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THE ROLE OF CARTOGRAPHIC PRESENTATION METHODS IN ANALYSIS OF SPATIAL STRUCTURE OF PHENOMENA

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Abstract. Thematic scope of spatial data – both topographical and geographical – presented on maps is enormous. It can embrace processes and phenomena that occur as discrete or continuous, that are measured in nominal, ordinal, interval or ratio scales. It is also important if the data is absolute or relative. Visualization of such data variety is a process which involves choice of both proper cartographic methods and graphic variables.

The role of a map in analysis of spatial structure is not only a visual assessment (most often in an ordinal scale), but what is more important, a map presents a source data used in investigation on characteristics and regularity of spatial data distribution. The research aimed to explain occurrence of a particular spatial pattern and their local and regional changeability.

The quantitative indicators of spatial structure (e.g. indicators of homogeneity, diversity) as the result of spatial analysis are presented in a form of cartographic models. The visualization of the outcomes allow for more detailed recognition and description of spatial structure of the phenomena. Among the methods of cartographic presentation, in the paper there are used: choropleth map, geometric choropleth map, dasimetric map and isoline map. These cartographic presentations constitute the models of various characteristics of spatial patterns and relationships. The methods of modeling and presentation of analysis presented in the paper, refer to real distribution of phenomena. Therefore it considers their local and regional variation, that is of great importance for practical aspect of research.

Key words: spatial structure, cartographic modeling, cartographic methods

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INTRODUCTION

Thematic scope of spatial data – both topographical and geographical – presented on maps (in form of cartographic models) is enormous. It can embrace processes and phenomena that occur as discrete or continuous, that are measured in nominal, ordinal, interval or ratio scales. It is also important if the data is absolute or relative.

Source data may be the results of direct or indirect measurements, as well as variety of maps and cartographic elaborations. Among vast data types, the one that are an output of geographic analysis aimed to determine spatial structure of phenomena and relations between them is of great importance.

RESEARCH METHODOLOGY

Visualization of such data variety is a process which involves choice of both proper cartographic methods and graphic variables. A structure (structure – construction, method of construction) may be defined as a distribution of components of the particular system and relationships between these elements. The group of relationships is characteristic for a given system and expresses how parts of the particular system are related with each other.

A map is an image of a space, a model which reflects distribution of objects, phenomena and processes. A map's characteristics determine that a it is the best model of distribution (pattern) and relationships between presented phenomena. The role of a map in analysis of spatial structure is not only a visual assessment (most often in an ordinal scale), but what is more important, a map presents a source data used in investigation on characteristics and regularity of spatial data distribution. The research aimed to explain occurrence of a particular spatial pattern and their local and regional changeability.

The purpose of the research is to present chosen methods of modeling spatial structure of phenomena and their relationships. Moreover, the attention is paid to a choice of reference unit and mapping methods at the stage of presenting results.

In the paper, various methodical and cartographic solutions are presented exemplified on analysis of population structure performed within rural areas in dolnoslaskie voivodship. The dot map (Fig. 1) depicts population distribution. The dots are topographically placed in built-up areas. The accuracy of presentation is ½ dot weight. This kind of presentation enables to visual evaluation of a phenomena distribution, notice trends in the layout and assess its intensity in ordinal scale.

A distribution of relay stations is taken into account as an extra element in the research of relationships. The stations are located in rural areas and presented on the symbol map (Fig. 2).

A dot map is a very good source material for performing spatial distribution analysis. Presentation of the outcomes in form of cartographic models – thematic maps elaborated with use of various cartographic methods, significantly simplifies assessment of spatial structure. [Galant 2009, Krzywicka-Blum 2003, Klimczak 2003, Mościbroda 1999].

