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Cartographic modelling of the urban quality of life – aspect of green areas in the City of Lublin (Poland)

Modelowanie kartograficzne w ocenie jakości życia w mieście – aspekt zieleni miejskiej w Lublinie

Abstrakt: Prace z zakresu rozmieszczenia i ewaluacji zieleni w mieście w kontekście potrzeb mieszkańców mają duże znaczenie w związku z postępującym rozwojem przestrzennym miast i presją na wykorzystanie każdego wolnego kawałka gruntu. Szerzej możemy mówić tu o jakości życia w mieście, biorąc pod uwagę komponent zieleni. Warto również zwrócić uwagę, że analiza przestrzenna jakości życia w mieści jest trudnym i złożonym zagadnieniem, dlatego też rzadko jest przeprowadzana w obrębie miast. Typowe jest natomiast analizowanie jakości życia w odniesieniu do miasta jako całości, co pozwala na analizę porównawczą pomiędzy miastami. Nie daje to jednak możliwości analizy strukturalnej wewnątrz miast.

Celem pracy było zaproponowanie możliwości wykorzystania zdjęć satelitarnych z satelity Ikonos 2 oraz technik związanych z GIS dla potrzeb analizy terenów zielonych ośrodków miejskich oraz modelowania jakości życia w mieście. W artykule przedstawiono sposób integracji danych pochodzących z rejestracji teledetekcyjnej, dotyczących roślinności, oraz danych dotyczących rozmieszczenia ludności w mieście. Modelowanie kartograficzne doprowadziło do określenia rozmieszczenia przestrzennego wskaźnika jakości życia w mieście w aspekcie zieleni. W związku z tym wyniki mogą być przydatnym narzędziem w monitorowaniu i planowaniu przestrzennym.

Na podstawie zobrazowania satelitarnego Ikonos 2 wygenerowano rozkład przestrzenny znormalizowanego wskaźnika zieleni (NDVI). Było to podstawą wydzielenia dwóch klas zieleni: zieleni wysokiej (zbiorowisk drzewiastych i krzewiastych) oraz zieleni niskiej (głównie roślinność trawiasta). Aby określić wskaźnik terenów z zielenią przypadających na mieszkańców, niezbędne było wykorzystanie informacji o rozmieszczeniu ludności, którą to opracowano w formie mapy kropkowej. Określenie cząstkowego wskaźnika jakości życia przeprowadzono w polach podstawowych, a następnie zwizualizowano, używając metody izoliniowej. Proponowana metodyka dała w rezultacie przestrzenny obraz zjawiska, który stał się podstawą analizy rozmieszczenia terenów z roślinnością w odniesieniu do miejsca zamieszkania ludności Lublina.

Słowa kluczowe: jakość życia w mieście, teledetekcja, integracja danych, Lublin

Abstract: It is well recognized that green areas play a key role in improving urban environment. However, due to pressures from new development, urban greenery is seen to be rapidly declining in terms of their area and quality. Therefore, there is a need for proper planning control to ensure that the provisions of green spaces are adequately used for city dwellers. Information technology has created an opportunity to develop new approaches in preserving and monitoring the development of urban greenery.

This paper will discuss cartographic modelling in the scope of use of Geographical Information Systems (GIS) and remote sensing in providing solutions in monitoring urban quality of life (QoL). The author will focus on population distribution and urban greenery to assist in monitoring urban QoL at local context.

On the basis of IKONOS 2 satellite images the NDVI index for the high and low greenery was calculated to specify the space structure of greenery in Lublin. In order to determine the influence of green areas for residents, the map of population distribution was used. This weighted dot map was created on the basis of the place of residence data. These materials allowed the author to describe and analyse the quality of life index, which was calculated in fixed minimal mapping units. As the result of studying images of spatial distribution of the quality of life in Lublin was obtained in a form of synthetic isopleth maps. This modelling was based on software Erdas Imagine (NDVI, the classification of IKONOS 2 image) and ArcGIS (analysis of vector and raster).

Keywords: urban quality of life, remote sensing, data integration, Lublin

INTRODUCTION

The studies on the distribution and evaluation of urban green spaces in the context of inhabitants' needs gain importance due to spatial development of cities and the pressure to use every unoccupied place. Nearly 80% of European Union residents live in cities, therefore, the need for appropriate and detailed planning is enormous in this respect.

The studies on urban green spaces with the use of remote sensing data are not frequent. Large areas of cities and high level of urban tissue complexity require the use of detailed research data. Due to this barrier widely available material in a form of maps is frequently used. The maps, however, present a generalised view of the data, what makes the analyses not precise or detailed enough to be used in every situation. Other problems in assessing the actual size of green areas result from discrepancies between planning documents and high variability of areas occupied by particular types of urban greenery. It is worth emphasizing that these difficulties can be overcome quickly and comparatively cheaply using remote sensing data.

The potential to use high definition satellite images in planning urban areas is enormous. One should comprehend the advantages of the analyses based on precise material. In Poland there are relatively few studies on the evaluation of green areas in cities which are based on remote sensing material. Such research is, however, widely used in other countries (e.g. Lo 1997, Schöpfer *et al.* 2005, Krellenberg 2007; Li and Weng 2007; Pham *et al.* 2011).

The aim of the present paper is to evaluate the use of satellite images from IKONOS 2 satellite and GIS-related technologies for the analysis of urban greeneries and cartographic modelling Quality of Life in the city. The evolution of green areas was made for the cross section of Lublin.

Urban green spaces and Quality of Life

Vegetation together with the relief is one of the basic elements forming landscape and defining its ultimate look. Vegetation is an omnipresent element that accompanies nearly all people's activities. Due to its importance the problem of greenery and green areas was addressed by numerous authors in literature. Despite this, there are still numerous inaccuracies related to precise definition of this term.

Discussing the term of green areas, it is worth to emphasise characteristic features of these areas which influence the problems and their precise definition. Among many attributes of green areas, one should notice their diversified physiognomy, the area they cover, changeability in time and space, what make them a still active element of urban structure (Haber and Urbański 2005; Chmielewski 2010). They also have different roles and are related to different aspects of life and human activities. They may be discussed in two different contexts – as an element of terrain coverage or the means of land use. The land cover is related to the understanding of green areas as biologically active terrain (Mądry and Słysz 2011), whereas land use refers to legal and planning aspects.

Consequently, greenery was defined differently by different groups of interest and the same object is frequently counted to a few different classes at the same time. Sometimes a uniform definition is missing in the debate between the theoreticians and practitioners (Szumański 1994).

