DASYMETRIC MAPPING AS AN ANALYTICAL TOOL FOR THE CITY DEVELOPMENT IDENTIFICATION AND ITS CARTOGRAPHIC VISUALIZATION

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Abstract

The paper represents the result of an application of dasymetric mapping on the city development identification based on the aerial photography in the Olomouc region. Dasymetric mapping is a method of thematic cartography, which uses areal symbols to classify volumetric spatial data. Dasymetric mapping is suitable for the population density visualization because of its ability of realistic placement over geography. The same approach can also be used to monitor the development of the city in the long time period. To monitor such developments can be used aerial photographs in combination with statistical data related to the same time units, in which the aerial images were taken.

This contribution describes the methods of dasymetric mapping application, advantages and disadvantages of the methodology use and the resulting cartographic visualization and statistical evaluation on the example of Olomouc city. A good indicator of the city development is besides the city population density also the urban area type (residential buildings, industrial areas), which can be detected from aerial photographs. Detection of these areas and the subsequent application of statistical data are suitable for dasymetric visualization of the city development.

Keywords: dasymetric mapping, aerial photography, city development

INTRODUCTION

The dasymetric mapping uses areal symbols to classify spatial volumetric data. This method of thematic cartography was developed and firstly termed by the Russian cartographer Tian-Shansky, who developed the multi-sheet population density map of European Russia, published in the 1920s (Preobrazenski, 1954 in Bielecka, 2005).

Dasymetric mapping allow realistic spatial visualization, it is considered as a hybrid between isopleth and choropleth maps. This method is based on non-administrative divisions. The population density is usually expressed numerically in terms of the number of persons per square kilometre. It means that the user does not know whether population occurs uniformly in the displayed area or whether the same average values of the population occurs once on a small area and sometimes disproportionately on the larger area. It can be difficult to compare the population living in multi-panel buildings, single-family houses in the suburbs or in houses in villages. Population density may be the same for the two administrative units, but in fact it does not take into account when comparing the total population size structure of the units and urban area types. It is therefore appropriate that statistical data from administrative units are related to the actual built-up area. During the analysis of the characteristics of the substrate aerial images is suitable to use dasymetric mapping methods, which makes the result more illustrative representation than using methods of choropleth maps. The development of the city is much more related to the distribution of population density in urban area types than in theoretical administrative borders, which include uninhabited areas, etc.

Besides the density of the population a good indicator of the city development is the urban area type (residential buildings, industrial areas), which can be detected from aerial photographs. Detection of these areas and the subsequent application of statistical data are suitable for dasymetric visualization of urban area types and population density in the study area as well.

STUDY AREA

Method of dasymetric mapping based on the aerial photos was applied on the set of photos of Olomouc city. Olomouc is a city in the east of the Czech Republic, located on the Morava River. It is the administrative centre of the Olomouc and with its 102,000 residents it is the sixth largest city in the Czech Republic. In its urban zone there is a population about 480,000 people.

The city was officially founded in the mid-thirteenth century and became one of the most important trade and power centres in the region. Olomouc was fortified by Maria Theresa during the wars with Frederick the Great, and this fact significantly influenced the development of the city in terms of spatial expansion. Its inner part is the second-largest historical monuments preserve in the country (Olomouc tourism, 2012).

Department of Geoinformatics has aerial images of Olomouc region from the Military Geographic and Hydrometeorologic Office in Dobruška. All these images are from the period 1927 to 2006, in the TIFF format.

Statistical data

Statistical data about population in Olomouc were obtained from the Czech Statistical Office (CSO), additional data were obtained from the Department of Computer Science of Municipality of Olomouc and some information and additional data were obtained from VDB (public database) and publications of Czech Statistical Office, such as Historical Lexicon of Municipalities (CSO, 2006).

For aerial photos with missing link to the statistical data (aerial photograph was made in the year to which population data are not available), the necessary data were obtained by using statistical calculations between the years in which data were known. This imputation was created on the basis of population development over the years. Due to the fact that main aim of the work is to estimate population density, this method was chosen as the most suitable. Availability of data is listed in Table 1. Complementary data of urban area are from previous work realized at the Department of Geoinformatics (Sádovská, 2011).

Table 1. Availability of statistical data related to the aerial images

Year Aerial photo	Year Population data	Year Urban area type
1927	1930	1927
1953	1950	1953
1971	1970	1971
1978	1980	1978
1985	1985	1985
1991	1991	1991
1994	1994	1994
2001	2001	2001
2003	2003	2003
2006	2006	2006

Methods of dasymetric mapping

The implemented dasymetric mapping method utilizes aerial images as input and complementary data to define different types of urban areas. In the combination with population data (statistical data from Czech Statistical Office and Municipality of Olomouc) are these data redistributed to a set of urban area zones formed from the intersection of the urban area types and aerial photos.

There were tested many methods how to classify the urban area types from the aerial photos. The most suitable method is to classify areas manually with regard to supplementary data of urban area types.

METHODOLOGY

The basis for the creation of aerial photo-mosaic was the underlying set of georeferenced images. Aerial photo-mosaics for individual years were compiled in the ERDAS IMAGINE program environment, preparation was carried out in the MosaicPro, which is located in the Data Preparation, within the tool Mosaic Images. Number of individual frames was different for each year, for example year 1971 was recorded on 27 aerial images, year 1978 was recorded on 37 images and year 2003 was recorded on 18 images. Aerial images for the first two years were available only in shades of grey; next aerial photos were processed as colour images.

