

**LAND-USE PLANNING AND SATELLITE IMAGERY
USED FOR GREEN AREAS PROTECTION
– CASE STUDY OF THE CITY OF ŁÓDŹ, POLAND**

Marcin Feltynowski, Ph.D.

*University of Łódź
Faculty of Economics and Sociology
Institute of Spatial Planning
Department of Regional Economics and Environment
Rewolucji 1905 r. no. 39, 90-214 Łódź, Poland
e-mail: marcin.feltynowski@uni.lodz.pl*

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Abstract

The article presents the issues of spatial planning on the case study of Łódź. Of significance in Łódź are its outer peripheries, which due to their natural value have become areas that must be protected and monitored in order to limit the anthropogenic impact. Protection of these areas may be carried out through the usage of instruments such as local land-use plans which help to limit the green field development phenomenon and to look after the biologically active surfaces within the borders of the city. The second step which may concern the areas with local land-use plans, as well as those without current local land-use plans, is monitoring. Such monitoring may be carried out through the analyses of satellite imagery of the city area. Such activities are a kind of low-budget enterprises which bring many benefits at a very small cost resulting from the purchase of satellite imagery. From the perspective of the authorities, a crucial fact is that the material collected during the analyses of the satellite imagery may be used in the initial phase of the planning process as an element of the inventory of areas designated for the development of land-use plans.

Keywords: spatial planning, land-use plan, land cover, satellite imagery

JEL classification: R52, O18, O21

Introduction

Spatial planning is a tool that allows for land management in accordance with the rules of sustainable development in terms of the care of spatial order. Spatial planning plays a vital role on the peripheries of the cities and suburban areas. It can be assumed that the peripheries of cities are threatened by the activities connected with suburbanisation, which also influences the central city and particularly its borderland (Zimnicka, Czernik, 2007; Wójcik, 2013). Current processes that are present in Polish cities coincide with the city lifecycle presented by Klaassen (Klaassen, 1988), who indicated four phases of a city lifecycle: urbanization, suburbanization, deurbanisation and reurbanisation. The suburbanisation phase is based on an increased dynamics in reference to settling of the population on the peripheries of cities rather than in the central areas of the city. It has to be emphasized that Central-Eastern Europe is going through the second phase of the city lifecycle (Markowski, 2011; Pichler-Milanović, Gutry-Korycka, Rink, 2007), which means they are facing planning problems, especially on the peripheries. Peripheries may be defined as areas distant from the historical centre of the city that lose the connection with the city centre, but they stay within the borders of an administrative unit, becoming a place of biologically active areas (Pirveli, 2008).

A significant supportive instrument for the areas threatened by the anthropogenic impact connected with changes of land use are local land-use plans that may be used by the local authorities in order to shape the land development on the peripheries (Izdebski, Nelicki, Zachariasz, 2007; Feltynowski, 2010; Mroziak, Wiśniewska, 2013; Nowak, 2013). The structure of the Polish spatial planning system after 1994 led to a situation where communities did not necessarily have in their areas documents that may have an impact on land development. In the case of Polish urban communities, spatial planning becomes a challenge resulting from the fact and necessity of reconciling many interest groups in the city. The acceptance of spatial policy is desired because of the mitigation of future spatial conflicts within a community. The weakness of the planning system with reference to local land-use plans is mentioned also on the science forum, where the following negative elements are emphasized: an extended role of specialist documents influencing the accomplishment of investments excluding land-use plans, too explicit in practice promotion of the private interest over the public interest, chaos regarding the interpretation of legal regulations, vast politicizing of self-governments (Markowski, 2011). Ignoring local land-use plans, particularly in big cities, may lead to an increasing chaos in spatial planning and land development of the basic units of territorial division (Kopeć, 2009). The lack of land-use plans has a negative impact on the environment, for example investment pressure on

environmentally valuable areas or local landscape (Rzeńca, 2011; Nowak, 2013). The problem of spatial planning on the peripheries of the cities is also mentioned in the international literature (Ryan, Throgmorton, 2003).

The issues which have been discussed in the Polish metropolises result also from the knowledge gap regarding the access to open source software and low-budget materials in order to monitor city areas for changes taking place in land development. One of such tools may be an analysis of the satellite imagery, which is presently available and affordable for local governments due to the developing market of services connected with these materials (Meinel, Lippold, Netzband, 1998). This is possible due to the usage of imagery and GIS open source software, which does not require advanced skills when the data are collected for the internal needs of the community.