The topic of influence of green areas on environment and the functioning of urban areas has been discussed in literature a number of times. The significance of green spaces in forming urban landscape was already pointed out in the Renaissance. Although it was not common and concerned only higher social classes (Przesmycka 2005). Today the issue is more important. Green areas are a much more valuable element of urbanised areas. It is emphasised that green areas are the means of protecting people and their environment in the face of ceaseless changes of city landscape and urbanization. More and more frequently the need to consider city as a place of living is underlined (Czochański 2010). Such situation entails the need to satisfy people's basic needs such as the need of rest and work. The influence of greenery on all these areas is not to be ignored. Therefore, it is greenery that defines the way contemporary cities and its components are perceived (Sutkowska 2006), and the multiplicity of its roles seems an indispensable element of each urban organism.

Green areas in cities have many different functions. They may be aggregated to five major categories: natural (ecological), social and health, economic, cultural and aesthetic. Green areas play many important roles in city environment and influence the inhabitants in direct and indirect manner. Therefore, it seems necessary to ensure appropriate acreage of green areas not only for good functioning of the city organism but also to ensure inhabitants' appropriate life quality.

High resolution satellite images in mapping urban areas

The resolution of images influences the interpretation capacities for its users. Thus, it is not surprising that satellite data that were available until the end of 20th c. (e.g. Landsat, SPOT) with their maximum terrain resolution of 10 m did not meet the requirements of mapping and analysing complex areas. It was still in 1980 that researchers indicated the resolution of the sensors used for obtaining detailed remote sensing data should be at least 5 m (Welch 1982). Such capabilities could be obtained only with new generations of very high resolution (VHR) commercial satellites – e.g. IKONOS, QuickBird, WorldView, OrbView.

A group of high resolution satellites provide images of space resolution of down to 1 m. Such images are made as panchromatic or multispectral images. The research on the use of this data showed that they can be used to prepare and update maps in scales higher than 1:10 000. Rapid development of satellite techniques is the only chance for future development of this potential.

The properties of large scale satellite images are broadly used in the studies of urban environment with complex spatial and functional structure. These places are challenging for remote sensing techniques due to mixing categories of areas and the materials they are made of, what translates into high level of spectral variation and its impedes image segmentation (Kuo *et al.* 2001; Small 2003; Small and Lu 2006). High resolution sensors do very well with such data. High resolution allows to obtain images at a level that guarantees detailed enough image that gives a possibility to attribute pixels to each class of land cover.

Greenery is one of the elements of urban environment that should be explained and defined more precisely for the purposes of management and planning.

As it was mentioned before, even small green areas play a very important role in urban landscape. Therefore, in case of analyses aimed at defining the influence of green areas on people's quality of life (QoL) and the functioning of cities as such the identification of small green areas is extremely important.

This is one of the reasons for using high resolution images in the management and planning of urban areas. It becomes more common and displaces more traditional (and time-consuming) methods of obtaining the data. Peculiar differentiation of city areas is still a challenge for satellite remote sensing, what is reflected in large interest in these areas and indicates the necessity to improve the methods and tools that are used in research.

STUDY AREA AND DATA SETS

Lublin is one of the major Polish cities. 9^{th} location in terms of population (339 850 in 2017) and 16^{th} location in terms of area (147.5 km^2). The population density is 2304 people per km^2 (in 2017). The city is located in central-east Poland about 160 km from capital Warsaw, on the north edge of Lublin Upland at the height of 163–238 m above sea-level.

The analysis of green areas in urban environment requires images of high detail of data. These requirements are met by high resolution satellites, such as IKONOS-2. It is equipped with an infrared band which allows for the identification of green plants. Both of these features decided on the use of images from this satellite in this article. Satellite data does not record spatial information from green objects that are hidden from observation from above. Therefore, the analysis does not include greenery covered with artificial materials, for example to protect against excessive sun exposure.

Data for analysis were acquired on 18.08.2011 (during peak vegetative season) by satellite imagery from IKONOS-2. Images were recorded in the UTM system and cover area between 51°11'9.39'' and 51°17'20.82''N and 22°29'23.5'' and 22°29'35.51''E (Fig. 1). The geometrically corrected IKONOS data has a resolution of 1 m (0,82 m in nadir) for the panchromatic data (PAN) and 4 m (3,28 m in nadir) for the multi-spectral data (Multi). IKONOS/PAN covers a spectral range from the visible red to the near-infrared region (450–900 nm). The IKONOS/Multi covers four bands, and bands 1 to 4 cover the visible blue (445–516 nm), green (506–595 nm), red (632–698 nm), and near-infrared (770–888 nm) regions, respectively. The IKONOS data are collected at 11 bits per pixel (Dial *et al.* 2003).