After considering the possibility of applying the chosen methodology there was determined following procedure: the whole area was covered with square cells and the values of urban area types were obtained by the evaluation of the underlying aerial images. As a suitable dimension of the square grid was set 100 m size, which is sufficiently detailed to the definition of various types of buildings as well as it is suitable for the resulting cartographic visualization. The result grid size is 264 × 217 squares.

The whole process of digitizing of the urban area types was realized in the software ArcGIS Desktop. There were classified five basic types of urban area – *separate housing*, *residential and apartment housing*, *panel housing* (tower blocks), *industrial areas* and *gardening areas*. For the purposes urban maps there were classified also other areas that include military objects and agricultural areas, which are not inhabited.

Digitization (assignment of the building types) was realized with regard to the majority of the type of buildings in the underlying image of the squares. If there were placed objects of type *separate housing* and *panel housing* as well, the square was assigned a value of panel housing, because it is quantitatively more significant. The work was realized regardless of administrative boundaries in its graphic design.

Number of squares of the urban type, together with the number of inhabitants in the administrative area was input data into the calculations. There were using weights (Tab. 2) that allow calculating specific population density in the defined area. These values were then re-entered in the attributes of the square grid.

Weights of individual urban types

To calculate the average value of population density in different types of urban area it was needed to define training sets in combination with statistical data. There were selected locations where occurred always one type of buildings. From the statistical data and polygon development of testing areas, there were counted an average population density for each urban area type.

There were used at least 10 samples of each type of urban area to achieve relevance. To determine the number of population density in each type there was used layer with address points that allow using the number of inhabitants in each house. For each type of urban area there was calculated the average value that was rounded to simplify the calculation. The values were as follows:

Table 2. Urban area types weight

Urban area type	Average of population density	Weight of urban type area
separate housing	160 / km^2	1
residential housing	820 / km^2	5,13
panel housing	2 230 / km^2	13,94
industrial areas	0,13 / km^2	0,0008
gardening areas	0,01 / km^2	0,00006

Cartographic visualization

There were realized two sets of output maps. In the first set of ten maps there is presented the population density (Fig. 1–10), in the second set of maps there are presented urban area types (example on Fig. 11). Both sets were processed in the period from 1927 to 2006 and both are processed by the same extent. It means the city of Olomouc and the surrounding areas. As a topographic base there were used aerial photo-mosaics.

The population density maps for different years were processed in different territorial range, which depended on the size of the underlying aerial photo-mosaics. Largest areas were processed for the years 1971 and 2003. On the contrary, for example, years 1953 or 1985 are shown completely, as their mosaics were far less extensive.

Map symbols for population density presentation were prepared according to the frequency graph of all values created from whole period 1927 to 2006. Intervals were adjusted to the form in which they are visualized on maps. The same range of values and colors of each interval is particularly important for visual comparison (Slocum et al., 2005).

