperatures, more frequent occurrence of strong winds, increased exchange of waters with the offing (greater salinity), greater mobility of coastal water, especially on marshy coasts.

2. The visla project

The project called 'System of the environmental and spatial information as the background for the sustainable management of the Vistula Lagoon ecosystem (VISLA) is a research undertaking that concerns the improvement of methods to monitor and manage the natural environment of the Vistula Lagoon. The project is co-funded by the Kingdom of Norway through the Norwegian Financial Mechanism. The project coordinator is Uniwersytet Warmińsko-Mazurski (University of

Warmia and Mazury)in Olsztyn, and the partners include Norsk Institutt for Vannforskning in Bergen, Norway and Państwowa Wyższa Szkoła Zawodowa(the State School of Higher Professional Education) in Elbląg.

The main aim of the project is to improve the quality of control, diagnosis and forecasts concerning the condition of the environment in shallow coastal waters, i.e. in the Vistula Lagoon, and its changes. The project proposes an innovative complex tool for sustainable management of the area which is shortly to become a place of many investment actions. The project focuses on establishing the basic framework for water quality improvement and nature reclamation in the Vistula Lagoon. These objectives meet the requirements of Water Framework Directive and the NATURA 2000 agenda

The project aims at implementing an innovative web service for the management of environmental ans spatial resources of the Vistula Lagoon. The main research objective of the projects is the construction of a mathematical model as a set of formulas that will allow prediction of environmental consequences of various kinds of interference with the spatial system of the Vistula Lagoon as well as long-term processes connected with climate change scenario. The basic tool used for creating a spatial model of the Lagoon is satellite remote sensing combined with the modeling of hydrodynamics and water quality monitoring processes. The combination of mathematical modeling making use of a set of biogeochemical and hydrobiological data with satellite imagery is the greatest innovative feature of the project. It is widely accepted in applied ecological sciences that spatial modeling of ecosystems modifications is the most appropriate approach to developing effective ecological engineering tools for the management of natural resources under global change conditions.

2.1. Project participants

The project is carried out by an interdisciplinary team comprising employees of Katedra Ekologii Stosowanej UWM(Departament of Applied Ecology, University of Warmia and Mazury) (6 people, including project manager), Katedra Fotogrametrii i Teledetekcji UWM (Departament of Photogrammetry and Teledetection)(3 people), Instytut Geodezji UWM (Geodesy Institute) (1 person), Instytut Politechniczny PWSZ (Polytechnic Institute, the State School of Higher Professional Education)(3 people), Instytut Fotogrametrii i Kartografii Politechniki Warszawskiej (Institute of Photogrammetry and Cartography, Technical University,Warsaw)(1 person) and 4 people from Oceanography, Remote Sensing and Marine Modelling division of the Norwegian Institute NIVA. Meteorological model data for the project were provided by Instytut Meteorologii i Gospodarki Wodnej(Institute of Meteorology and Water Management) and Instytut Morski (Maritime Institute) in Gdynia.

2.2. Project objectives

One of the main goals of the project is to produce a WEBGIS-based information system. Therefore the project itself is regarded as an information system. It includes a number of elements which collaborate to make up a non-linearly functioning system.

Project objectives are systemic in nature:

- Interaction of the VISLA system with the systems in its immediate surroundings
- Integration of data inside the system
- Presentation of research results, spatial data

The objectives recur in various configurations and under various conditions.. For example, satellite data acquisition requires a number of different operations connected with data collection, preliminary processing, orthoimage generation, various processes of picture analysis.

The VISLA project was envisaged and designed as an information system. The most important feature of such an approach is treating the project as a set of elements which can be described using abstract formal means. Structural analysis and the UML language have been used for his purpose.

Ecological studies of the Vistula Lagoon focus on the explanation of the phenomena which are responsible for the adverse ecological effects such as blue –green algae blooms, bacterial pollution and decreased ichthyofauna population. A set of abiotic and biological factors is examined:

1. Acquiring information about geological and hydrodynamic conditions in the reservoir.

2. Construction of a system of meteorological factors influence (temperature, atmospheric precipitation, winds, insolation, PAR).
3. Examination of the exchange, flows and retention of the main nutrients (C, N, P, Ca, Fe, Si) in the deep water, the suspension(including phytoplankton) and bottom sediments.
4. Determination of the composition and dynamics of the bacterial plankton in the Lagoon waters.
5. Examination of the taxonomic structure dynamics as well as biomass changes and phytoplankton vitality(pigments), blue-green algae blooms dynamics and toxicity .
6. Determination of the Lagoon ecological systems biodiversity (zooplankton, bottom fauna, ichthyofauna, ornithological fauna).
7. Examination of the trophic dependencies: phytoplankton (bacterial plankton) – zooplankton – ichthyofauna and bottom fauna – ichthyofauna.

Research tools include remote sensing technologies. Acquisition of satellite data took place repeatedly during two research seasons in the years 2008 and 2009. They were significant for two reasons: they supplied spatial information system for the land area around the reservoir and provided information about the physical and chemical parameters of the water and their distribution in time and space. The project title itself suggests a close connection of the research with GIS.. GIS tasks link RS and ECO tasks with Web tasks. Their main aim is to collect, store and process ECO and RS data and make them available in the form of geobases or thematic maps for the setting up of a web service. Meanwhile, a desirable effect of the creation of the Vistula Lagoon information system is its incorporation into the Regional Spatial Information System. It was then necessary to take inventory of the existing data resources.. The analysis was made from the point of view of the data utility for supporting the management of the ecosystem in the Vistula Lagoon and adjacent areas .

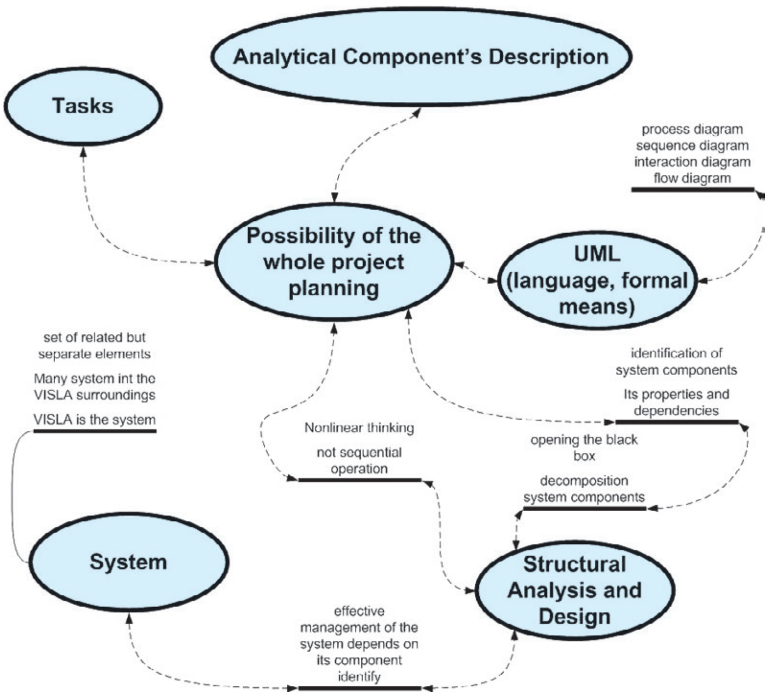

Fig. 1. Diagram showing correlations of the system elements design.
Rys. 1. Schemat obrazujący współzależność elementów projektowania system.