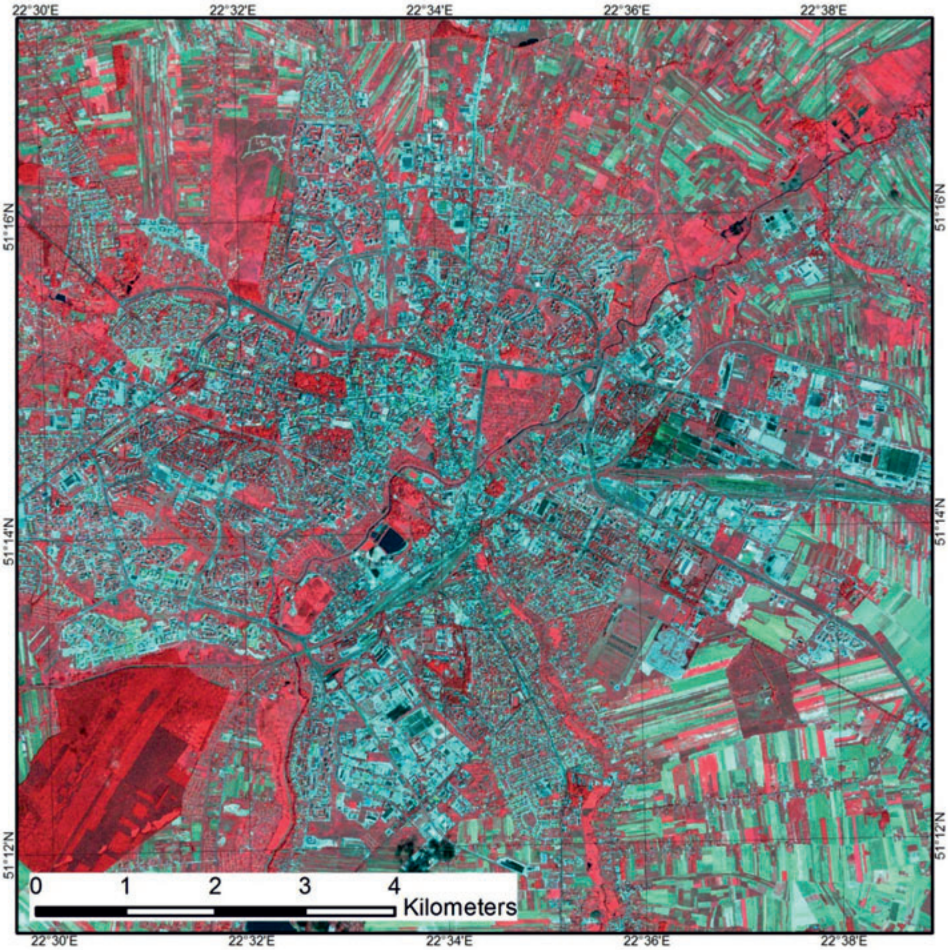

Fig. 1. Satellite image of Lublin from IKONOS-2 (spectral composition 4,3,2)
Ryc. 1. Zdjęcie satelitarne Lublina (IKONOS-2, kompozycja spektralna 4,3,2)

Population data

The analysis of Lublin population quality of life in terms of green areas requires the collection of data concerning the distribution of people. For this purpose, a dot map of distribution of residence was used, as in Fig. 2 (2015) in the scale of 1:20 000. The original map was prepared by Tomasz Frąś (2005) as an MA dissertation in Department of Cartography and Geomatics, Maria Curie-Sklodowska University in Lublin. This data was updated in 2015. Its use allowed to research the spatial distribution of the influence of green areas

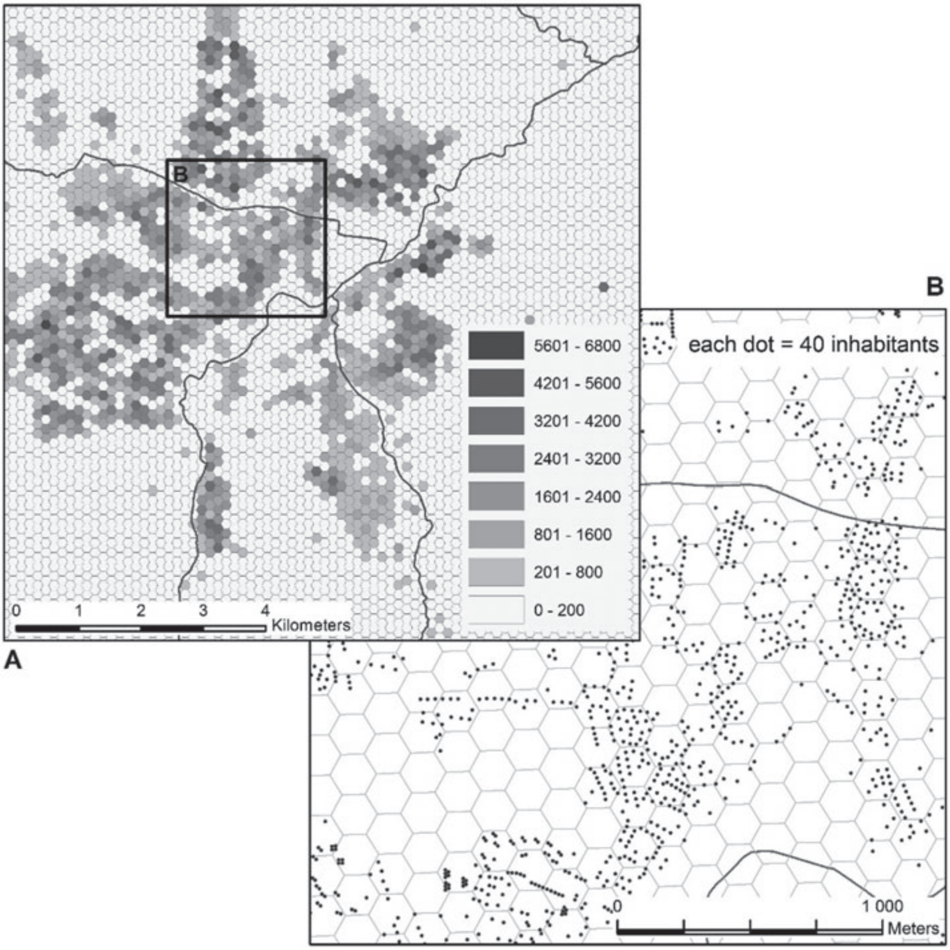

Fig. 2. Population distribution in Lublin (2015). A – Choropleth map of population density (persons per 1 km^2) – dot map transformation with minimal mapping unit 2 ha, B – Population dot map (according to place of residence data)

Ryc. 2. Rozmieszczenie przestrzenne ludności w Lublinie (2015). A – Kartogram gęstości zaludnienia (osoby/km^2) – transformacja mapy kropkowej dla pola podstawowego 2 ha, B – Mapa kropkowa ludności według miejsca zamieszkania (waga kropki 40 osób)

on quality of life in the city. The level of map generalization was determined by the weight of a dot which was 40 people. The map is a model of population distribution which shows the phenomenon in a topographic way, i.e. in accordance with actual place of residence of Lublin population.

METHODOLOGY

Identification of green areas

It was crucial for the research to distinguish green areas from other classes of land cover. The process was made in ERDAS Imagine programme. Green areas were selected with the use of Normalised Difference Vegetation Index (NDVI) based on radiometric information included in the red and infrared bands recorded in satellite images. NDVI is one of the most frequently used indicators in greenery analyses, and is calculated in accordance with the formula (Jensen 1996):

$$NDVI = (NIR-RED)/(NIR+RED),$$

where NIR is the value of pixels in the near infrared and RED is the value of pixels in the red channel.

As a result, vigorously growing healthy vegetation has low red-light reflectance and high near-infrared reflectance, and hence, high NDVI values. This relatively simply algorithm produces output values in the range of –1.0 to 1.0. Increasing positive NDVI values, shown in increasing shades of green on the images, indicate increasing amounts of green vegetation. NDVI values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water, snow, ice, and clouds.