Such an approach to spatial planning and the necessity to monitor the areas remaining without spatial development plans has been a convincing factor leading to the need to analyse these areas of large cities and their activity within them. The case study is Łódź, which is one of the top Polish cities as far as the occupied surface and population figures are concerned. This has enabled the assessment of spatial planning in Łódź and indicates the possibilities of monitoring the areas which do not possess local land-use plans with particular attention paid to the peripheries of the city.

The aim of this study is to show how to use spatial information and satellite imagery in the spatial planning process in the city. The aim of the article is to present the sphere of spatial planning, which is a tool of spatial policy of communes. The article shows that GIS is a powerful tool that can be used for the analysis and assessment of spatial changes in the community. The article indicates that there is still a long way to go for local governments with regard to the efficient use of spatial information. The work indicates that the main problem of the Polish local governments is the lack of land-use plans. This article presents ideas of how to use free data and open source software in the decision-making process in communes in the field of spatial planning. The article shows some evidence that spatial data can help in the spatial planning process in cities, especially on their peripheries.

1. Spatial planning in Poland on a local level

The spatial planning system in Poland is divided into three levels: national, regional and local. The most important of these is the local one, where the documents that have an impact on future spatial shape are drawn up. The system of spatial planning acts in communities and

consists of the study of land use conditions and directions, which, being an obligatory document, are drawn up by local authorities in the administrative borders of a community. This document is supposed to create spatial policy in the basic unit of territorial division. Its provisions must be respected by local authorities and institutions subordinate to them. Provisions of the study do not influence the local society directly.

The accomplishment of the local spatial policy regulations included in the study of land use conditions and directions can only be carried out by an enactment of a local land-use plan which has to be unanimous with the study provisions. Local land-use plans are a basis for community land management. According to this document, local authorities may influence the space users and create spatial order according to the sustainable development rule. An important element in the process of creating local land-use plans is social participation. The fact of local actor participation in the process of spatial planning allows for the usage of their knowledge and taking into consideration positions that could be omitted in case of the lack of citizens' participation. A problem in the Polish reality is the fact that these documents are optional which results in the lack of these documents in many crucial areas. This situation is confirmed by the statistical data of Central Statistical Office of Poland, which may lead to the conclusion that in 2013 only 28.6% of the country's area had binding local land-use plans. In the subject literature, it is indicated that one should strive towards full coverage of local plans, however, it is assumed that in reality this will be about 50% of the country's area (Śleszyński, Bański, Degórski, Komornicki, Więckowski, 2007).

On a community level a so structured spatial planning system, forced on the governing body the necessity to introduce an alternative to the local land-use plans. These were building permits and planning permissions. In case of these documents, the law does not provide simple directives, which is the reason for further discussions on the topic, including those concerning the scope and necessity of their accordance with the study of land use conditions and directions. In many scientific articles there are divagations concerning the negative impact of the decisions on the spatial planning area in view of the substitution of local land-use plans with them (Kopeć, 2009; Ziobrowski, 2010). It seems to be similarly significant to limit the role of the local community in the process of issuing building permits (Kopeć, 2009), which is not permissible in case of local land-use plans or the study of land use conditions and directions.

The similarity of the procedures of the study and local planning compilation allows one to indicate that one of the vital elements in these procedures is natural environment. In case of urban areas it should be referred to as the urban greenery, urban forests and agricultural areas which, within the city area, constitute an element of the environmental system (Giecwicz, 2005;

Krzyk, Tokarczuk, Heczko-Hyłowa, Ziobrowski, 2013). These areas are usually located on the peripheries and due to this fact an important task of the local authorities is to impose restrictions on investment in these areas and to monitor progress in order to balance the development of these parts of the city. In the case of urbanized areas the role of local land-use plans is to retain spatial order, particularly in the urban area.