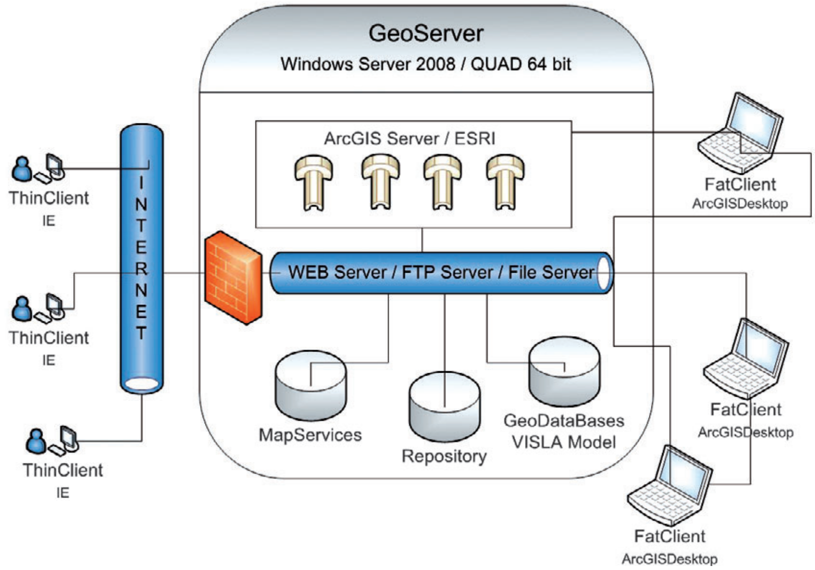

Fig. 2 The VISLA project geoserver architecture
Rys. 2. Architektura geoserwera w projekcie VISLA

An important aspect of the works carried out was to define common grounds for collecting research material of such variety. Appropriate structure of databases was determined while the particular data sets (RSIP, ECO and RS) were subjected to preliminary processing before being deposited in database. Thus, for the data in the existing cartographic resources:

- record format was determined,
- conversion to ArcGIS INFO- served formats was carried out
- systems of coordinates were standardized
- reconfiguration of data discrepancies was performed

Due to the interdisciplinary nature of the collected information, the compatibility of the structure of data exchange among particular sections of the VISLA project was checked for the ECO and RS data in the first place. Attention was paid mainly to the uniformity of terminology with respect to the parameters determined during ECO measurement campaigns. The next step was to define spatial references and check the correctness of the data spatial position basing on the RSIP resources. The sets of information prepared in this way were imported to the database. The final stage of the works was to make thematic maps on the basis of the collected material.

The development of the Internet, its infrastructure and system software and applications has made it possible for the project teams to work as scattered teams. Apart from human resources, data resources, software and computation capacity of computers are scattered too. (Dragicevic S., Barlam S. 2004).

The Internet tasks within the framework of the VISLA project fall into several categories:

- project repository service,
- making html documents available on the www server,
- making map services available on the ArcGis Server (ESRI).

The tasks related to project repository organization, which allows the documents and data to be stored in an orderly format that is known to all project participants, are based on an ftp client's access to the server. The access is not anonymous and is limited to selected directories. The project information portal is organized as a simple html document-based service. The service is placed in the domain of the University of Warmia and Mazury, Olsztyn, named: http://visla.uwm.edu.pl. Spatial data which are collected and processed within the project framework are made accessible in the form of mapping services by means of ArcGISServer 9.3 (ESRI). In this case, mapping services are map documents based on personal geobases. The whole web solution is based on the geoserver shown in Fig.2 and is a foundation for the scattered team's collaboration.

It consists of the following components:

- Geoserver – a computer with a quad-core processor
- Windows Server 2008 operating system as a file and www server
- ArcGISServer 9.3 as WEBGIS environment based on NET platform
- Fat client with ArcGISDesktop
- Thin client with a Web browser

Such a solution lets different project participants play different predetermined roles corresponding to appropriate powers and available resources.

2.1. Project components

The VISLA project perceived in a linear way consists of three consecutive stages (Fig. 3):

- Data collection
- Computation and data processing
- Making the designed products such as models, databases, Web services.

2.1.1. Official data, remote sensing data and in situ measurements

National Spatial Information System collects data and makes them available at different levels of public administration. Due to the size of the area, precision and topic of the data for constructing the system of information about the Vistula Lagoon, data collected at the voivodeship level were used. At the moment there are no directory servers in Poland comprising National Geodetic Resource (Gotlieb et al. 2006). Data search and identification were carried out by means of a query at Voievodship Centres for Geodesic and Cartographic Documentation in Olsztyn and Gdańsk. The purchased RSIP data were in SHP files (Shapefiles) and concerned 3 districts around the Lagoon(Nowy Dwor, Braniewo, Elbląg) A comparison of the data sets from two voivodeships showed some thematic layers to be missing (Tab 1).

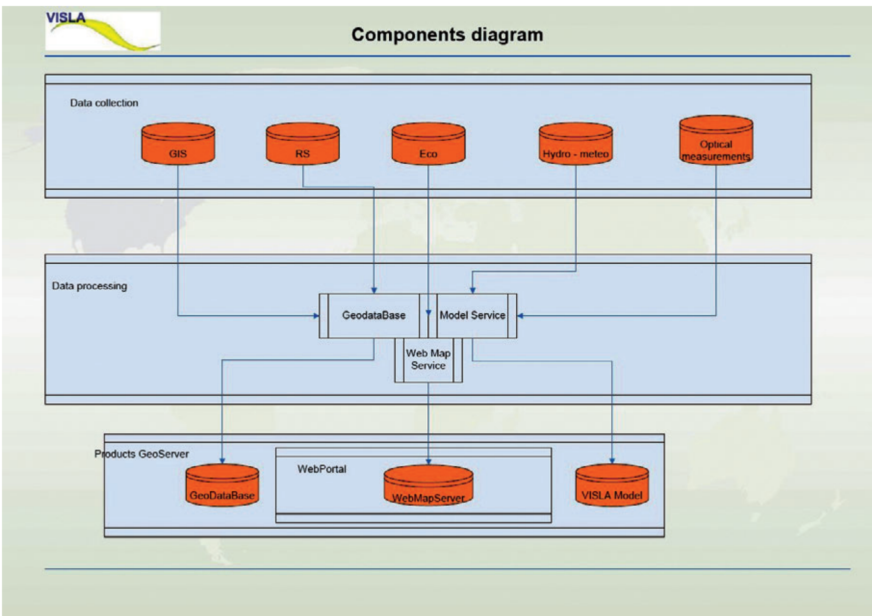

Fig. 3 Project components scheme – project stages
Rys. 3. Diagram komponentów projektu – fazy projektu

Tab. 1. RSIP data list for particular districts.
Tab. 1. Wyniki zestawienia danych RSIP dla poszczególnych powiatów.

		Voivodeship of Pomorze	Voivodeship of Warmia and Mazury	
		Nowy Dwor district	Braniewo district	Elbląg district
Administration		Voivodeship boundary, district boundaries, commune boundaries, district head offices, commune head offices	commune boundaries, district boundaries, postal codes	commune boundaries, district boundaries, postal codes e
Economy		Sea ports area	Ports	Ports
Technical infrastructure		Electricity lines, pipelines	-	-
Geographical environment	Environmental protection	natura2000, protected landscape areas, natural reserves protection zones, landscape parks, landscape parks protection zones, nature monuments, natural reserves	reserves, protected landscape areas	reserves, protected landscape areas
	Space	Water level elevation points, Elevation points (benchmarks), contours	-	-
	Land use	lakes,forests, sea, rivers_lines rivers polygons, islands	lakes, forests,rivers, rivers polygon	lakes, forests,rivers, rivers polygon
Social and cultural environment		hospitals, historical monumentsi, localities with more than. 2000 inhabitants., localities with fewer than 2000 inhabitants., primary schools and gymnasiums	localities with more than. 2000 inhabitants., localities with fewer than 2000 inhabitants.	localities with more than. 2000 inhabitants., localities with fewer than 2000 inhabitants..
Communication and transport		roads, railway, sea ports, crossroads	roads, railways, low altitude airway, ports, water lanes	roads, railways, airport, low-and high-altitude airway, ports

Research material was extended to include a 1:50 000 scale hydrographic map in the Polish coordinates system PUWG „1992". The thematic content of the map comprises some 70 indices arranged on several information levels (http://serwisy.codgik.gov.pl/temap/hydro.html):

- topographic watersheds,
- surface waters,
- underground water outflows,
- first-level underground waters,
- soils permeability,
- water economy phenomena and objects ,
- hydrometric points of stationary measurements.