The use of NDVI eliminates a number of errors which are noticed only if contrasted with other. Firstly, it is impossible to divide by 0; Secondly, the indicator accounts for changes in lighting, the distribution of slopes and exhibitions as well as other external factors determining the reflection of the radiation. All of these elements determine its frequent use.

NDVI was calculated in a software Erdas Imagine. Obtained image of NDVI and its frequency are presented in Fig. 3 and Fig. 4.

It is worth to mention that the values of NDVI for individual image pixels are in the range of –1 to 0,809232 (Fig. 3). This proves the fact that in the image there are both green and non-green areas. It is also noticeable visually. The areas of high degree of coverage with plants are marked with light green. The non-green areas, developed areas are distinguished by grey and black.

In order to make a precise division an assumption was made that the value of NDVI for greenery was above 0.2. The resultant image was controlled on the basis of the field studies and available materials (Krukowski *et al.* 2016).

In order to expand the research two classes of greenery were selected – low greenery and high greenery. They could be distinguish in the process of supervised classification of NDVI image. The differentiation of these two types

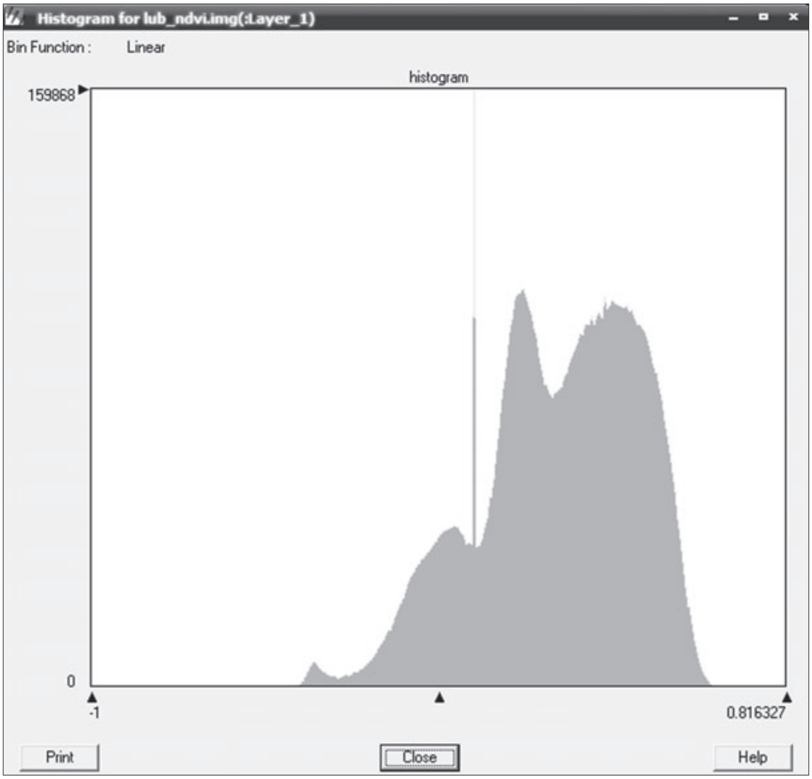

Fig. 3. NDVI histogram for the research area
Ryc. 3. Histogram wskaźnika NDVI

of greenery was possible due to the correlation of NDVI with the projective surface of leaves, and it with green biomass. It was assumed that high greenery has larger biomass and higher NDVI value, in comparison to low greenery. Analysing the training fields in NDVI images with the obtained knowledge from other materials and field research the threshold level was determined for both categories. The result of the classification is presented in Fig. 5. The images of greenery were presented in a form of raster file and the next ones were imported from ArcGIS in order to make the next analyses.

Data aggregation

Another stage of modelling quality of life was the definition of minimal mapping units that divide the area of the city, which were the basis for data aggregation on population and greenery. The data aggregated in the fields were the

Fig. 4. Normalised Difference Vegetation Index (NDVI) – light grey tones indicates healthy vegetation

Ryc. 4. Znormalizowany wskaźnik zróżnicowania roślinności (NDVI) – jasne tony wskazują na obszary pokryte roślinnością w dobrej kondycji

Fig. 5. Classification of high and low vegetation

Ryc. 5. Obraz wyniku klasyfikacji roślinności wysokiej i niskiej basis to calculate the greenery indicators – total green spaces, low green spaces, high green spaces and resultant index characterising the area covered by green spaces per one inhabitant.

Hexagons, as figures that are most similar to a circle were considered the most appropriate here (Mościbroda 1999). The problem was to define the scale of a single field. Different values were adopted for hexagons. Some of them (100 000 m^2, 200 000 m^2, 50 000 m^2) did not produce sufficient results, others were too small (10 000 m^2), what needlessly fragmented the image and did not allow to make further analyses. Decisively, the image was divided into 6579 hexagons of 20 000 m^2 (2 ha). Such areas corresponded to four sports pitches. At the same time this is the area that allows for free perception of the surroundings. With this size it is also possible to present green spaces which are relatively small but important, e.g. small cemeteries, places of memory, etc. This guarantees certain uniformity in development of such area.

A network of minimal mapping units was used as a base to build cartographic models – choropleth and isolpleth maps presenting the structure and distribution of green spaces in Lublin and quality of life index. The construction of maps was based on centroid networks generated from the hexagons. The presented models were prepared in GIS environment – ArcGIS software.

RESULTS AND DISCUSSION

Identification of green spaces from spatially complex city area allowed to complete the proper part of the work, i.e. the analysis of distribution and structure of green spaces in Lublin.

Among 6579 hexagons within the image, as many as 6473 contained green areas. The sizes of the areas in each hexagon were not known. In order to obtain this information the raster image of green had to be transformed into polygons vector layers and then identified to which hexagon they, or their fragments belong to. Each green polygon was attributed the number of the hexagon it (or its fragment) belong, what allowed for an automatic calculation of green space area within hexagons.

The data presented in the maps are the values of specially designed indicator. They include: the shares of low and high greenery, the ratio of high to low greenery, the ratio of green areas to other elements of the urban structure, the area of green spaces in km^2. The image based on this area allowed to analyse green spaces in Lublin and its vicinity. In order to define the QoL in Lublin as a resultant of the greenery presence the index of green spaces, i.e. the amount of greenery per 1 inhabitant was used.

All the analyses were made on the minimal mapping units (the hexagons); the cartographic model of the indicator distribution is called the choropleth method. It allows to process the abrupt changes into a fluent model presented with a method of isopleth.