Monitoring the on-going spatial changes plays an important role in spatial planning. At the first stage this allows for the inventory of the area and in subsequent years it ensures the observation of the transformations. More and more common in spatial monitoring is the usage of satellite imagery which has become the basis for spatial planning (Yang, 2002, Al Rawashdeh, Saleh, 2006; Sönmez, Onur, Sari, Maktav, 2007; Schneider, 2012; Horvat, 2013). An important element in land-use monitoring is the analysis connected with green and agricultural areas. Unfortunately, public administration in Poland rarely uses these types of tools in spatial planning. Such analysis is omitted and is not taken into consideration in works carried out by of local governments. However, it has to be emphasized that the ever increasing market demand connected with such satellite imagery would result in decreased costs of their acquisition and should induce local authorities to use this element in planning activities in the peripheries because these areas are exposed to changes in land development due to their attractiveness and possibility of close contact with nature.

2. Methods

For scientific reasons, this article uses comparative analysis which enables the indication of changes in land development of chosen Polish cities. In the case of Łódź, this has been a deliberate choice. However, the other cities have been chosen on the basis of two rankings of Polish cities excluding the capital city of Warszawa. The ranking concerned two features: population and the geodetic area of the cities. These two measures (population and city area) are the primary indicators used in the evaluation of diversification of local government units in the context of the size of the city (Runge, 2012). In case of the geodetic area, it is known that the biggest area of the city needs more outlays on land-use plans and it is much more problematic because of the different groups of local actors participating in the planning processes. The features were ordered on the basis of segregation of the cities ranging from the largest to the smallest facilities. In the next step, a method of perfect segregation was used where the middle rank allowed for the selection of cities to be used in the comparative analysis. The middle rank was determined on the basis of model 1 (Stabryła, 2011).

$$\bar{R}_i = \frac{\sum_{j=1}^n R_{ij}}{n} \quad (1)$$

where:

$\bar{R}_i$ – the average rank of the i city,

R_{ij} – the rank assigned to the i city due to the j criterion of selection, where $i = 1, 2, \dots, m$,
 $j = 1, 2, \dots, n$,

n – the ranking potential (the number of selected criteria).

Further analysis was based on data from the Central Statistical Office of Poland and concerned the coverage by land-use management plans of cities indicated in the first stage. This method allowed for estimating which of the selected cities was characterized by the biggest plan coverage.

A further stage of the research was supposed to show whether the areas surrounding the city of Łódź in 1988 have land-use plans. This analysis was carried out with the use of the open source Quantum GIS software. Thanks to the analysis it was also possible to indicate the peripheries that should be monitored by the local authorities because of the possibility of their transformation. In this part of the work, it has been indicated how to analyse satellite imagery in order to indicate green areas and farmlands that are within the range of the city area. For this reason, free satellite imagery LANDSAT was used, due to which it was possible to superimpose images of different spectral bands and indicate the areas where local society interference was minimal. The research shows the possibilities of the usage of satellite imagery in works connected with spatial planning.

For the compilation of the land-use map a supervised classification was used. In this type of classification, separate land use areas are indicated on the basis of definite image elements. These are the so called training areas, as defined by the user. Apart from the training areas, an important element in this kind of classification is the knowledge of the area. Useful materials in this type of works are: the inventory of the area and the analysis of cartographic materials. The training areas are models for class images created during the analysis. For this reason, each pixel of the image is assigned to a definite class (Churches, Wampler, Sun, Smith, 2014). Combining the supervised classification method with the inventory of the area is of particular importance for the employees of city halls who should know the area of their city and use this knowledge in the decision-making process.