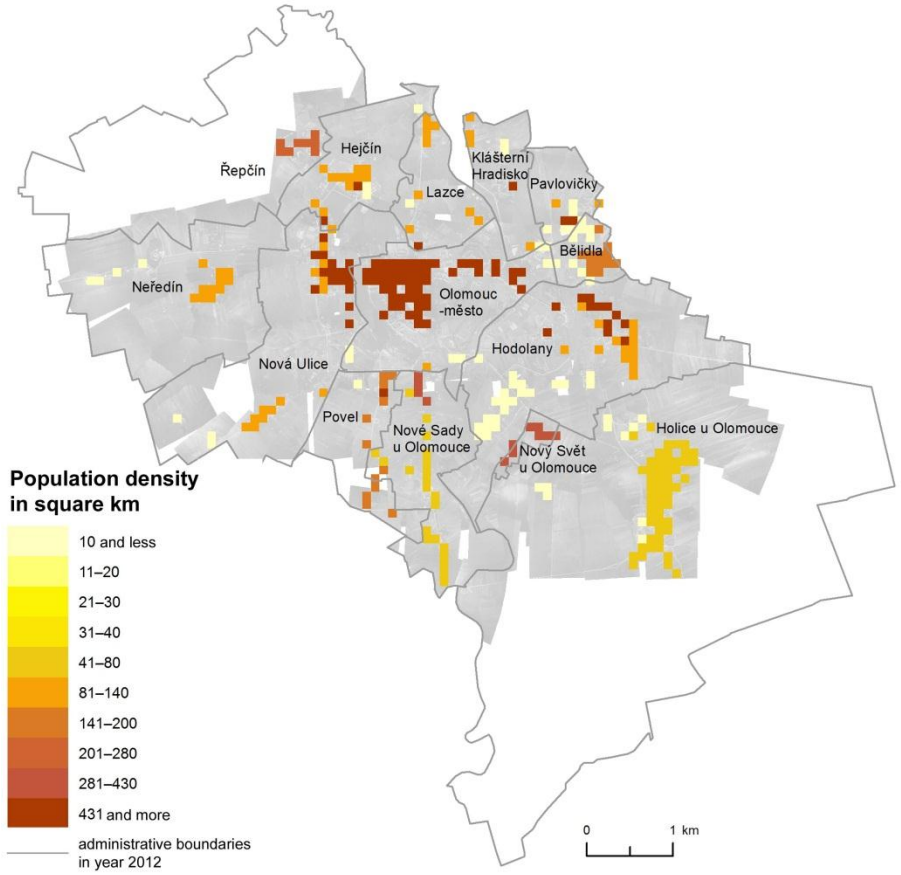

Fig. 1. Population density in Olomouc region in 1927

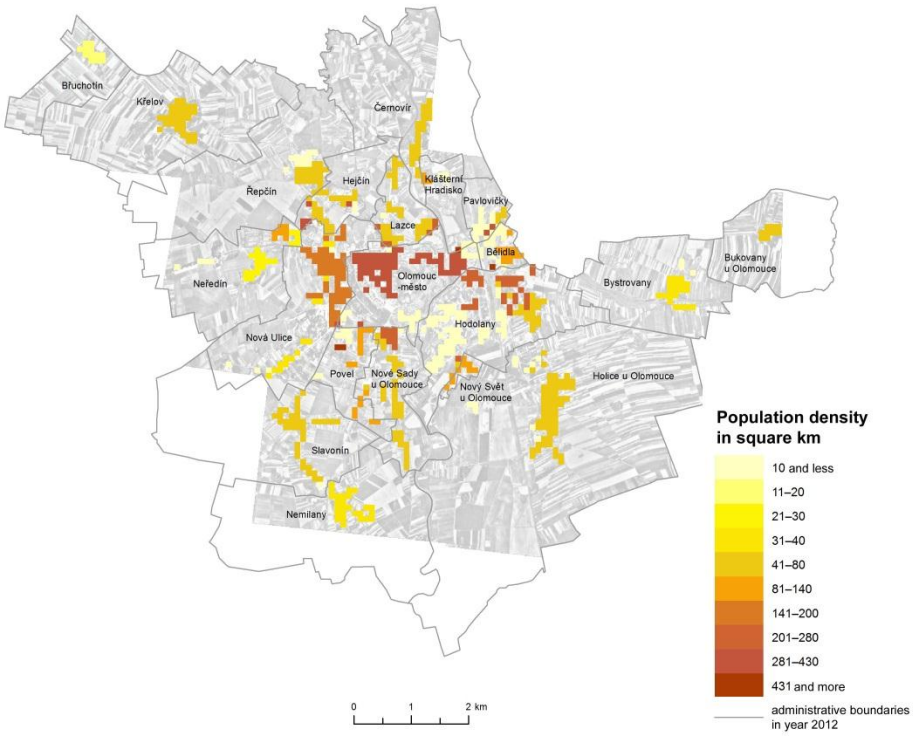

Fig. 2. Population density in Olomouc region in 1953

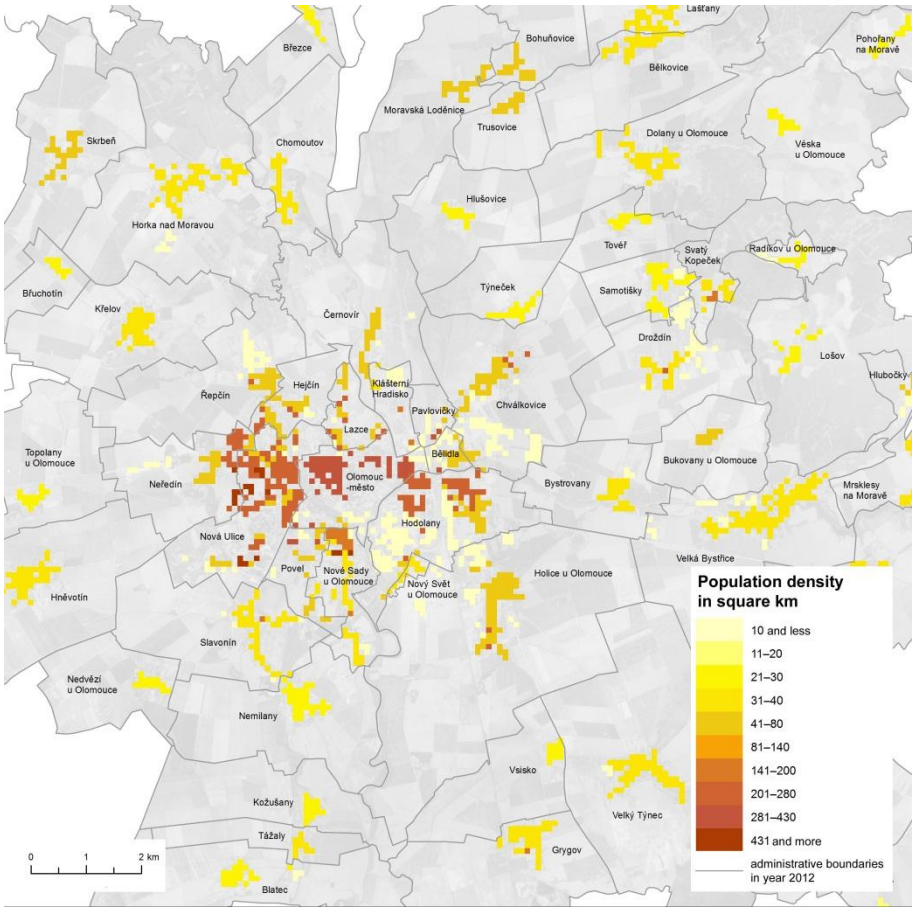

Fig. 3. Population density in Olomouc region in 1971

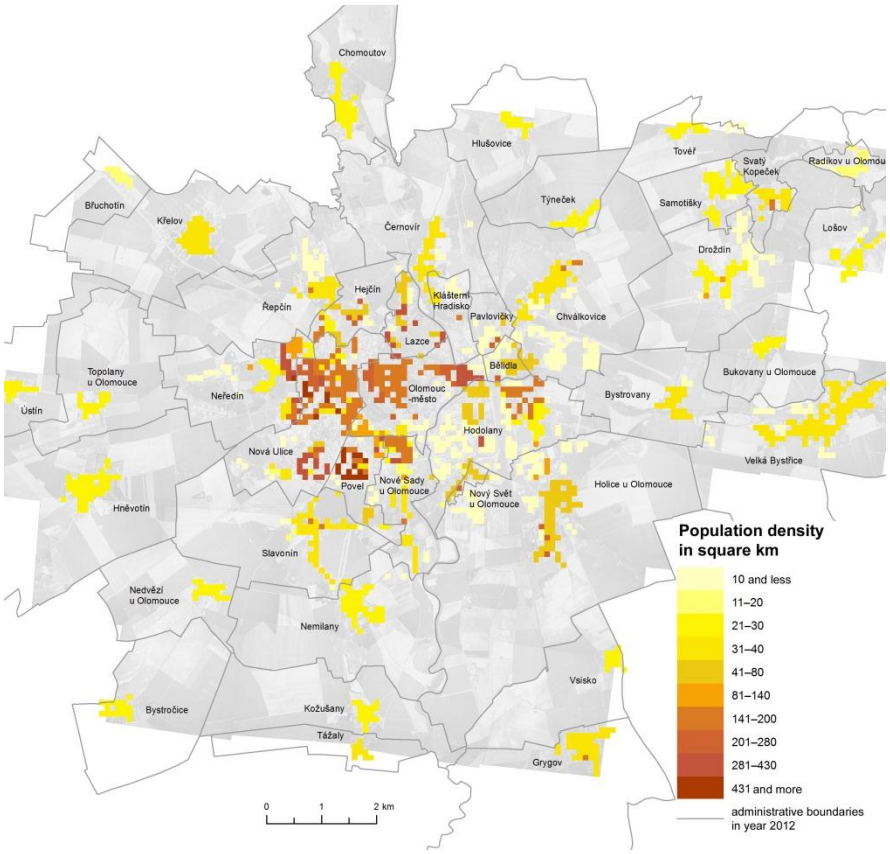