Many difficulties appeared in case of the green index – the amount of green areas per one inhabitant. In literature this index is frequently used as quality of life index in urban area. Usually it refers to all green spaces in the city and all inhabitants. However, the use of this index brings interpretation problems and doubts concerning the advisability of its use. It is not always possible to calculate the index for the whole area as it can be calculated for the populated areas. If a given area is unpopulated the value of the denominator is value "0" and it is impossible to calculate such a formula. Because the city also consists of industrial and services areas, extensive water and forested areas the cartographic model has certain gaps. This problem arises for all uninhabited areas. It is worth to note that such area may be both green spaces and can be completely deprived of green areas, e.g. industrial areas. Theoretically the quality of life can be completely different. Therefore, it is necessary to have such sizes of basic hexagons that at least one person lives there. On the other hand, such a solution leads to generating an image that is over-generalised to large extent.

In order to solve this problem the model of isopleths was used that shows local trends in the spatial distribution of QoL in a continuous manner. The index values underwent an interpolation procedure with a local polynomial. Consequently, the model of quality of life in the city in the context of total green spaces and high greenery was illustrated in a form of isopleth maps.

The evaluation of green spaces condition in Lublin was made on the basis of a number of analyses. The distribution of green areas in Lublin and its vicinity is presented as choropleth map in Fig. 6. In the image there are c.a. 77.9 km^2 of green spaces of different kind. In contrast to the size of the whole satellite scene 10 km × 10 km (100 km^2) the area of total green spaces occupies nearly 80% of the image. This proves that Lublin and its vicinity are the terrain of high level of greenery. Only one fifth of the area is occupied by other classes of land coverage. The share of green spaces in the hexagons for the territory of Lublin and its vicinity is presented in Fig. 6. The data is presented as a percentage what facilitates the analysis and interpretation of the results. The data concerning particular percentage categories was presented in Table 1. The regions with small amount of green spaces are characterised by over 25% share of greenery in the total area. They make only 3% of the total area of Lublin and its vicinity. The areas with significant, large or extra-large share of green spaces dominate (over 90% in total).

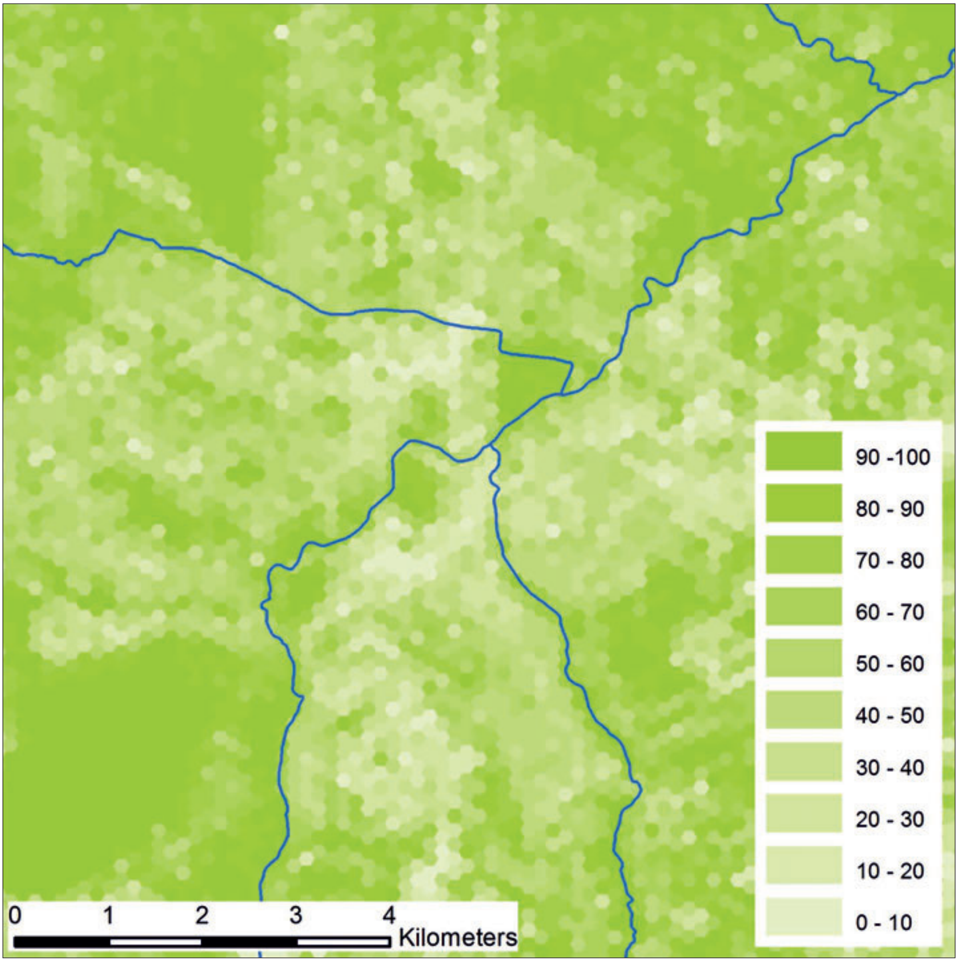

Fig. 6. Percentage of green areas (high and low vegetation) to other classes of land cover
Ryc. 6. Udział procentowy powierzchni terenów zieleni w stosunku do pozostałych klas pokrycia terenu

Tab. 1. Categories of the green areas share in Lublin (research area)
Tab. 1. Klasyfikacja terenów zieleni i udział w powierzchni Lublina (obszar objęty badaniami)

Percentage of green areas *Udział procentowy terenów zielonych*	Share in the city area [%] *Udział w przestrzeni miasta*
low (0–25%)	3%
medium (26–47%)	2%
significant (48–66%)	33%
large (67–88%)	31%
extra-large (89–100%)	31%

High greenery, low greenery

Green spaces can be analysed not only in terms of their distribution but also their structure. The present work uses the division into high and low greenery. The division is important from the perspective of functions these areas have in improving people's quality of life. Low greenery plays a significant role in regulating thermal and humidity conditions, and high greenery is an acoustic isolator, for instance. The ratio between low and high greenery is very important due to their differentiated physiognomic features and influence on natural conditions. For instance, extensive areas of low greenery without elements of high greenery