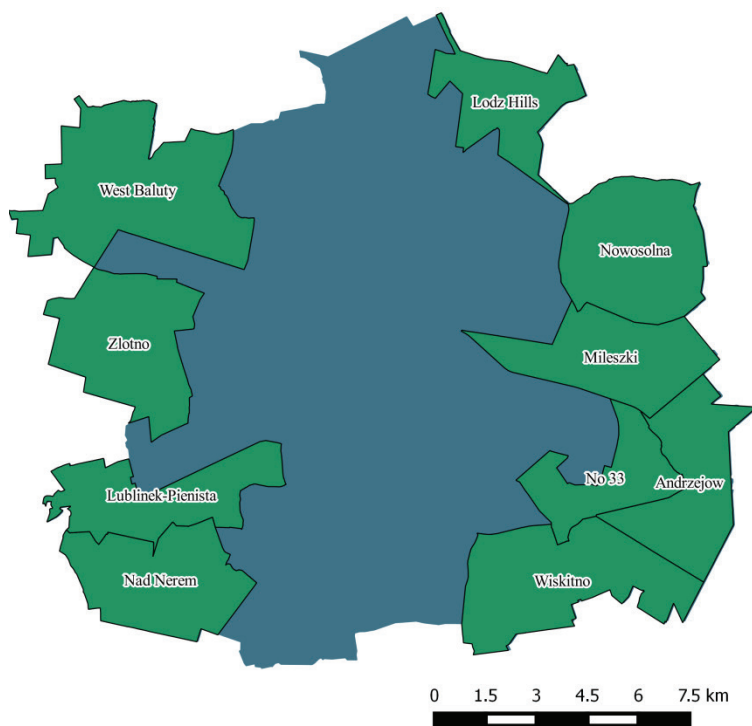


Figure 1. New and enlarged housing estates of the city after changing the city borders in 1988

Source: own work.

All these activities were made possible due to the usage of satellite imagery from Landsat satellite, available for the scientific environment on Global Land Cover Facility websites. Landsat 7 images with the ETM+ sensor were used. On their basis it was possible to carry out the visualization of biologically active surfaces with the use of the images from three bands. The combination of the seventh, fourth and first band gave more explicit effects, as a result it was possible to visualize these areas in Łódź.

In case of changes in the environmental sphere of the city, one class was created. It includes forests, inner city green areas and farmlands. The assessment by the supervised classification allowed for the indication of where in Łódź in 2005 were the areas in question, and how many of them were on the peripheries of the city belonging to Łódź in 1988. With the use of the ILWIS programme it was possible to indicate models for the biologically active surfaces and define their features, which in consequence allowed for the usage of the image classification algorithm.

This article uses a distance measure called Mahalanobis distance. The Mahalanobis distance depends on the distances towards class means and the variance-covariance matrix of

each class. The class name with the shortest Mahalanobis distance is assigned if this distance is smaller than the user-defined threshold value. The threshold value three was used in the case of classifying the biologically active surface of the peripheries of Łódź.

The applied method, both in the case of the research material used and in the scope of the software used, is favourable for the public sector. The officials in charge of spatial planning have the possibility of using free software and satellite imagery, which in the case of large cities does not considerably burden the budget. This methodology requires only the elimination of the knowledge gap concerning the use of software usage for the assessment of the on-going transformations in land development of the city's area, paying particular attention to the peripheries.

3. Results

3.1. Łódź, changes of its borders and care of the peripheries

According to the carried out analysis, apart from Łódź, at the highest positions in the ranking were the cities of: Kraków, Wrocław, Szczecin, Gdańsk and Poznań (Table 1). Accordingly, it was possible to compare the areas of individual cities included in the land-use plans. Among the cities chosen for the analysis only in Łódź under 10% of its area covered by land-use plans. In the case of the other cities the index was more than 40%. The territorial unit with the highest value of the discussed index was Gdańsk, which had 68% of the surface included in the land-use plans (Table 2). The analysis of the index allowed for the assumption that among big cities selected for the comparative analysis, Łódź is the only city with such a small percentage of land-use plans. This pressurises the Łódź authorities towards perspective thinking as for the needs concerning land-use plans compilation. According to the Central Statistical Office of Poland, Łódź authorities plan the coverage of the whole city area with land-use plans that are at variance with data that is made available by Łódź City Hall Urban Office, which shows that currently Łódź is in the process of drawing up plans for about 80% of its area. At the same time, it has to be emphasized that over 43% of the plan projects are developed for longer than 3 years.

Łódź is a territorial unit which has powiat's rights. It is located in the direct neighbourhood of the intersection of the two main Polish motorways: A1 (E75) and A2 (E30). To the North-East of the city there is a part of Łódź Hills Landscape Park, which is also located in the area of other four nearby communities. At the end of 2013, Łódź had local plans for 6.2% of the administrative areas. Territorial development of the city ended in 1988, when 7,890 hectares were attached to it, that is about 27% of its present area (Figure 2). However, as this results

from the spatial analyses, few plans include Łódź areas that were incorporated into its borders in 1988.