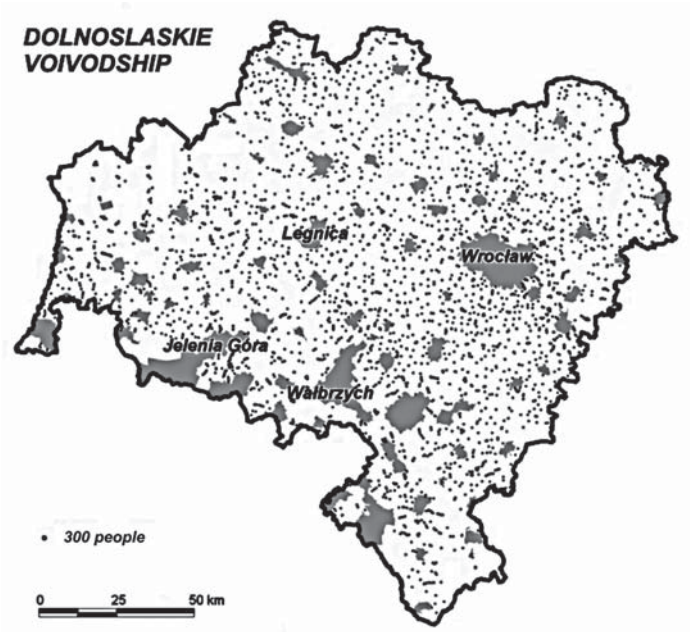

Fig. 1. Distribution of population living within rural communes in Dolnoslaskie Voivodship
Rys. 1. Rozmieszczenie ludności zamieszkującej gminy wiejskie w woj. dolnośląskim

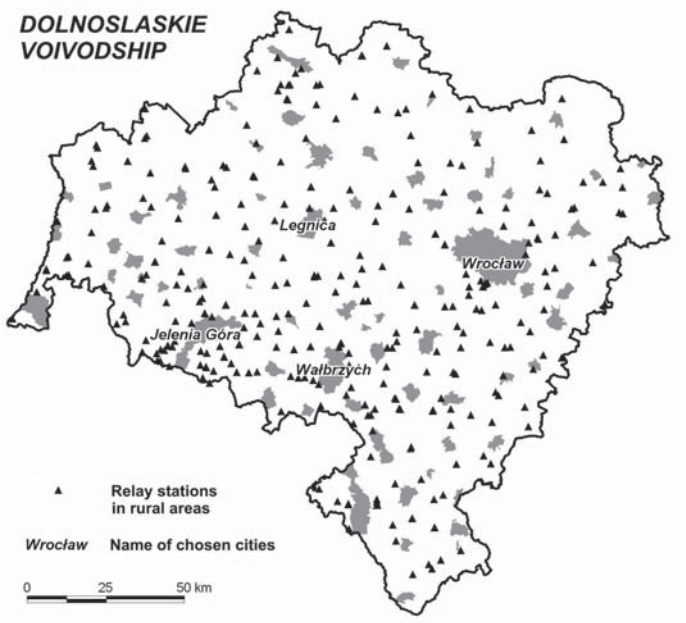

Fig. 2. Distribution of mobile telephony relay stations
Rys. 2. Rozmieszczenie stacji przekaźnikowych telefonii komórkowej

The intensity of a phenomenon may be expressed in absolute data values using a dot map. The example is the pie diagram presented on Figure 3. Geometric units of Temkart grid are used in this example as reference units [Podlacha 1990]. A size of reference unit should be adjusted to the accuracy of source data and the degree of phenomenon generalization which depends on the aim of research. The assumed reference units and used method of presentation allow to assess distribution in relation to geographic location of the phenomenon in a voivodship.

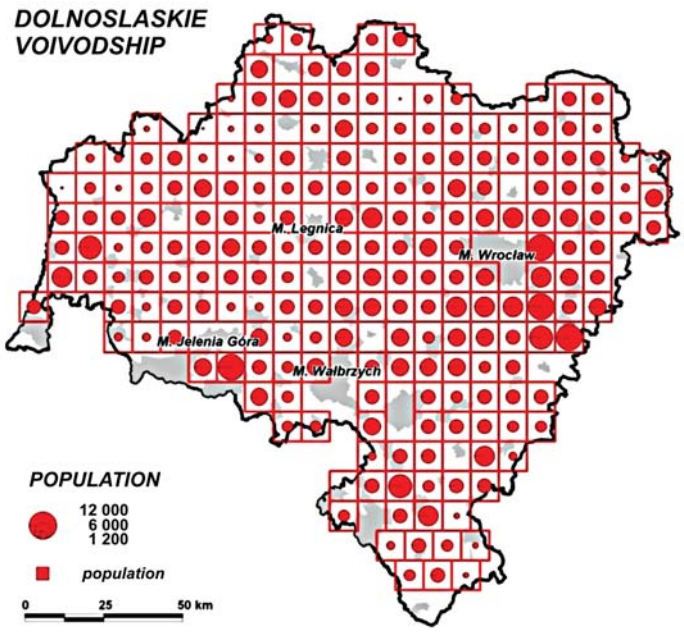

Fig. 3. Distribution of population in geometric units (Temkart grid) of 9 x 9 km
Rys. 3. Rozmieszczenie ludności w jednostkach geometrycznych sieci Temkart o wymiarach 9 x 9 km