While RSIP data can be purchased for one administrative unit area, thematic maps are made available in section cuts. 7 sheets of hydrographic map in vector form in MapINFO format were bought. These are: N-34-63-A,B,C,D; N-34-64-A,C i N-34-76-A. Since the sheets were made at different time, their accuracy is determined to refer to the years 2005 – 2007.

The above data were made accessible as research material on the basis of agreements signed with the Marshall of particular voivodeships.

To build the information system concerning the Vistula Lagoon, selected layers from a detailed geological map and geological-economy map made available courtesy of the State Geological Institute were also used.

Basic data are acquired by means of remote sensing from high spatial resolution satellites such as Landsat 5 and, occasionally, SPOT and ALOS. The main source of superspectral data for optical characteristics of water is the CHRIS/PROBA. system. The initially planned use of the EO-1/ALI scanner proved impossible due to 'political and technological' reasons. The system operator abandoned the idea of commercial service and let the satellite be programmed as part of free web services but did not guarantee imaging.. Landsat 5 high-resolution images are a source of data for both water and land areas to supply the spatial information system built for the communes near the Lagoon. In 2009 a system of ENVISAT/ MERIS data acquisition for the Vistula Lagoon was designed within the framework of Cat 1project of the European Space Agency. MERIS image provide information on three main physicochemical parameters associated with water optics: Chlorophyll-a (Chl-a), dissolved organic matter CDOM (Colored Dissolved Organic Matter) and TSM (Total Suspended Matter).

In situ measurements

In order to obtain much environmental information for building a database and a prognostic model of ecological conditions in the Vistula Lagoon, measurements were made of over 50 parameters of physical, chemical and biological properties of the waters and their surroundings,:

- in situ meteorological parameters: air temperature, air humidity, atmospheric pressure, the intensity of solar radiation, wind speed and direction,
- physical parameters of water: water temperature, oxygen saturation, Secchi disk visibility, suspension composition,
- physical parameters of sediments: granulometric composition and sedimentation rate,
- chemical parameters of water and sediments: total and dissolved carbon, nitrogen and phosphorus ,silicate and iron content, C,N and P content in sediments and their resuspension, biogene loads from catchment area as external data.,
- biological parameters of water: chlorophyll-a and pheophytin content, condensation., biomass and taxonomic composition of phytoplankton, zooplankton and benthos and parameters of bacterial pollution of water, among others, faecal coli bacteria.

2.1.2. Computational models

The project uses GEMSS computational model which allows prognoses of both hydrodynamics (Edinger, 2001, Prakash i Kolluru, 2005) and water quality as well as hydrobiological properties (Edlinger, Kierks, Kolluru, 2003). This is a 3D model composed of previous hydrodynamic models (GLLVHT) and water quality model (CE-QUAL-W2), which allows applications in prognosis and simulation of changes in physical, chemical and biological(phytoplankton, bacterial plankton, zooplankton) parameters of water reservoirs. It can also be applied to analyzing the spread of coastal waters pollution and biogeochemical response of the ecosystem to climate change as in the case of the STELLA model (Mortimer and Krom, 2008). The Vistula Lagoon model will be part of the web service devoted to environmental management of the reservoir..

3. Characteristics of the planned project results

The project was envisaged as a venture whose products could be located both in the scientific field and practical as well as public utility spheres. For this reason, the expected products will cover a wide range of uses on project completion:

1. the project website with acquired satellite image and databases concerning researched physical and chemical parameters as well as biodiversity.
2. thematic maps of the parameters resulting from a GIS analysis in electronic and paper form.
3. guide books for the Lagoon users with descriptions of the environment and biodiversity in electronic and paper form (based on databases).
4. computer programme – mathematical model for forecasting changes in the Lagoon environment under the influence of anthropogenic factors and climate change.
5. training for the computer programme users.
6. scientific publications on the ecology and biodiversity of living resources in the Lagoon (5).
7. scientific publications on abiotic environment. biogeochemistry and biogenes distribution in the Lagoon waters (5).
8. scientific publications on remote sensing, GIS and mathematical modeling (5).

9. international scientific conference on the management of the environment and living resources of coastal reservoirs.
10. a popular-science book in Polish, Norwegian, English and Russian.
11. information campaign (leaflets, lectures, presentations) aimed at the local community: schools, universities, self-government, ecological organizations and others.

The target group of the project products receivers would comprise units of territorial self-government administration in the vicinity of the Lagoon., the boards of civil maritime navigation and ports, environmental protection services such as inspectorates and wastewater treatment plant owners in the localities on the Lagoon, fishing companies, boards of the protected areas, schools and universities.. Research work would be presented at thematic international conferences on estuaries, lagoons, remote sensing, mathematical modeling in ecology, etc..

The Vistula Lagoon problems are mentioned both in the Pomorze Voivodeship Development Strategy and social-Economic development Strategy”

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AN interdisciplinary approach to the environmental and spatial information system built for coastal waters. vistula lagoon case study.

Streszczenie

Interdyscyplinarne podejście do tworzenia systemu geoinformacyjnego służącego ocenie zagrożeń środowiskowych wód przybrzeżnych oraz rozwojowi obszarów ekologicznie wrażliwych jest przedstawione na przykładzie założeń metodologicznych projektu pt. „System informacji środowiskowo-przestrzennej jako podstawa do zrównoważonego gospodarowania ekosystemem Zalewu Wiślanego (VISLA)” realizowanego w ramach Polsko-Norweskiego Funduszu Badań Naukowych. Głównym problemem powodującym trwałe zaburzenie równowagi ekologicznej ekosystemu jest nadmierna produkcja pierwotna fitoplanktonu. Przyczyną tego zjawiska są zróżnicowane przestrzennie procesy dostarczania ze zlewni oraz z osadów dennych związków fosforu i azotu. Czynnikami regulującymi rozprzestrzenianie się tego typu zanieczyszczeń są zmienne przestrzennie układy procesów hydrodynamicznych, meteorologicznych i biogeochemicznych. Interdyscyplinarne badania zjawisk przyrodniczych przy wykorzystaniu technik teledetekcji oraz zastosowanie modelowania matematycznego mogą pozwolić na kontrolę, prognozy i skuteczniejsze działania zmierzające ku poprawie jakości wód tego zbiornika. Głównym celem projektu jest zbudowanie systemu informacji przestrzennej pozwalającego na przewidywanie środowiskowych konsekwencji różnych interwencji w ekosystem Zalewu Wiślanego oraz procesów związanych ze scenariuszami zmian klimatycznych.