Fig. 4. Population density in Olomouc region in 1978

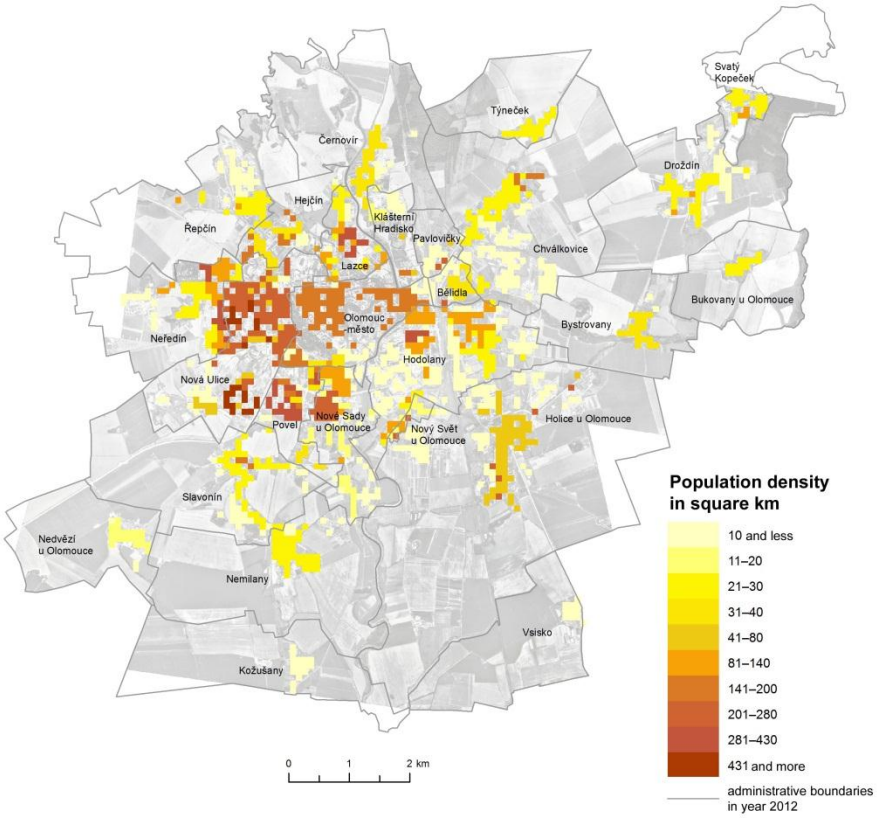

Fig. 5. Population density in Olomouc region in 1985

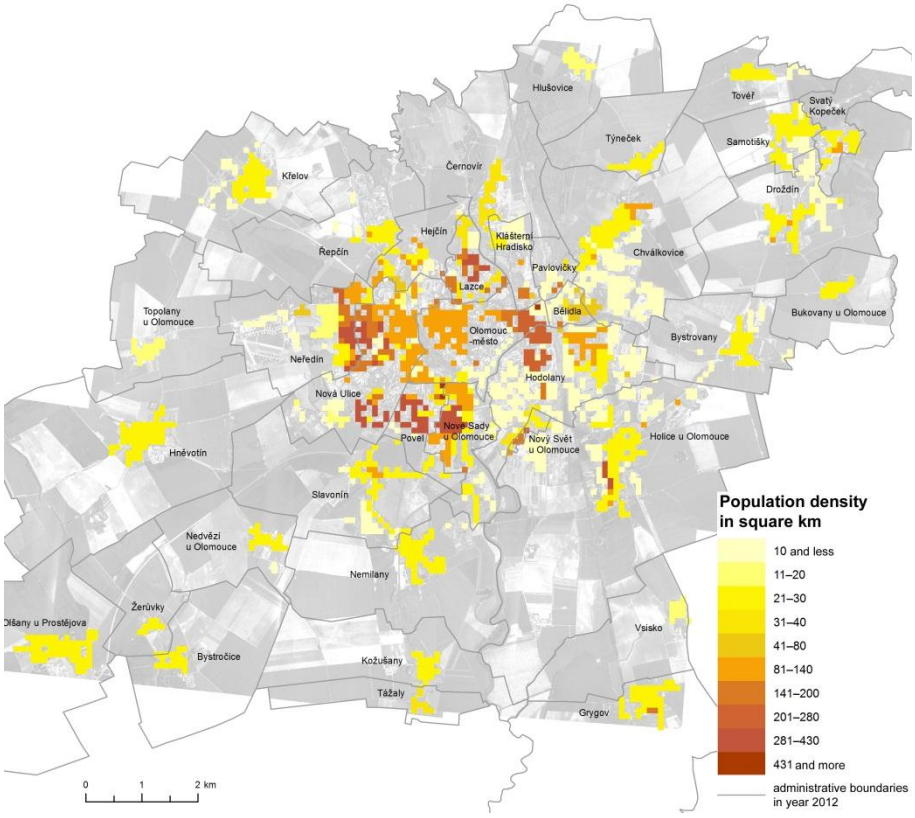

Fig. 6. Population density in Olomouc region in 1991

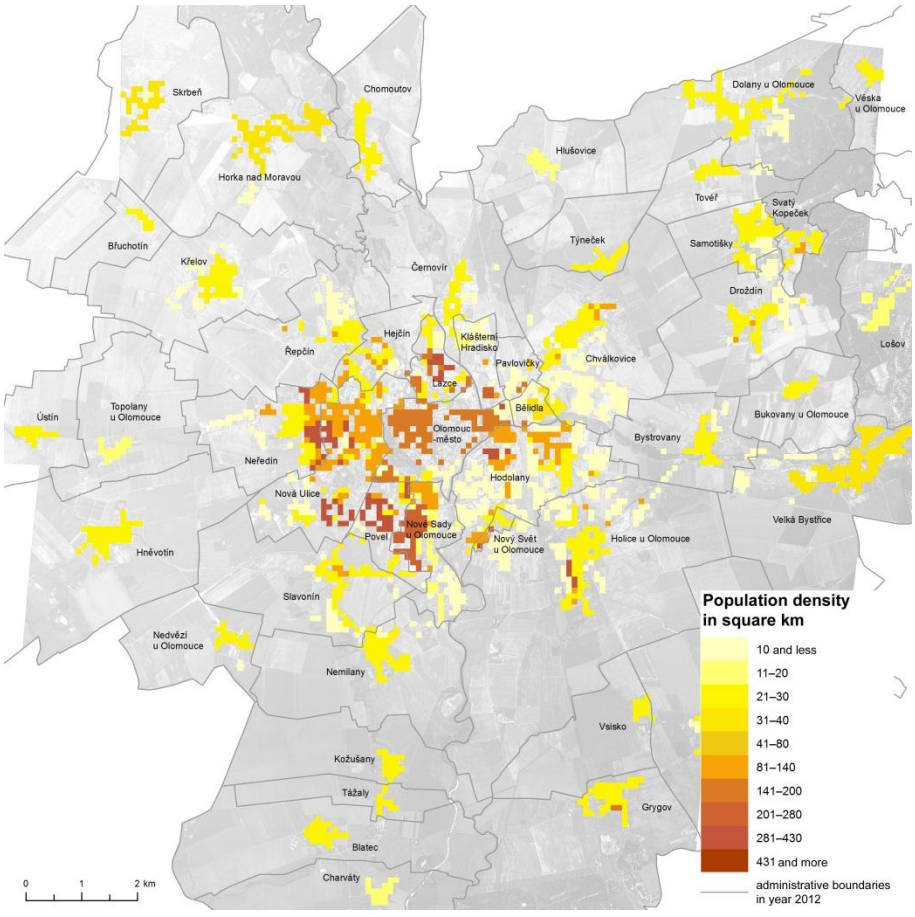