Referring data to areal unit – administrative unit, geometric unit (square, rectangle) or irregular (Thiessen poligon) enables to determine the intensity of a phenomenon, and calculate quantitative indicators of spatial structure as a result of spatial analysis. For this purpose, the measures of intensity and fragmentation are used, the indicators of homogeneity, diversity, randomness are calculated with application of fractal geometry and entropy. The new models may be elaborated based on these quantitative characteristics. The visualization of the outcomes allow for more detailed recognition and description of spatial structure of the phenomena. Among the methods of cartographic presentation, in the paper there are used: choropleth map, geometric choropleth map, dasimetric map and isoline map.

Determination of a reference unit is necessary to calculate the intensity of a phenomenon – density of features – which is the most common measure of dispersion on a given area. The density G is calculated as follows:

$$G = N/P$$

where:
P – area within the features occur,
N – is the number of features.

The density index is different depending on assumed reference unit. The map on Figure 4, presents density of population in communes, as the area of commune is assumed as a reference unit.

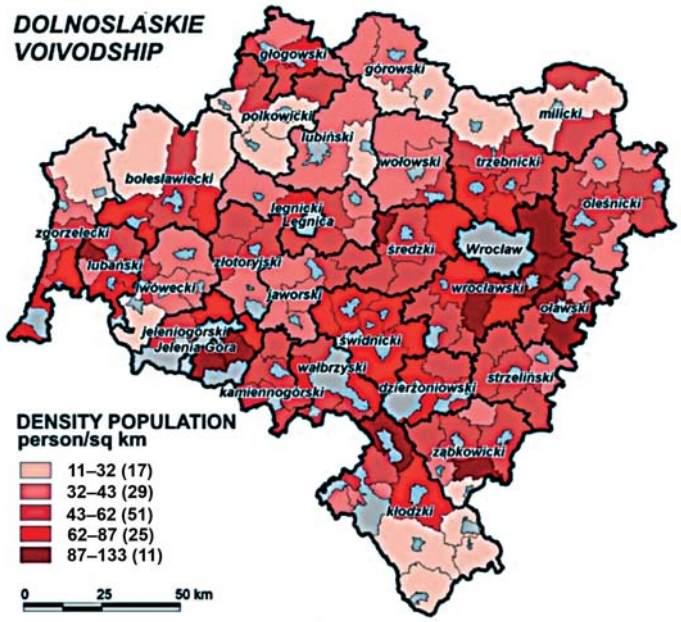

Fig. 4. Diversity of density population in rural communes of Dolnośląskie Voivodship
Rys. 4. Zróżnicowanie gęstości zaludnienia w gminach wiejskich w województwie dolnośląskim

This presentation (Fig. 4) does not take into account local variation of a phenomenon within a commune. Regardless of the arrangement of dots, which are the input to calculate the number of people, the same density is designated within a whole area of a commune.

A dasimetric map, used in presentation of spatial structure of density population, takes under consideration the real distribution in the area of voivodship. The assumed size of a grid influence on the accuracy of density determination (Fig. 5).

The number of people may also be referred to area of the Thiessen polygon. Two approaches are presented in the paper. In the first one, the Voronoi diagrams are constructed based on dots representing 300 people lived in rural areas, and in the second, the dots represent relay stations. Both maps present indicator of the intensity.