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DESCRIBING THE CANOPY CLOSURE OF FOREST STANDS USING THE METHOD BASED ON THE AIRBORNE LASER SCANNING AT THE EXAMPLE OF CHOJNA FOREST DISTRICT

Key words:

airborne laser scanning (ALS), canopy closure of forest stands

Abstract

Canopy closure is a very important parameter of forest stand characteristic with ecological and economical significance. During the forest stand inventory, the crown coverage is specified as a descriptive value in quite a subjective way and the forest compartments are qualified to fixed classes based on the guidelines (IUL). The Airborne Laser Scanning (ALS) offers the possibility to generate Digital Surface Model (DSM; also called Crown Height Model) and based on this the stand characteristic can be determined. This paper presents a method of crown cover (canopy) estimation based on ALS data. Estimation was carried out separately for the whole area of compartments and focusing on the inventory plots. Study area was located in Chojna Forest District (RDLP Szczecin). Study was done based on 49 coniferous compartments (inc. 95 sample plots) and 67 deciduous compartments (134 plots). ALS data were collected in September 2006 using Riegl LMS Q-560 (full waveform) device mounted on helicopter (flying altitude 500 m). Reference data (forest inventory based on sample plots) were collected during July/August 2006. Based on ALS, the DSM and nDSM (normalised) were generated as raster (1x1 m; GeoTIFF). Crown cover was obtained from nDSM by pixel classification using height attributes (ERMapper). The profile analysis of ALS point cloud of each forest compartment was conducted to eliminate points from second storey. For the compartment level the SILP data were used as reference. To compare the descriptive data with ALS estimations transformation from descriptive to number values was done. Verification of ALS method was done through on-screen vectorization of crowns using aerial orthophoto (pixel size 12cm) in 5 forest compartments. Digital boundaries of the compartments coming form Forest Digital Map (LMN) were examined using nDSM and orthophoto RGB. Results show that crown cover estimated from ALS point cloud on the compartment level for coniferous forest fits in 53% to the reference data (SILP). Crown cover based on ALS was lower than SILP value only for 10% of compartments. In 37% compartments we observed higher overestimations using ALS. Different results occurred in deciduous compartments where ALS crown cover value was higher than SILP for 47%, lower in 13% and with no difference for 40% of compartments. In deciduous compartments reverse correlation between stand height and difference value between SILP and ALS crown coverage was found.

Differences between ALS crown coverage for all compartments and sample plots were insignificant. Crown cover value for coniferous and deciduous sample plots was higher (3.7% and 2.9%) than coverage for corresponding forest compartment. This proves great usefulness of ALS data in sample plots arrangement planning in stands. Results obtained through screen vectorization on orthophoto were similar to ALS method. During data retrieving the significant errors in Forest Digital Map (LMN) vectors occurred, which shows that verification of forest compartments boundaries is needed every time when ALS data or aerial images are taken.

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METODA OKREŚLANIA ZWARCIA KORON W OPARCIU O LOTNICZY SKANING LASEROWY NA PRZYKŁADZIE DRZEWOSTANÓW NADLEŚNICTWA CHOJNA

Słowa kluczowe:

lotniczy skaning laserowy (ALS), zwarcie drzewostanu

1. Introduction

Forest economy requires possession of precise data concerning assessment characteristics of forest stands which include, among others, canopy closure. The feature has an ecological and economic significance and affects the light and moisture relations in the forest stand. The most popular method of canopy closure assessment is its visual appraisal from the ground level. The accuracy of the method depends only on the experience and conscientiousness of the assessor who should check the canopy closure over the whole area of the forest stand and determine its mean value based on the observation. The information concerning canopy closure and other assessment characteristics is acquired during the forest stand inventory which is extremely costly. For this reason, there has been an increased interest in alternative methods of data acquisition which can support or even altogether replace field surveys. One of the methods is Airborne Laser Scanning (ALS) which has been used for many years in Scandinavian and North American countries (Hyyppä et al. 2004). The forests in those countries are much less diverse as regards species composition and structure ,which certainly facilitates data collection by remote sensing. On the other hand, advanced works on the utilization of such methods are in progress in Germany where the forest species structure is similar to Polish forest stands. Although studies of forest closure determination are not so advanced as in the case of forest stands tree height determination, many papers have appeared showing ALS potential in the field. (Morsdorf et al. 2006, Reutebuch et al. 2005, Holmgren et al. 2008). The aim of the paper was to demonstrate the possibilities of using ALS data to determine canopy closure in farm forest stands. The assessment was made on two levels of particularity by means of determining closure parameter for the whole sub-compartment and for circular test areas.

2. Study area

Study area covered Obręb Piasek (Piasek precinct) in Chojna Forest District (Regional Bard of State Forests, Szczecin) because of up-to-date inventory (forest arrangement works,2005), optimum size of the area covering 5-7 thousand ha and its compact shape. Another significant aspect was species diversity in the area (pine tree *Pinus sylvestris* 61 %; common oak *Quercus robur* and sessile oak *Quercus petraea* about 11 %; common beech *Fagus sylvatica* 16 %; others 5%) terrain relief and habitat conditions (Zajączkowski, Wężyk 2007).

3. Methods

Prior to field surveys, sub-compartments in Piasek precinct were designated and circular test areas were selected there. The selection was made on the basis of SILP/LAS description using the criteria of mean height and closure. For the purpose of the study, stratification groups were created : 5 height classes and 4 closure classes, separately for coniferous and deciduous forest stands. (Zajączkowski, Wężyk 2007). The final number of selected subcompartments was as follows: 49 coniferous compartments with 95 circular test areas and 67 deciduous compartments with 134 circular test areas. The size of the study areas depended on the forest stand height and ranged between 200 m^2 (stand height class of 10 and 15 m) and 500 m^2 (stand height class > 30 m). The center coordinates were measured in circular areas (dGPS; min. 300 epochs). Location of tree trunks (distance and azimuth from sr.pow) and crown centers was determined. Additional information helping to locate an area during determination procedure as well as on nDSM image and ortophotomosaic was a field sketch of the center location with geodetic measurements to landmarks such as forest track crossings or single trees.

Airborne Laser scanning was carried out by Milan-Flug company on September 9 and 10, 2006, i.e. a month after field measurements. A Riegl LMS Q-560 scanner (full waveform) coupled with a Rollei db44Metric digital camera were used for data acquisition. The scanning was performed at a relative height of 500 m in strips in the NE ↔ SW direction. One scan covered some 600m on the ground, and their transverse coverage was at a relatively high level of 60-80 %. dGPS adjustment was based on a German network of reference stations *SAPOS* because of its immediate vicinity of the study area. The assumed mean point density was 4 points/m^2. Apart from the data from the first and last reflection (based on full waveform analysis) Digital Terrain Model and Digital Surface Model were generated and converted into a 1,0 m grid (ASCII). Basing on DSM and DTM, a normalized Digital Suface Model (nDSM) was generated. It gave grounds for canopy closure determination.

In order to analyze particular subcompartments and circular areas, some points were selected from the nDSM set recorded in the ASCII (XYZ) format by means of the Digital Forest Map vector. At this stage, edition of boundaries proved necessary. It was carried out using nDSM. On the basis of the coordinates of circular areas centres determined by means of dGPS and the size of the ray corresponding to the size of the test area ,polygons of the circular plots were generated. They were used to select ALS point clouds.

According to Forest Arrangement Instruction (2003), forest stand closure refers only to the tree level and is so defined during inventory and entered in the SILP/LAS database. While determining closure from ALS data it is not advisable to take into account reflections from the undergrowth or forest floor in computations. In order to avoid this, point cloud was examined using LasEdit (Cloud Peak) programme. It made possible observation of point spatial distribution in vertical profiles of the analyzed stands and determination of the height of the first-floor crowns of the forest stand. On such grounds, relative height threshold was adopted for closure determination. nDSM raster image was reclassified into classes above crown base and below it (undergrowth). Canopy closure was defined as a ratio of the surface of the pixels representing tree crowns to the total surface of the sub-compartment (from Forest Digital Map). Raster layers were analyzed using ArcGIS (ESRI) environment.

4. Results and discussion

In order to compare closure defined using ALS with SILP/LAS database (from the 2005 assessment description), descriptive values were transformed into numbers according to the following scheme (Table 1).

Table 1. Closure classes according to SILP and the corresponding number ranges.
Tabela 1. Klasy zwarcia wg SILP i odpowiadające im wartości przedziałów liczbowych.

Descriptive value of canopy closure acc.to Forest Arrangement Instruction (2003)	Suggested values in numbers (0 ÷ 1) acc to FAI (2003)
full	0,91 ÷ 1,0
moderate	0,67 ÷ 0,90
intermittent	0,51 ÷ 0,66
loose	< 0,50

If ALS canopy closure value was within the range defined in Table 1, the analyzed subcompartment was ascribed parameter 0 which means that it does not differ from the assessment description. When the ASL closure was by one class higher than the SILP data, it was ascribed parameter +1 (a difference of two classes; parameter = +2). If ASL closure was by one class lower, the parameter was -1 (lower by two classes: parameter = -2). Results of comparative analyses were presented separately for coniferous sub-compartments (Fig. 1) and deciduous sub-compartments (Fig. 2) by means of subcompartment histograms with ascribed parameter values representing differences in closure parameter definitions.