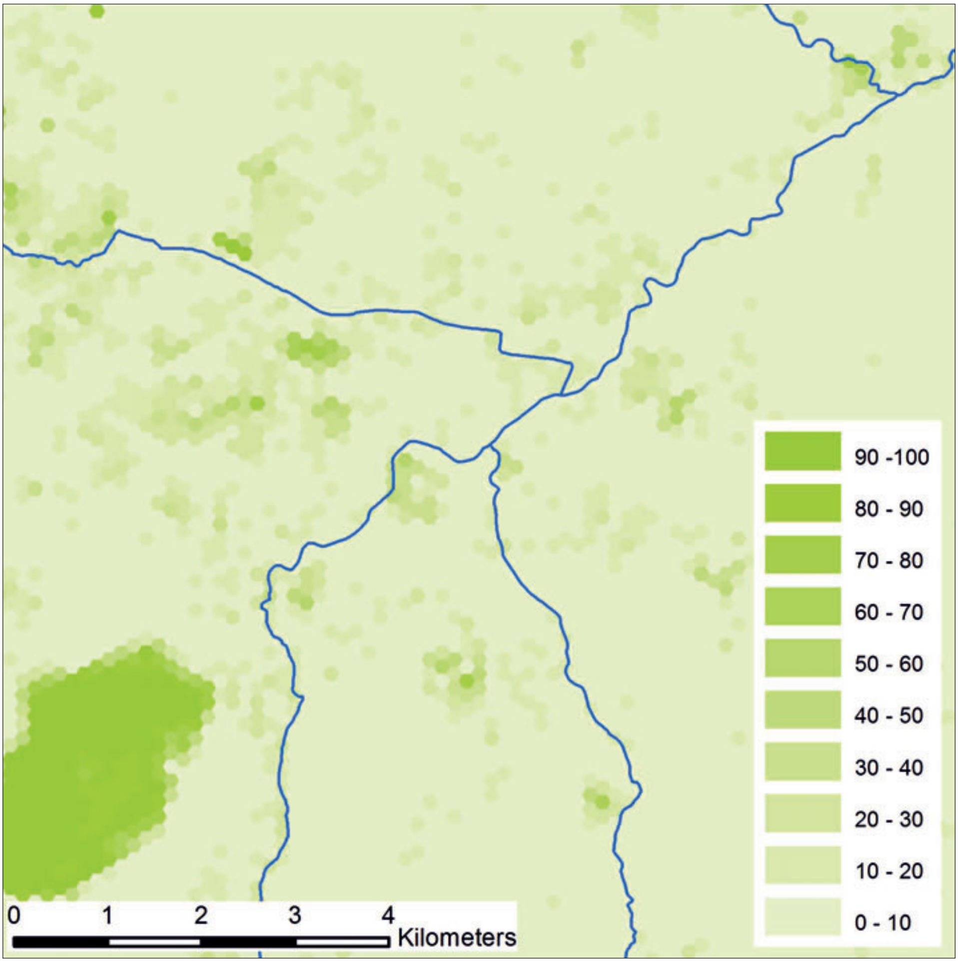

Fig. 7. Percentage of high vegetation to other classes of land cover

Ryc. 7. Udział procentowy powierzchni terenów zieleni wysokiej w stosunku do pozostałych klas pokrycia terenu may cause temperature inversion and unfavourable changes in the environment. Such areas also have lower aesthetic values for their users, due to lack of scenic diversity (Szczepanowska *et al.* 1984).

Within the image there are 77.9 km^2 of green spaces, in which 68.1 km^2 is low greenery and the remaining 9.8 km^2 is high greenery. For the area of Lublin the values are 33.6 km^2 (low greenery) and 2.9 km^2 (high greenery) respectively. This gives the ratio of high greenery to low greenery at the level of 1:12, what makes low greenery predominant in Lublin and its vicinity. The share of various

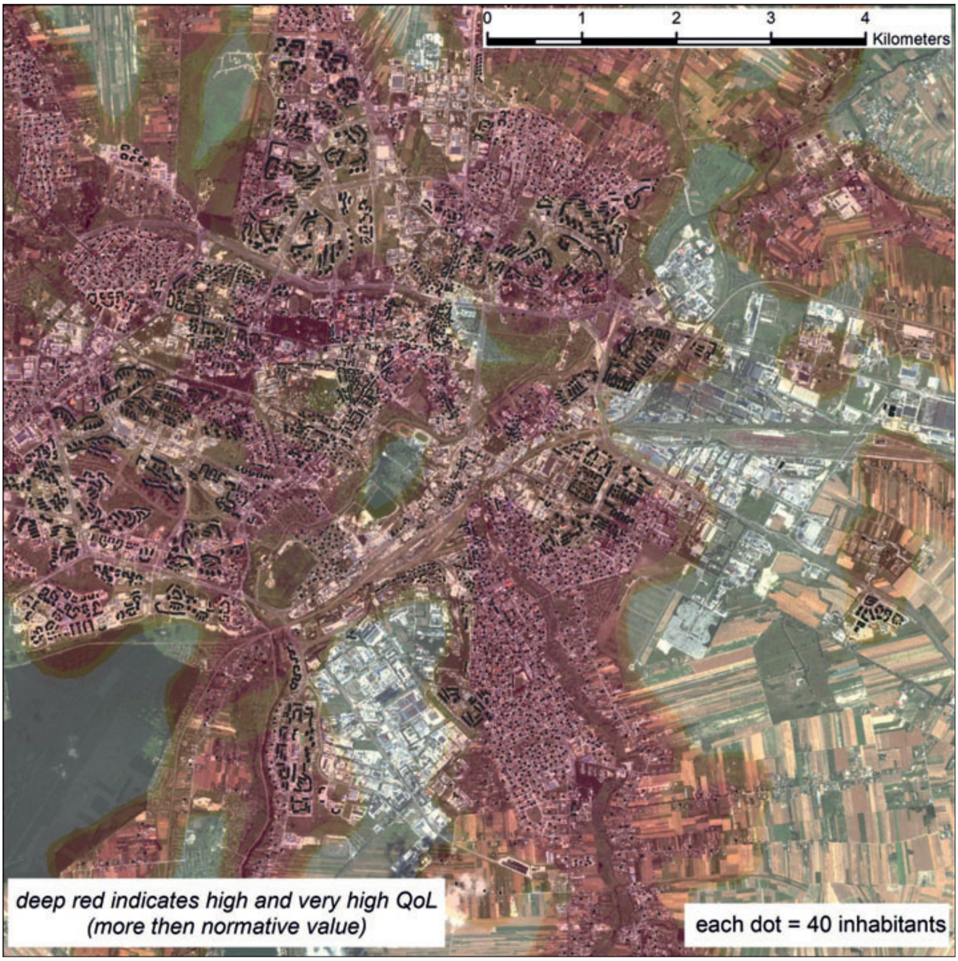

Fig. 8. Local tendency, prediction map of QoL in Lublin in the aspect of total greenery. Isopleth map of QoL with population distribution shown by dot density method

Ryc. 8. Tendencja lokalna, mapa predykcji jakości życia w Lublinie w aspekcie zieleni. Mapa izopletowa jakości życia oraz rozmieszczenie ludności przedstawione metodą kropkową classes of green spaces differs in different parts of the city. The distribution of the high greenery in Lublin is showed in Fig. 7.