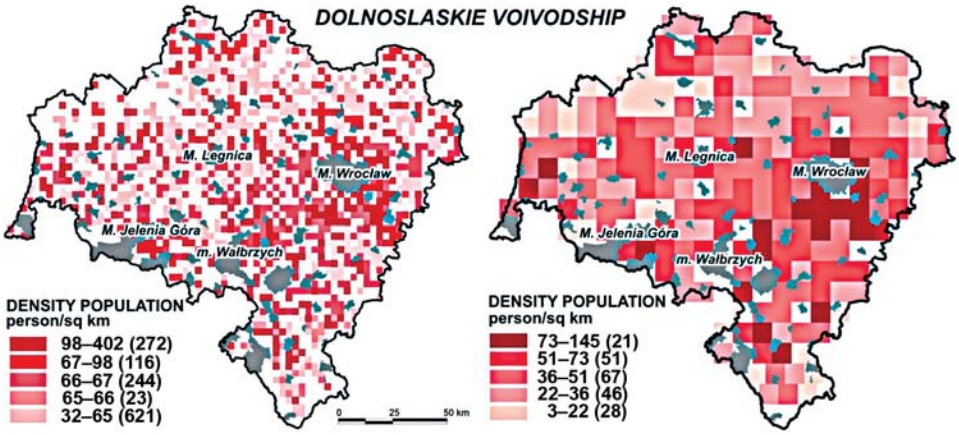

Fig. 5. Diversity of density population in geometric units (Temkart grid) of 3 x 3 km and 9 x 9 km in Dolnoslaskie Voivodship

Rys. 5. Zróżnicowanie gęstości zaludnienia w polach sieci Temkart 3 x 3 km i 9 x 9 km w województwie dolnośląskim

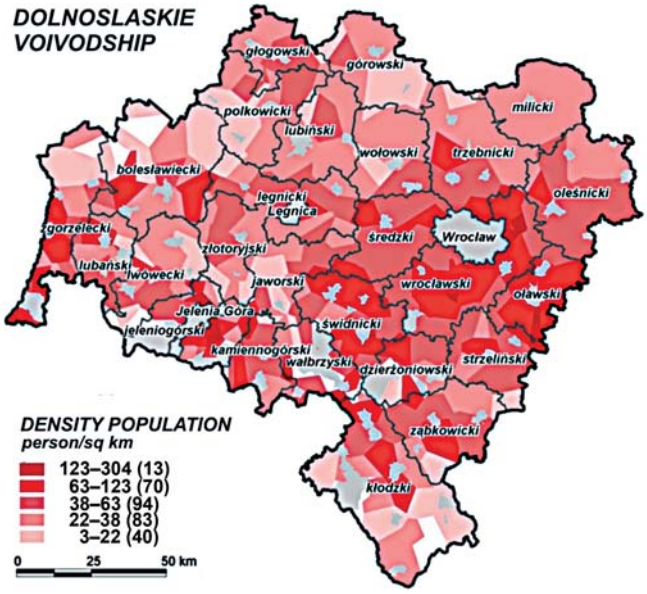

Fig. 6. Structure of density population in Thiessen polygons created on the basis of dot map (dot weight – 300 people)

Rys. 6. Struktura gęstości zaludnienia dla sieci wieloboków powstałych na podstawie mapy kropkowej (waga kropki 300 osób)

Density of population referred to Thiessen polygon constructed around relay station, delivers new extra information in comparison to the first approach. Instead of polygon area, a single relay station is assumed as reference unit.

The map on Figure 7 presents the relation between two phenomena. One can observe and indicate small or big intensity of number of people in relation to distribution of relay stations, as well may conclude on location of new stations.

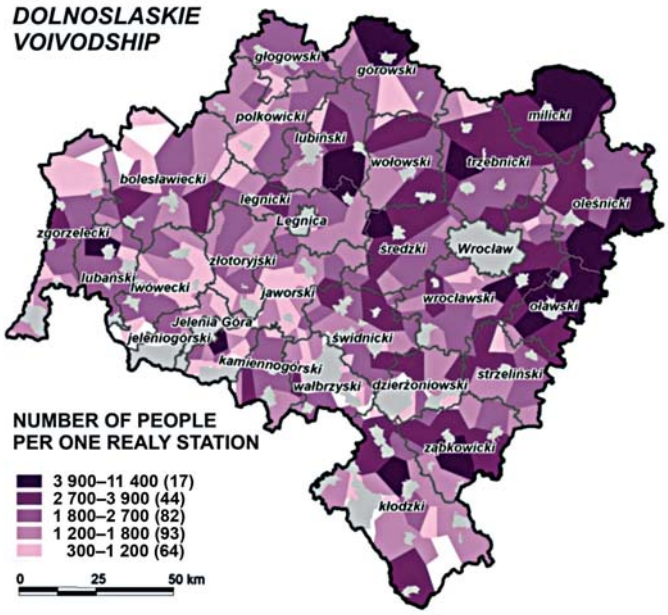

Fig. 7. Number of people per one relay station
Rys. 7. Wskaźnik liczby osób przypadających na jedną stację telefonii komórkowej

The map on Figure 7 presents the relation between two phenomena. One can observe and indicate small or big intensity of number of people in relation to distribution of relay stations, as well may conclude on location of new stations.