Closure determined using ALS data for coniferous forest stands proved to match the reference data from inventory in 53% of the cases. It was lower by

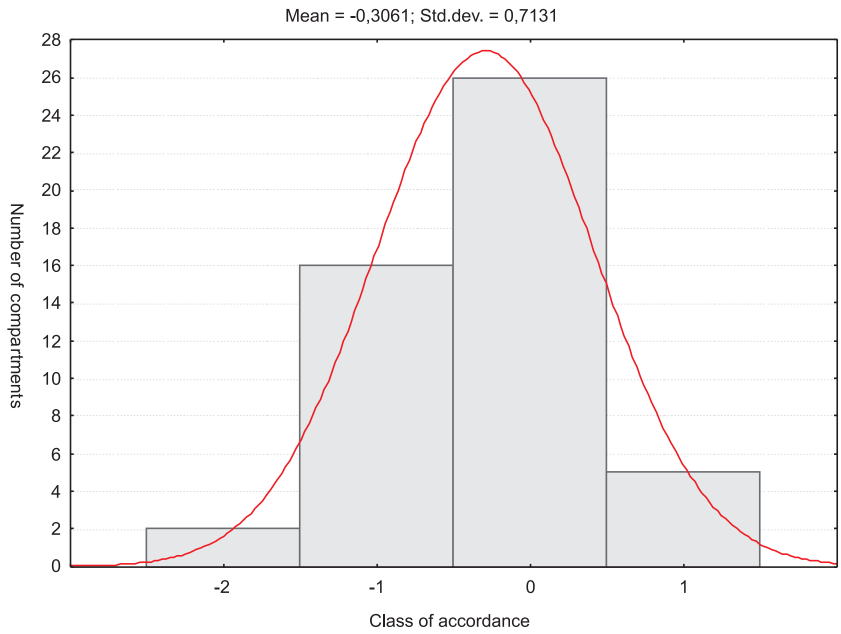


Fig. 1. Histogram of ALS- determined closure parameter compatibility with SILP reference data for 49 coniferous subcompartments.

Ryc. 1. Histogram zgodności parametru zwarcie ALS z danymi referencyjnymi SILP dla 49 analizowanych pododdziałów iglastych.

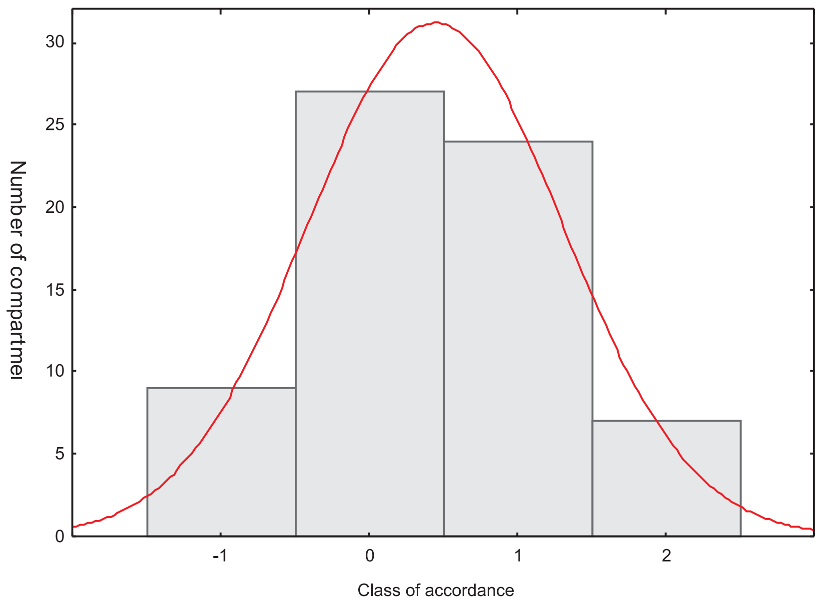
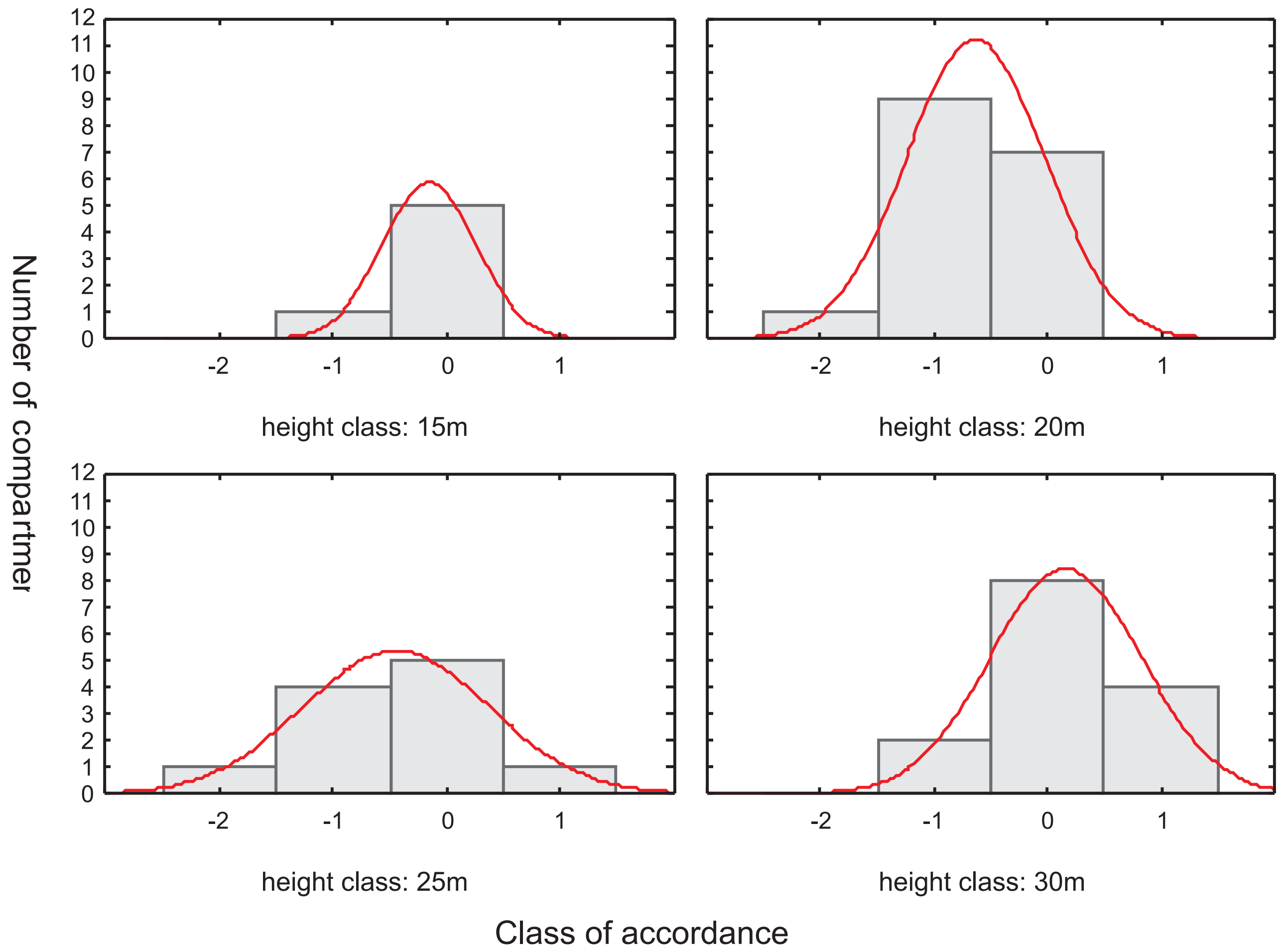


Fig. 2. Histogram of ALS -determined closure parameter compatibility with SILP reference data for 67 deciduous subcompartments.