Table 1. Ranking of Polish cities taking into account the population and area of the city in 2014

City	Rank of population	Rank of the city area	The average rank
Kraków	1	1	1
Łódź	2	3	2.5
Wrocław	3	4	3.5
Szczecin	6	2	4
Gdańsk	5	5	5
Poznań	4	6	5

Source: own study using data from Central Statistical Office of Poland.

Table 2. Percentage of the area covered by land use plans in cities in the 2013

City	Percent of land use plan
Gdańsk	68.0
Kraków	48.2
Łódź	6.2
Poznań	40.1
Szczecin	46.0
Wrocław	54.6

Source: Central Statistical Office of Poland.

Areas incorporated into Łódź in 1988 are the peripheries of the city which after political transformations in the country were under the pressure of changes throughout the whole period of the transformation. In accordance with the indications, with a few exceptions, these areas do not have local plans which enhances the anthropogenic impact on the areas that are free from building development and remain within the limits of Łódź Hills Landscape Park. In these areas there are only three local plans, which are fully located in the areas incorporated on the peripheries (total plan surface of 53 ha), the other four plans partly include the areas incorporated in 1988, which covers about 230 ha. This shows that in the twenty-year period from the introduction of new land development regulations in Poland, only 283 ha of the areas newly incorporated into Łódź in 1988 were included in the spatial land-use plans. It constitutes only 3.6% of the total area incorporated into the city. Such a policy by the authorities becomes

a threat to the spatial order and sustainable development in the city's peripheral areas and are characterized by good landscape and environmental values.

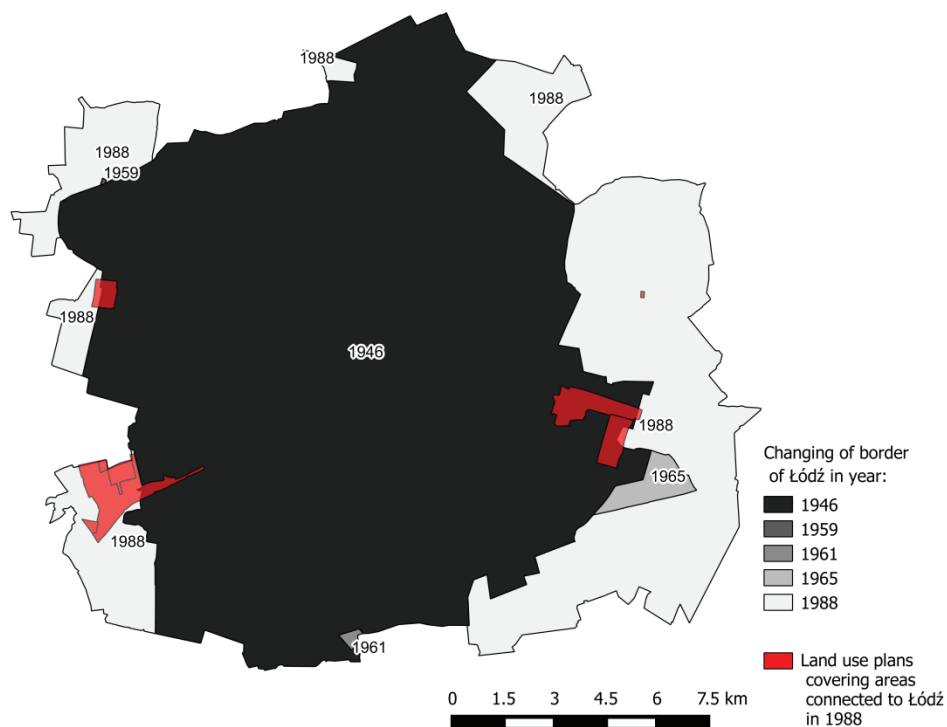


Figure 2. Changing of borders of Łódź since 1946 to present days and land use plans covering areas incorporated into Łódź in 1988

Source: own work based on Stępniewski, Szambelan (2010) and <http://gis.mapa.lodz.pl/MPZP/default.aspx> (access date: 18.04.2015).

Research has shown that in the areas incorporated into Łódź in 1988, there are many areas that are of high environmental value, which is the reason why they should be managed wisely and responsibly (Figure 3). The analysis of the satellite imagery allows for the indication that the area of Nowosolna housing estate in Łódź is the only area that is used more intensively. This results from the fact that this area is well-communicated with the city centre with a simultaneous possession of high environmental values, which are offered by the peripheries. In this area, however, biologically active areas are still an important element of the landscape. This results from the fact that 30 years ago the area of the estate was a village, which still makes

it an area that has some features characteristic for rural areas. Similar conclusions can be drawn with reference to the other areas under the analysis.