Application of geometric units (Temkart) in the research gives a possibility to determine the distribution on a phenomena with use of entropy index – Shannon's index (SHDI). The concept is mainly found in physics and theory of information, however it is also used in cartography, for example, to determine information capacity of a map [Czuba, Pasławski 1995]. The SHDI tends to be called a diversity index and it is one of the most common indicator of landscape diversity used in Europe. It is also applied to assess diversity of land use forms recognized on the basis of satellite image classification [McGarigal, Marks 1994].

In the paper the index of relative entropy is used. The index expresses a degree of features' diversity in assumed density classes. The calculations are made as follow:

$$h = \frac{\sum_{i=1}^{k} H_i}{H_{max}}$$

where:

H_i – entropy index in *i* class, calculated according to formula:

$$H_i = -\omega_i \log_2 \omega_i$$

where:

ω_i - frequency in *i* class

H_{max} – maximum entropy calculated according to formula:

$$H_{max} = k\left(\mathrm{k}^{-1}\log_2 \mathrm{k}^{-1}\right) = \log_2 k$$

where:
k – number of classes

The relative entropy ranges from 0 to 1 depending on diversity of features' set. The value close to 0 means pattern clustered in one class, and the value of 1 – maximum diversity (a share of features in each class is similar).

The index of entropy defines the structure of a phenomenon within researched area, but it does not deliver information on distribution of particular classes within the area (Fig. 8). This can be assessed based on density map (Fig. 5). The same value of index may characterize completely different spatial patterns, which have similar shares of units on density classes. When calculating the index of entropy, to establish proper reference units and data classification method are of great importance [Krzywicka-Blum 2003, Klimczak 2003].

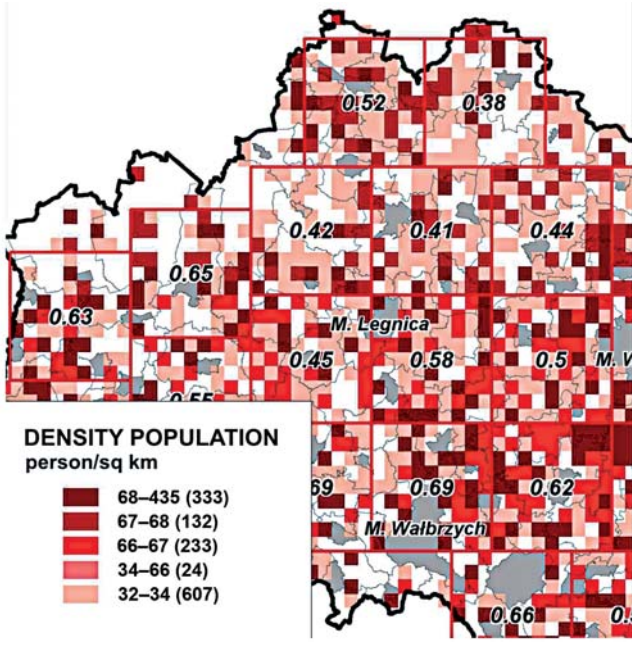

Fig. 8. Index of relative entropy in sub-areas calculated based on choropleth map of population density

Rys. 8. Wskaźnik entropii względnej – wyznaczony na podstawie kartogramu gęstości zaludnienia w przyjętych podobszarach