Ryc. 2. Histogram zgodności zwarcie ALS z danymi referencyjnymi SILP dla 67 analizowanych pododdziałów liściastych.



Ryc. 3. Histogram of ALS determined closure parameter compatibility with SILP/LAS reference data for 4 forest stand height classes of coniferous subcompartments (15, 20, 25 and 30m).

Ryc. 3. Histogramy zgodności parametru zwarcie ALS z danymi referencyjnymi SILP/LAS dla pododdziałów iglastych dla 4 klas wysokości drzewostanów (15, 20, 25 i 30m).

one class, 2 classes and higher by one class in 33% , 4% and only 10% of the cases, respectively (Fig. 1). The situation was different as regards deciduous forest stands where no differences were found in 40% of the cases while higher values of ALS- determined closure were noted in 47% of the cases(by one class :36%, by two classes: 11%). Lower values of ALS -determined closure were found in 13% of the analyzed deciduous subcompartments.

In order to discover the influence of forest stand height on the accuracy of canopy closure determination, the ALS method was analyzed as regards compatibility with the SILP/LAS database for height classes of 15, 20, 25 and 30m (Fig. 3 and 4). A 10 m class was also taken into account for deciduous tree stands.

An analysis of the diagrams (Fig. 3 and 4) shows that the discrepancies between the ALS- determined closure and the reference data(SILP) for deciduous forest stands increase as the tree height increases. Starting with „10m" class, for which lower values were observed than those in SILP/LAS database , to „30m" class where the values are markedly higher (overesti-

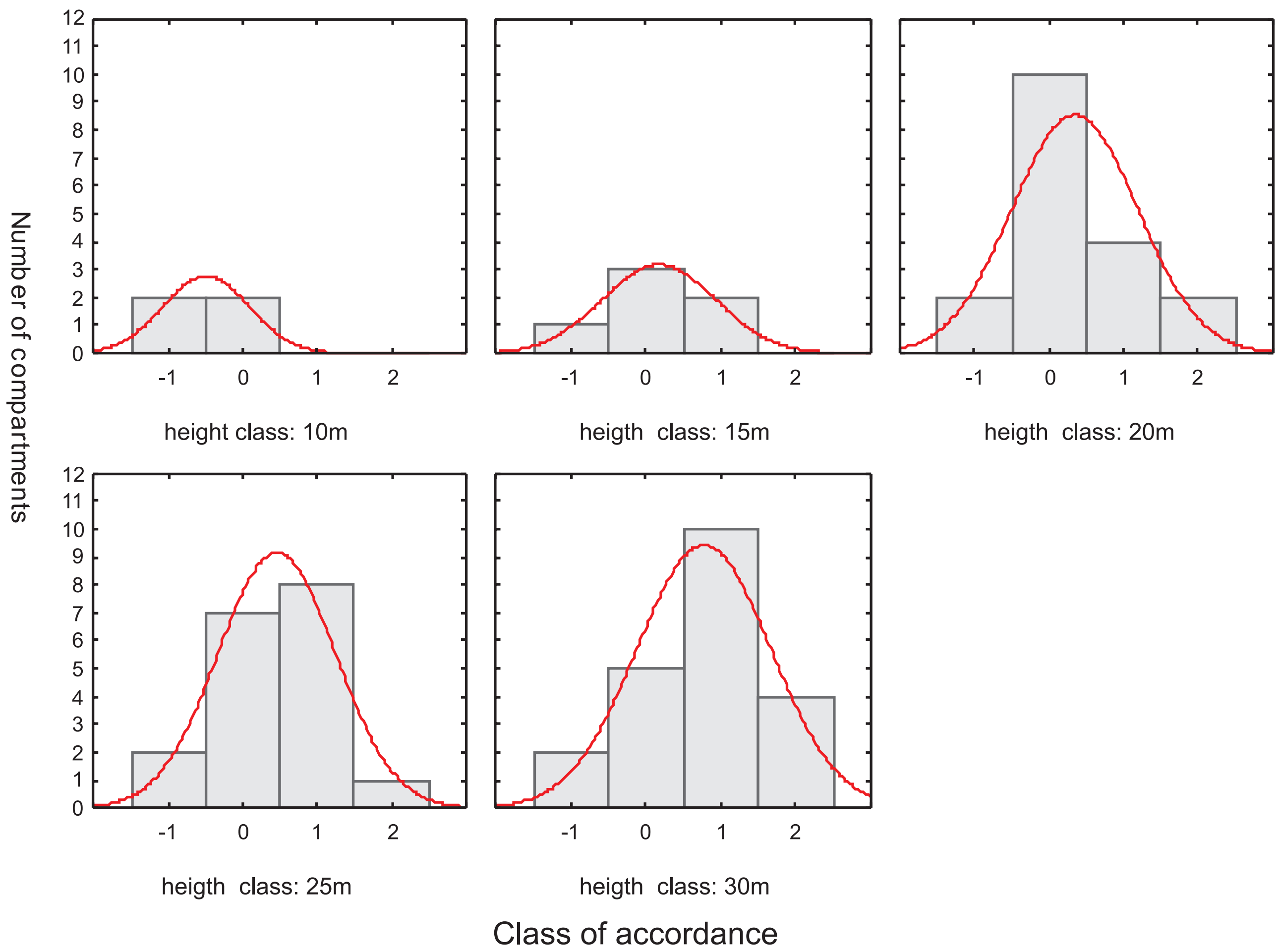


Fig. 4. Histogram of 'ALS closure' compatibility with SILP reference data for deciduous subcompartments in 5 height classes.

Ryc. 4. Histogram zgodności „zwarcie_ALS" z danymi referencyjnymi SILP dla pododdziałów liściastych w 5 klasach wysokości.

mation, Fig.4) This regularity is not observed in coniferous forest stands where the biggest differences were noted in „20m" class (Fig. 3). The reason for this could be subjectivity of the assessors who underestimated the closure parameter in higher deciduous forest stands or made the evaluation when there was no foliage (in winter or spring). Due to a different crown structure of coniferous species, the evaluation might have been easier to make.

Closure determination using ALS was also carried out on circular test areas and the obtained results were compared with the values acquired by means of the same method for whole subcompartments which had 2-4 circular test areas each. In order to compare closures, the arithmetic mean was calculated for the circular areas. The results have been shown as percentage differences for coniferous forest stands (Fig. 5) and deciduous stands (Fig. 6).

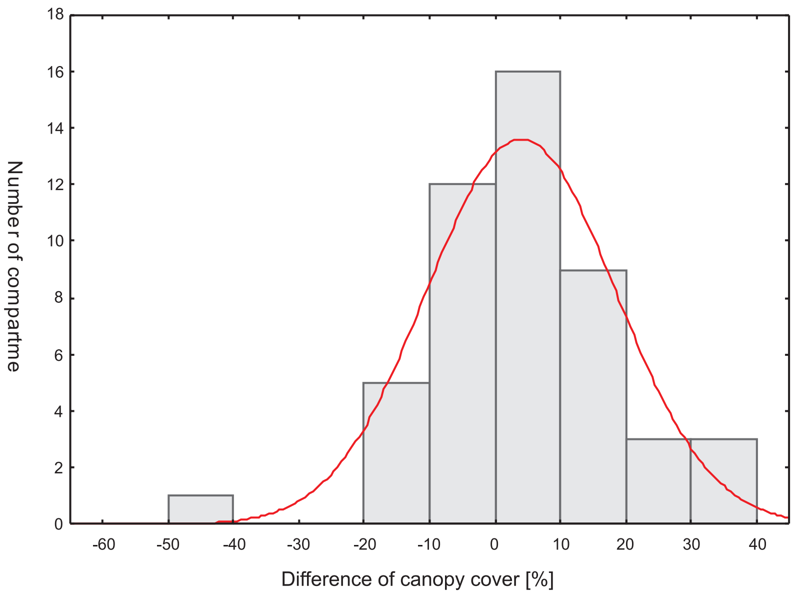


Fig. 5. Histogram of the differences [%] between ALS closure determined for the circular areas and ALS closure analyzed for the whole area of coniferous subcompartments.