Fig. 7. Population density in Olomouc region in 1994

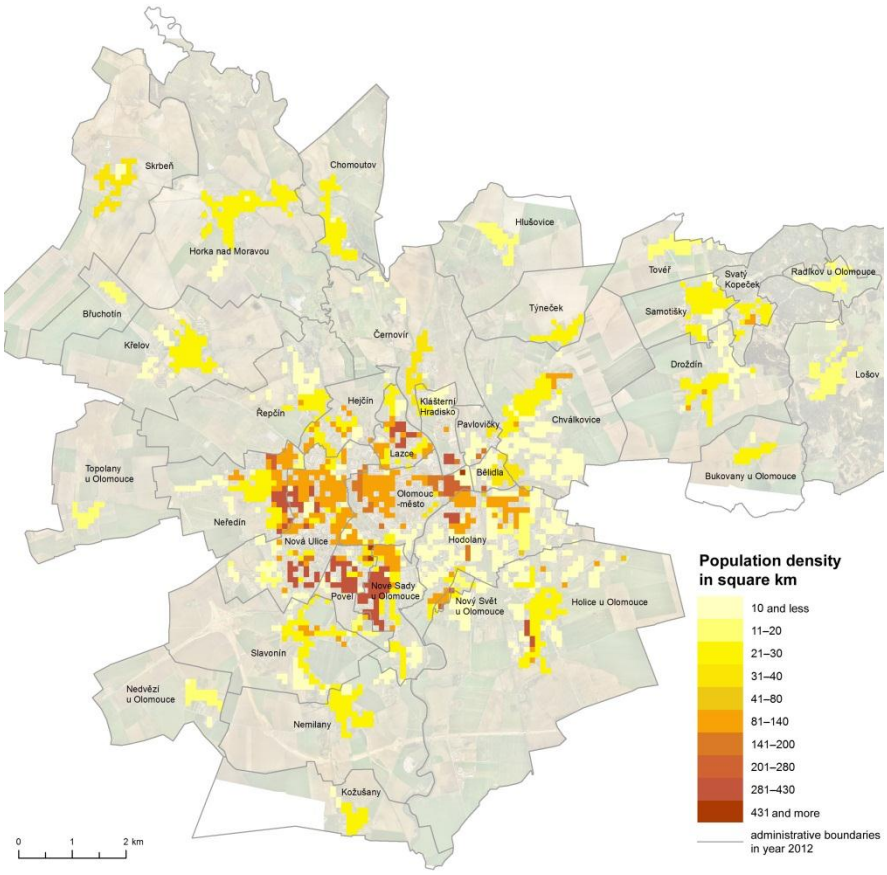

Fig. 8. Population density in Olomouc region in 2001

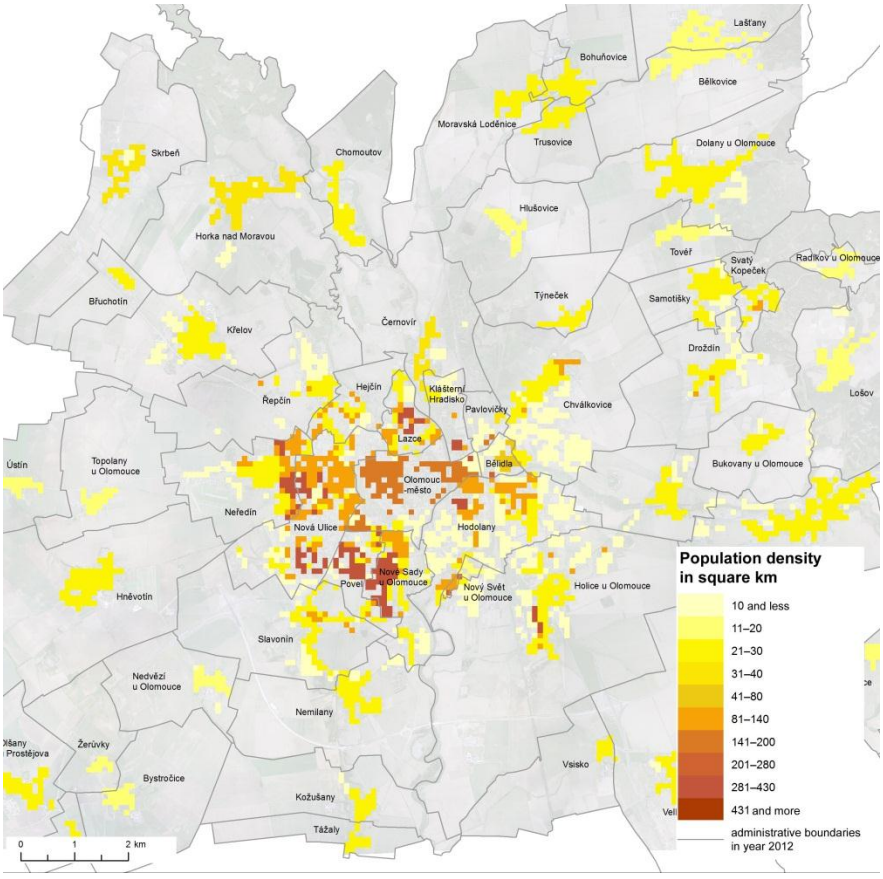

Fig. 9. Population density in Olomouc region in 2003

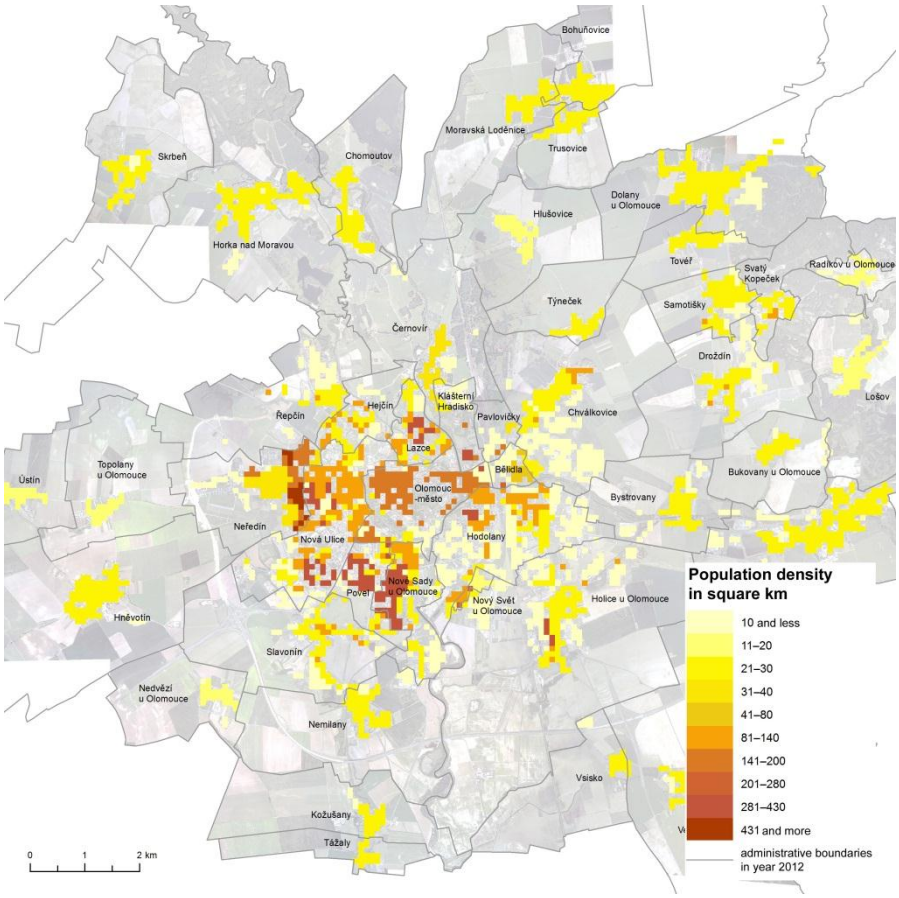

Fig. 10. Population density in Olomouc region in 2006