Quality of Life in Lublin

The opinions about the size of green areas per one inhabitant are shared. It is estimated at 8–15 m^2 per 1 inhabitant with regards to total green areas of the city. According to Czerwieniec and Lewinska (1996), the indicator should exceed 15 m^2 per inhabitant, and according to the norms by WHO it should be 50 m^2 (Walkowicz 2001).

The image covers the area populated by 362 360 people, including 353 500 in Lublin (in 2004). In the same area there is 36.5 km^2 of green spaces, what makes 103 m^2 per 1 person. Considering the above mentioned notice it can be stated that the area is twice as large for Lublin than it was advised by WHO for areas of good quality of life. The model of spatial distribution of the green index in Lublin was presented in Fig. 8 and Fig. 9. The isopleth prediction map presents a local tendency of determining the index in the city. The value of index was estimated by local polynomial interpolation deterministic algorithm (Chiles, Delfiner 1999). The data concerning the quality of life determined on the basis of green index (for total green spaces and high greenery) is presented in Table 2 and Fig. 10.

The city has quite good environmental conditions for dwelling. Favourable indicators of green spaces per 1 inhabitant (i.e. exceeding 15 m^2 per person) concern 30% of Lublin. High value (i.e. c.a. 500 m^2 per person) concern the areas of detached houses. Green areas in such places have fewer users. Their public accessibility is doubtful, as they are predominantly private gardens in the backyards.

Tab. 2. Quality of Life valorisation in Lublin calculated in hexagons

Tab. 2. Struktura jakości życia w Lublinie odniesiona do powierzchni miasta i liczby ludności

Quality o Life *Jakość życia*	City area in % *Udział po-wierzchniowy*	Population in % High greenery aspect *Populacja w %: zieleń wysoka*	Population in % Total green spaces aspect *Populacja w %: zieleń ogółem*
very low (< 1 m^2/pers.)	0.7	24	1
low (1–8 m^2/ pers.)	8.8	55	4
medium (8–15 m^2/pers.)	7.2	12	22
high (15–50 m^2/pers.)	21.3	8	51
very high (> 50 m^2 /pers.)	8.6	1	23
not specified – uninhabited	53.4		

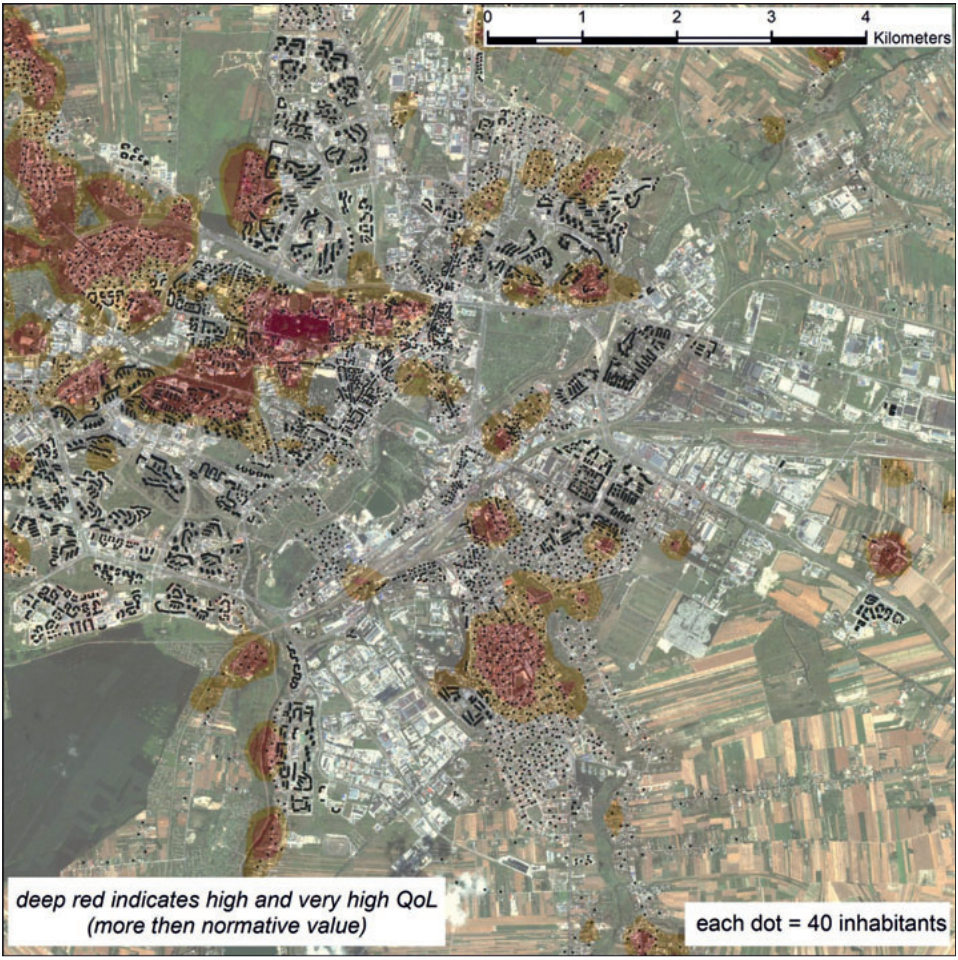

Fig. 9. Local tendency, prediction map of QoL in Lublin in the aspect of high greenery. Isopleth map of QoL with population distribution shown by dot density method

Ryc. 9. Tendencja lokalna, mapa predykcji jakości życia w Lublinie w aspekcie zieleni wysokiej. Mapa izopletowa jakości życia oraz rozmieszczenie ludności przedstawione metodą kropkową

Low values of green spaces index concern primarily two situations. Undoubtedly, the green index cannot be high for the areas where the acreage of green spaces is small or non-existing. Secondly, the index is lower if a given area is inhabited by a large number of people. Most often it is the case of multi-family residential estates. There are areas where both factors overlap, significant part of Lublin residential districts are multi-storey buildings and the green spaces in different estates are diversified.