Ryc. 5. Histogram różnic [%] pomiędzy zwarciem ALS określonym na powierzchniach kołowych a zwarciem ALS analizowanym dla całej powierzchni pododdziałów iglastych.

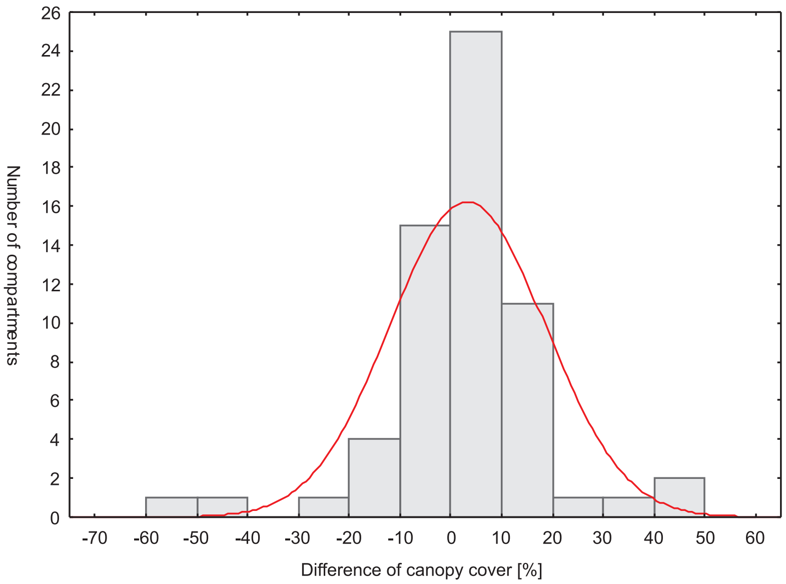


Fig. 6. Histogram of the differences [%] between ALS closure determined for the circular areas and ALS closure analyzed for the whole area of deciduous subcompartments.

Ryc. 6. Histogram różnic [%] pomiędzy zwarciem ALS określonym na powierzchniach kołowych a zwarciem ALS analizowanym dla całej powierzchni pododdziałów liściastych.

In over a half of the cases (57% of coniferous stands and 65% deciduous stands) the difference between ALS determined coverage for the whole subcompartment and the mean for circular areas was less than 10%. This shows that the circular areas location was very well selected and proved representative of the whole subcompartment. When the mean for the whole sample is analyzed, it appears that the ALS crown coverage vsalue for the circular areas was higher than that determined for subcompartments by 3.67% and 2.9% in coniferous stands and deciduous stands, respectively.

ALS method results were verified using screen vectorization of crowns on high-resolution RGB orthophoto for 5 subcompartments (Table 2).

In two out of the 5 analyzed subcompartments the closure determined using screen vectorization (orthophoto coverage) was identical with the ALS- determined coverage. Two subcompartments showed only a 6% difference while in the case of separation(19c), ALS coverage was lower by about 12%. As regards the SILP/LAS database ,i.e. the comparison of the 'Orthopho closure' and ALS method with the adopted range of values (Table 1), there was a considerable conformity of findings for all the subcompartments analyzed. (Table 2).

5. Conclusions

Crown coverage(canopy closure) determination using a new method of processed point cloud from airborne laser scanning (ALS) is both very precise and cost effective in comparison with expensive field inventory. ALS is fully objective in contrast with an assessor's subjective evaluation and the coverage parameter is described basing on an analysis of data from the whole of the study area (subcompartment) and not only from circular test areas. It helps to present the spatial distribution of an analyzed feature, e.g. over a subcompartment rather than only provide the mean value. ALS method ensures repeatability of measurements which has a great significance in periodic monitoring of forest areas. The method is objective and independent of weather conditions which guarantees compatibility of consecutive measurements in the same area and makes human factor play a less significant role. ALS method can be affected by heavy rain and fog and forest stand conditions which restrict laser beam penetration (e.g. full closure and multi-story structure) They can interfere with data collection and classification. Data acquired by ALS can be used to generate information not only on stand closure but also its height or the number of trees and other assessment characteristics which leads to the modeling of its resources.

Although ALS has been developing for over 20 years, its full potential is not used in Poland. The countries in Western Europe and North America demonstrate that the traditional forest inventory can practically be replaced with remote sensing, including ALS. It results not only from economic reasons but also from the need to implement the so-called precision forestry.

Table 2. Closure determination using crown vectorization on orthophoto and according to ALS data.
Tabela 2. Wyniki określania zwarcia na podstawie wektoryzacji koron na ortofotografii oraz wg. danych ALS.

Sub-compartment	Class h [m]	Closure class SILP	Closure range SILP (Table 1)	Analysed surface [m^2]	Crown number [item]	Closure ALS [%]	Closure orthophot[%]
110d	20	intermit	0,51-0,66	6061	344	52	53
19c	20	moder.	0,67-0,90	6863	313	63	51
1k	25	moder.	0,67-0,90	18489	1151	50	44
48c	25	moder.	0,67-0,90	5000	306	66	66
137i	30	intermit.	0,51-0,66	16099	428	44	50

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Streszczenie

Zwarcie koron drzew należy do niezmiernie ważnych cech taksacyjnych drzewostanu o znaczeniu ekologicznym i gospodarczym. W toku inwentaryzacji zasobów leśnych zwarcie określa się w terenie w sposób opisowy i dość subiektywny kwalifikując je odpowiednio do klas ustalonych przez Instrukcję Urządzania Lasu. Lotniczy skaning laserowy (*ang.* ALS) stwarza możliwości generowania Numerycznego Modelu Powierzchni Terenu (NMPT; *ang.* DSM), a na jego podstawie określanie wybranych cech taksacyjnych drzewostanu. Praca prezentuje możliwości nowej metody określenia parametru zwarcia koron w drzewostanach na podstawie analizy NMPT. Ocenę przeprowadzono na dwóch poziomach szczegółowości, tj. zwarcia określanego dla całych pododdziałów oraz kołowej powierzchni badawczej. Teren badań zlokalizowano w Obrębie Piasek w Nadleśnictwie Chojna (RDLP Szczecin). Analizie poddano 49 pododdziałów iglastych, w których założono 95 powierzchni kołowych oraz 67 pododdziałów liściastych ze 134 powierzchniami kołowymi. Chmury punktów ALS zostały pozyskane we wrześniu 2006 roku skanerem typu *full waveform* (Riegl LMS Q-560) ze śmigłowca, z wysokości 500m. w sierpniu 2006 zakończono zbieranie danych referencyjnych dla 229 powierzchni kołowych. Na podstawie danych ALS wygenerowany został NMPT oraz nNMPT (1x1m; GeoTIFF), który posłużył do analizy parametru zwarcia (klasyfikacja pikseli po atrybucie wysokości; ER Mapper). W celu wyeliminowania drugiego piętra i podszytu, na profilach ALS odczytywano wysokość podstawy korony, która stanowiła graniczną wartość analiz zwarcia. Dla poziomu pododdziału jako dane referencyjne posłużyły informacje zapisane w tabelach SILP\LAS. Do porównania tych wartości zastosowano transformację wartości opisowych na wskaźniki liczbowe. Weryfikacja metody ALS została przeprowadzona w oparciu o ekranową wektoryzację koron na ortofotografii cyfrowej dla reprezentatywnych części 5-ciu pododdziałów. Analizie poddano również poprawność przebiegu granic pododdziałów Leśnej Mapy Numerycznej (LMN), w oparciu o zintegrowany produkt rastrowy: nNMPT + cyfrowa ortofotomozaika RGB (piksel 12 x 12cm). Stwierdzono, iż zwarcie określone na podstawie danych ALS dla poziomu pododdziałów w drzewostanach iglastych było w 53% przypadków zgodne z danymi referencyjnymi z urządzania lasu. W 37% przypadków otrzymano wyższe wartości zwarcia ALS a jedynie w 10% niższe od referencji. Odmiennie przedstawiała się sytu-