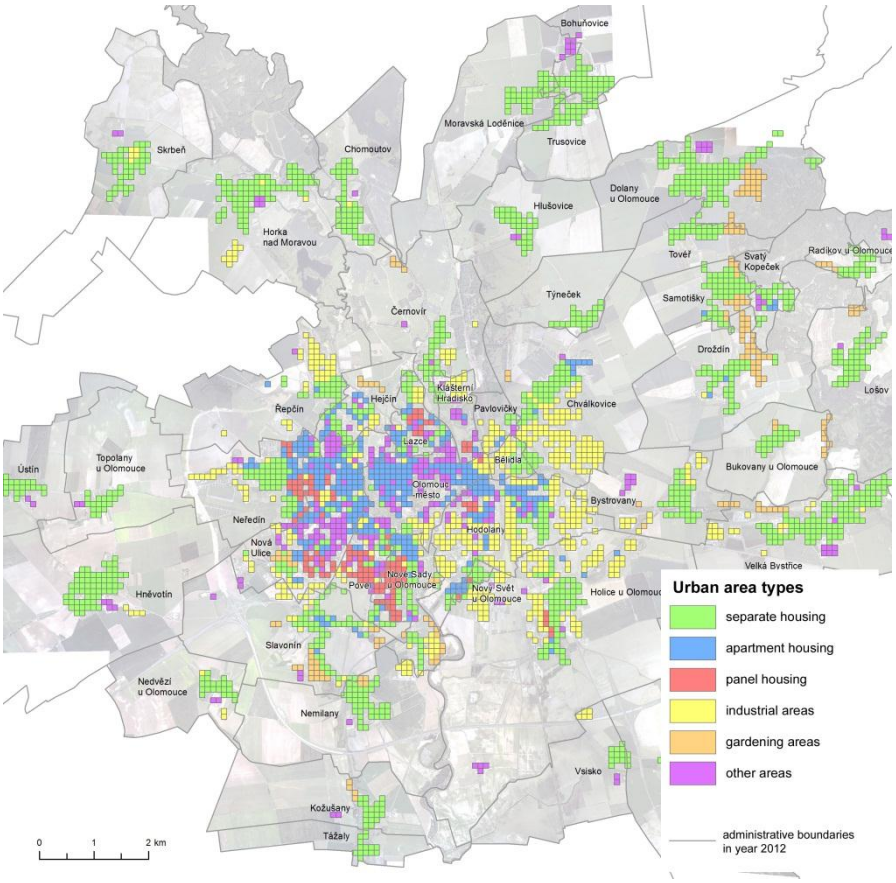

Fig. 11. Example of urban area types classification in 2006

Identification of urban development

In the resulting maps there can be identified certain developments in population density and in distribution of various urban area types in Olomouc. Population density is always related directly to the type of urban area in the locality; it is also not surprising that the lowest population density is in the southwestern part of Olomouc, where industrial sites are situated. The largest population densities are mostly in the residential buildings in the historic center of Olomouc.