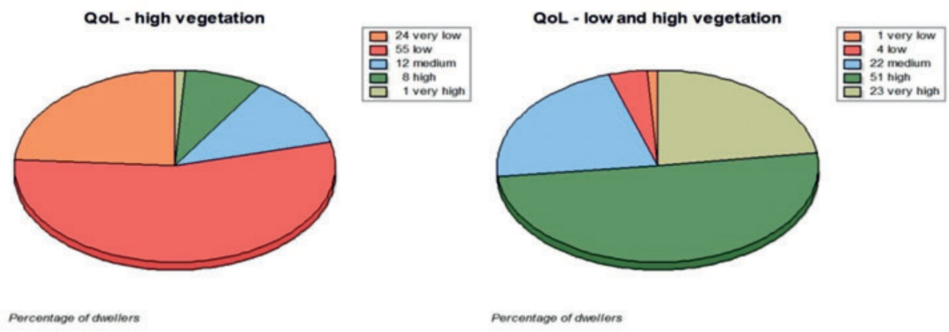

Fig. 10. QoL structure of Lublin population in the aspect of high vegetation and sum low and high vegetation

Ryc. 10. Struktura jakości życia mieszkańców Lublina w kontekście zieleni wysokiej oraz zieleni ogółem

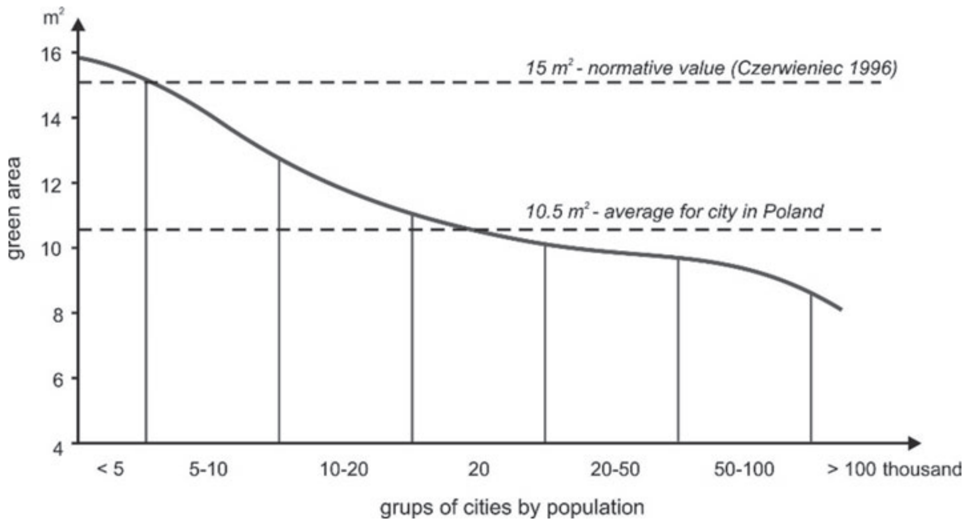

Fig. 11. Acreage of green area per 1 inhabitant in different sizes of cities (source: Szczepanowska *et al.* 1984)

Ryc. 11. Powierzchnia terenów zieleni przypadająca na jednego mieszkańca według wielkości miast w Polsce (źródło: Sczepanowska i in. 1984)

The values below the threshold, including the lowest values of less than 1 m^2 of green spaces per person are noted for the Old Town area. The lowest green index is noted for the Old Town Market Square and the surrounding tenements. This area certainly lacks green spaces. Dense building structure developed within the historic growth of the city. The need to preserve the place in an unchanged form causes a conflict of interests in case of introducing green areas in the existing urban development.

The changes in the size and structure of green areas show changes in urban population's needs. Green spaces in the city structures are more and more frequently resultants of competitive fight for the usable areas (Mierzejewska 2001). With such a significant role of green areas, it is alarming that their acreage is being continuously limited as this is the easiest way to obtain desirable building sites (Szczepanowska *et al.* 1984). The trend can be seen in the decreasing size of green spaces per 1 inhabitant with the increase of the size of the city (Fig. 11).

The phenomenon of advancing urbanization also concerns Lublin. The city is growing and overtakes new areas. The building developments are more and more dense. Nevertheless, the green index is maintained at a high level. Its value for Lublin exceeds the average for Polish cities and is among the highest in Poland.

CONCLUSION

Green spaces are strategic elements and should be taken into consideration while defining the direction of urban development. Not only the share of green spaces in urban structure, but also its size and distribution as well as the means of utilization are important.

Lublin is undoubtedly a green city. Large acreage of green spaces diversified in terms of their surface, physiognomy and species ranks the quality of life at a high level. The area of green spaces grows higher towards the city borders. With the increase of distance from the city centre, the amount of high greenery decreases and the low greenery goes up. In Lublin itself, low greenery is predominant and equally distributed throughout the city. High greenery is present in a form of irregular, differentiated in terms of their height spots.

High resolution satellite images appear to be extremely useful in researching green spaces in urban development. First, they allow to obtain precise and detailed data that guarantee the precision of studies. Second, the images can be obtained frequently, what allows for current update of the studies. Finally, precise distribution of green spaces in the city can be defined, the green areas can be selected from the non-green terrains and classified in terms of height, structure and the share of each element.

The opportunities to use satellite images in researching green spaces are enormous. Certain significant parameters can be assessed with their use for the purposes of spatial management and policy making. Combining satellite images with other data in GIS generate even broader possibilities.

To sum up, remote sensing material should be used more extensively in the research on urban green spaces than it has been so far. The horizontal distribution of green areas are still insufficient in case of research on urban green spaces. Cites grow horizontally, what changed the perception of space by the users of urban areas. The same size of green spaces in family housing development is perceived differently than in multi-family estates. The development of cities within their present range leads to the decrease of quantitative indicators of urban green spaces. In order to maintain the balance between "greenness" of the cities it is advisable that high greenery spread with the development of an urban centre. Therefore, it is worth to consider conducting broader research on green spaces with the use remote sensing material and three-dimensional GIS techniques. The use of satellite images in researching urban green spaces is a developing and prospective discipline.

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