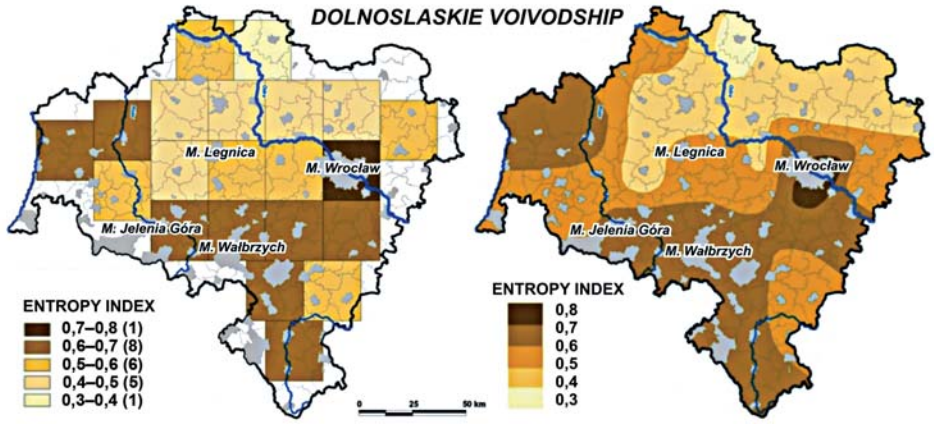

Fig. 9. Diversity of relative entropy index calculated for density population (a) and layout of isolines of the index

Rys. 9. Zróżnicowanie wielkości wskaźnika entropii względnej gęstości zaludnienia i układ izolinii tego wskaźnika w woj. dolnośląskim

On Figure 9, variation of the entropy index is presented with use of two cartographic methods. Choropleth map is closely related to the applied algorithm of research. The value of index is assigned to the unit in which the index is calculated, but data aggregation – characteristic of a choropleth map – generalizes the phenomenon by assigning a value from a class' interval instead of individual value to sub-area. The isoline method, due to continuous values representation, causes that in a given sub-area there are isolines resulting from interpolation between neighboring sub-areas. Hence, it may lead to incorrect interpretation as it does not present a real diversity of a phenomenon. One has to be aware of it while assessing the variation of entropy index based on such a map. However, it seems that isoline method allow for better evaluation of tendency in variation of diversity or heterogeneity (in assumed density classes).

CONCLUSION

The examples of visualisation of spatial structure of phenomena presented in the paper, are aimed to draw attention to a form of presentation which is comprehend as a choice of reference unit, method of presentation and graphic variable. This enables to observe tendency in arrangement of features and characterize a degree of their homogeneity or heterogeneity in geographical space. The use of the dasimetric map, the isoline map of phenomenon intensity or the map presenting the index of diversity, allow to observe causal relationships, as well as it offers possibilities of planning proper investments (in this case – increasing number of relay stations). Complete identification of spatial arrangements of features' set in research area, requires delimitation of local types of pattern. The methods of modeling and presentation of analysis presented in the paper, refer to real distribution of phenomena. Therefore it considers their local and regional variation, that is of great importance for practical aspect of research.

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ROLA KARTOGRAFICZNYCH METOD PREZENTACJI W ANALIZACH STRUKTURY PRZESTRZENNEJ ZJAWISK

Streszczenie. Zakres tematyczny danych przestrzennych – topograficznych i geograficznych prezentowanych na mapach w postaci modeli kartograficznych jest ogromny. Może obejmować zjawiska i procesy występujące w sposób dyskretny i ciągły, mierzone w skali nominalnej, porządkowej, interwałowej i ilorazowej. Ważny jest również sposób ujęcia zjawiska – bezwzględny lub względny. Wizualizacja tak różnorodnych danych to proces doboru odpowiednich metod kartograficznych i zmiennych graficznych.

Rola mapy w analizie struktury przestrzennej nie ogranicza się tylko do oceny wizualnej (najczęściej na poziomie skali porządkowej), ale służy jako materiał źródłowy do badań charakterystyk i prawidłowości w rozmieszczeniu zjawisk. Badania te mają wyjaśnić występowanie określonych typów układów przestrzennych i zwrócić uwagę na ich miejscową i regionalną zmienność.

Ilościowe wskaźniki opisujące strukturę przestrzenną (np. wskaźniki jednorodności, zróżnicowania) prezentowane w postaci modeli kartograficznych pozwalają na dokładniejszą charakterystykę struktury przestrzennej badanych zjawisk. W pracy wykorzystano metody: kartogramu, kartogramu geometrycznego, dazymetryczną i izolinii, które stanowią modele różnorodnych charakterystyk i relacji przestrzennych zjawisk. Użyte w pracy metody modelowania i prezentacji wyników analiz nawiązują do rzeczywistego rozkładu zjawiska, a więc zwracają uwagę na ich miejscową i regionalną zmienność, co ma duże znaczenie w użyteczności otrzymanych wyników.

Słowa kluczowe: struktura przestrzenna, modelowanie kartograficzne, metody kartograficzne

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