At the beginning of the seventies there began the construction of panel houses in urban areas of Neředín, Nová Ulice area and others. On the map of year 1978 there can be seen that, especially in the southern part of Nová Ulice area has grown large panel housing. The industrial development can be identified in the seventies and eighties, mostly in Hodolany area and southern parts of Chválkovice area. In small villages around Olomouc there can be seen slowly growing of separate housing.

On the map of year 1985 there can be seen the emergence of two large panel housing estates. These settlements were gradually expanded to the south and along the housing estate in the Povel area. These locations become one of the most densely populated in the coming years. The increase in industrial development has slowed in the last years and there is not any significant increase in any type of urban areas.

Statistical evaluation

Statistical evaluation (Fig. 12) was performed for the center of the city, because all the necessary data (especially aerial photographs) were available for all processed years. On the graph, there can be identified the increase in size of the area of residential houses and the rise in the area of industrial areas. The low number of panel houses is due to the fact that the most of this area is the historic center of the city. There there can be also identified changes in urban area types (for example industrial areas are converted to residential housing, separate housing areas are converted to industrial areas, etc.).

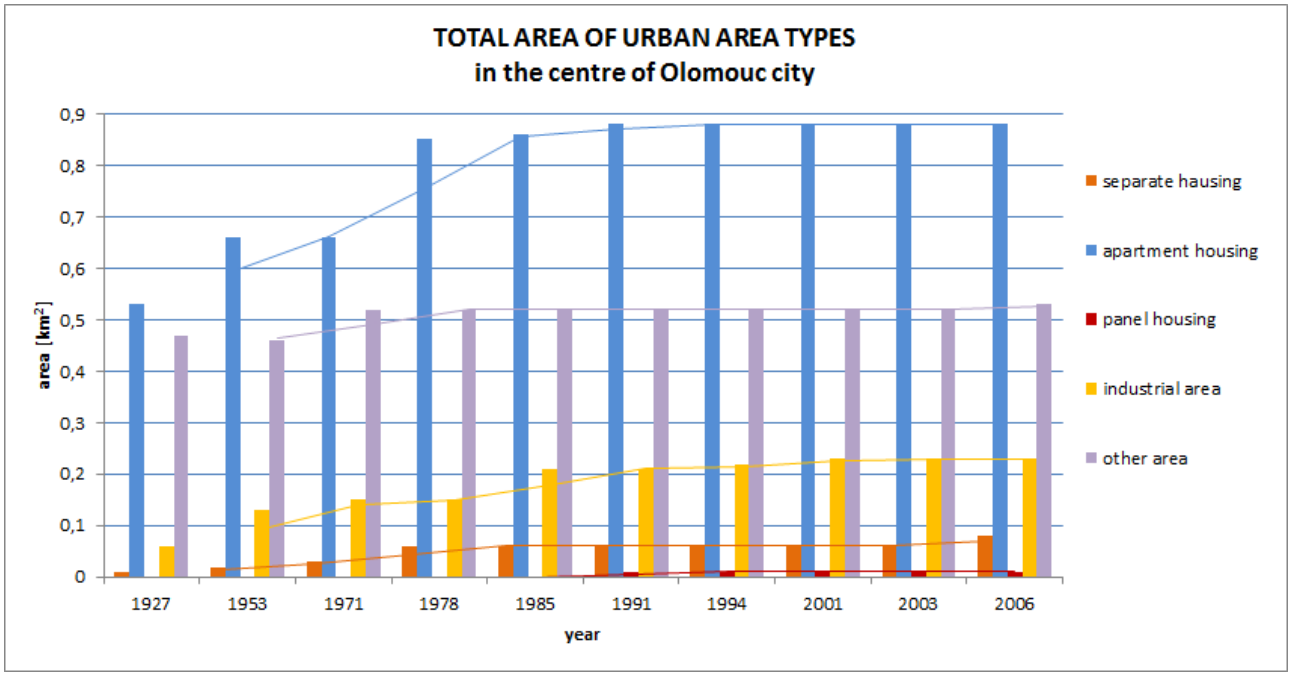

Fig. 12. Statistical evaluation of the urban area types in the city centre with trend lines

CONCLUSION

Method of dasymetric mapping based on the aerial photos was applied on the example of Olomouc city from period 1927 to 2006. The dasymetric mapping is a method of thematic cartography, which uses areal symbols to classify spatial volumetric data and is suitable for the population density visualization because of its ability to realistic spatial visualization. The same approach can also be used to monitor the development of the city in the long time period, applied is classification to different types of urban areas. To monitor such developments can be used aerial photographs in combination with statistical data related to the same time units, in which the aerial images were taken.

The methodology is unique because of the processed methods in a combination with several tools, that are usually used. A good indicator of the city development is besides the city population density also the type of buildings (residential buildings, industrial areas, etc.), which can be detected from aerial photographs. Detection of these areas and the subsequent application of statistical data are suitable for dasymetric visualization of the city development.

There were realized two sets of maps and animations of the outputs. In the first set of maps there is presented the population density, in the second set of maps there are presented urban area types. Both sets were processed in the period from 1927 to 2006.

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