acja dla drzewostanów liściastych, dla których nie zanotowano różnic w 40% przypadków, wyższą wartość zwarcia ALS w 47% natomiast niższą w 13% pododdziałów. Tylko w przypadku drzewostanów liściastych stwierdzono zależność, iż ze wzrostem ich wysokości występują coraz większe rozbieżności pomiędzy porównywanymi metodami. Porównanie wartości zwarcia ALS pomiędzy pododdziałem a wartościami dla powierzchni kołowej wykazało bardzo niewielkie różnice. Zwarcie analizowane na powierzchniach kołowych było zawyżone średnio o 3,7% w przypadku gatunków iglastych i 2,9% d-stanów liściastych. Potwierdza to wysoką użyteczność danych ALS w planowaniu rozmieszczenia powierzchni kołowych w drzewostanach. Wartość zwarcia uzyskana metodą wektoryzacji koron na ortofotomozaice okazała się w większości przypadków bardzo zbliżona do określonego technologią ALS. W toku prac wykazano znaczne rozbieżności przebiegu wektora granic LMN, co wskazuje na konieczność jego każdorazowej weryfikacji na podstawie NMPT lub nNMPT i ortofotografii, o ile jest dostępna.

GEOINFORMATICA POLONICA
WYDAWANA WSPÓLNIE PRZEZ PAU I AGH

Dynamiczny rozwój specjalistycznych metod geoinformatyki w różnych dziedzinach nauki i techniki, który w 1998 roku doprowadził do utworzenia Komisji Geoinformatyki w Polskiej Akademii Umiejętności w Krakowie, trwa nadal.

Z inicjatywy Profesora Janusza Kotlarczyka, założyciela Komisji, a także inicjatora i propagatora rozwoju specjalistycznych metod geoinformatycznych w geologii, nawiązana została w 2009 roku współpraca między PAU i Akademią Górniczo-Hutniczą w Krakowie, polegająca na współfinansowaniu i wspólnym wydawaniu czasopisma *Geoinformatica Polonica.*

Stosownie do podpisanej umowy, zarówno nakład jak i koszty wydawnicze każdego zeszytu ponoszone będą po połowie przez obie instytucje. Połowa nakładu pozostanie w dyspozycji PAU, a połowa w dyspozycji AGH.

Umowa o wspólnym wydawaniu czasopisma *Geoinformatica Polonica* wymaga corocznie weryfikacji przez obie instytucje. Wyrażamy przekonanie, że wola trwałej współpracy, wyrażona przez obie strony w trakcie negocjacji, będzie w przyszłości podtrzymana, a formalna umowa nabierze permanentnego charakteru.

Spodziewamy się, że wprowadzona w 2009 roku zasada publikowania w *Geoinformatica Polonica* artykułów naukowych w języku angielskim przyczyni się do popularyzacji w świecie polskich osiągnięć naukowych w zakresie specjalistycznej geoinformatyki, rozwijanej od wielu lat w Akademii Górniczo Hutniczej i wspieranej w całej Polsce przez Polską Akademię Umiejętności.

Prof. Józef Jachimski
Przewodniczący
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While writing the text the following principles shall be observed:

– individual lines shall not be ended with ENTER key,

– paragraphs shall not be spaced using TABULATOR or SPACE key,

– individual paragraphs shall be separated by one empty line inserted,

– words shall not be manually divided,

– individual lines in a paragraph shall not be justified using SPACE key,

– words shall not be spaced (e.g. t i t l e),

– words or sentences shall not be underlined (e.g. underlined).

WSKAZÓWKI DLA AUTORÓW PRAC

Kompletny materiał przeznaczony do druku o objętości nie większej niż 2 arkusze powinien zawierać:

– tekst zasadniczy w jezyku polskim lub angielskim,
– tytuł w języku polskim i angielskim,
– tabele i rysunki z podpisami w języku polskim i angielskim,
– krótkie abstrakty (do 15 wierszy) i słowa kluczowe w języku polskim i angielskim,
– obszerniejsze streszczenie (do 45 wierszy) w języku alternatywnym (angielskim lub polskim) wobec tekstu zasadniczego.

Dyskietkę z wpisanym tekstem należy przekazać do Redakcji wraz z jednym kompletnym wydrukiem przygotowanej pracy na papierze formatu A4. Liczba wierszy i znaków w jednym wierszu jest dowolna. Należy tylko zachować jednowierszowe odstępy między poszczególnymi akapitami.

Tekst powinien być zapisany w formacie WORD FOR WINDOWS.

Na marginesie nadesłanego wydruku prosimy zaznaczyć miejsca wstawienia rysunków i tabel.

Tytuły i podtytuły należy oddzielić od tekstu światłem górnym i dolnym oraz określić stopień tytułu (I rzędu, II, III... Rozdział zasadniczy – I rz., podrozdział – II rz., tytuł podrzędny – III rz., itd.) na wydruku.

Tabele należy umieścić w osobnym pliku w formacie WORD lub EXCEL. Na wydruku każda tabela powinna być opisana nazwiskiem Autora i numerem tabeli.

Wszelkie symbole we wzorach i powołaniach na nie w tekście należy pisać pismem prostym. Ważne jest, by 0 (zero) wpisane było przez klawisz cyfrowy, w celu odróżnienia go od litery O (o). Stosować jednostki miary zgodnie z obowiązującym układem SI.

Powołania w tekście na rysunki, tabele, wzory, rozdziały i podrozdziały – zgodnie z numeracją. W powołaniach na literaturę podajemy w nawiasie okrągłym nazwisko autora i rok wydania, np. (Rysiowa 1969) – jeden autor, (Nowakowski, Kapinos 1992) – dwóch autorów, (Kluz i in. 1972) – więcej niż trzech autorów, a w przypadku prac zbiorowych – tytuł (początek tytułu) i rok wydania (Poradnik... 1971).

Rysunki (możliwe po uzgodnieniu kolorowe) powinny być dostarczone:

– na papierze lub kalce (z podanym nazwiskiem autora i numerem rysunku),
– na dyskietce lub płycie CD-ROM w rozdzielczości: rys. czarno-białe 300 dpi (300 pikseli/cal), rys. kolorowe 600 dpi (600 pikseli/cal),
– w jednym z podanych niżej formatów:

a) *.TIF – format zapisu mapy bitowej wykorzystywany przez większość programów obsługujących skanery,
b) *.CGM – format zapisu grafiki wykorzystywany m.in. przez takie programy, jak: HARVARD PACKARD GRAPHICS, APPLAUSE,
c) *.CDR z programu CorelDRAW.

Literatura wg układu alfabetycznego powinna być umieszczona na końcu pracy z oznaczeniem „BIBLIOGRAFIA”.

W trakcie wpisywania tekstu należy przestrzegać następujących zasad:

– nie kończyć poszczególnych wierszy klawiszem ENTER,
– nie stosować zacięć akapitowych za pomocą tabulatora czy spacji,
– poszczególne akapity rozdzielać, wstawiając jedną pustą linię,
– nie dzielić ręcznie wyrazów,
– nie justować poszczególnych linii akapitu za pomocą klawisza spacji,
– nie rozspacjowywać wyrazów (np. t y t u ł),
– nie podkreślać wyrazów, zdań (np. podkreślony).