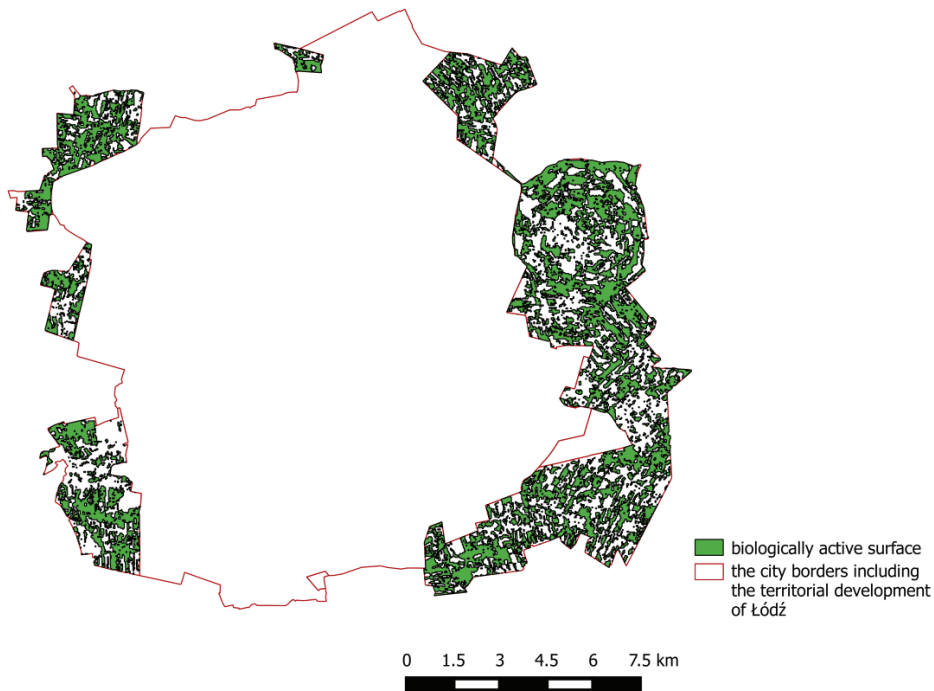


Figure 3. Biologically active area in the parts incorporated into Łódź in 1988

Source: own work.

It should also be emphasised that according to the carried out supervised classification in 2005 biologically active areas incorporated into Łódź in 1988, accounted for about 48%. This index shows that the peripheries of the city consist both of green areas as well as of agricultural productive land, creating a unique landscape within the administrative borders of the city. This also makes it necessary to introduce into the development policy the objectives aiming at proper management of these types of good, in accordance with the principle of sustainable development.

Conclusions

A significant element of the work is the fact that the majority of the biggest Polish cities, including Łódź, do not have the desired, indicated in scientific compilations, coverage of local

land-use plans. Particularly in such a city as Łódź, which since 1946 for over 40 years has been changing its administrative borders, local land-use plans become one of the main instruments of taking care of the landscape, especially in the peripheries. Working out local land-use plans for these areas allows the local authorities to enforce law and allows for the protection of valuable cultural, environmental and landscape elements in the peripheries. What is also crucial is the awareness of the use of these instruments in order to protect such public good as space. In case of spatial transformations, it is important to carry out these kinds of changes in accordance with sustainable development principles and retain spatial order in these areas.

It should be pointed out that urbanization in the outskirts is an expression of social progress. However, this progress cannot be deprived of supervision. The dynamism of the urbanization processes on the peripheries of cities may lead to disorder in urban structures. It is dependent on the phase of the city lifecycle. Initial stages impose on local authorities the responsibility to take care both of sustaining the functions fulfilled by the city centre and restricting the dynamism in the sphere of urbanization in the peripheries of Łódź. In case of the lack of local plans, local authorities should have knowledge concerning changes taking place in the peripheries, the source of which may be high quality satellite imagery. The limited research budget allows only for the use of free satellite material. Local authorities can secure within city's budget the funds for purchasing satellite imagery allowing for monitoring changes happening in the city's space, with particular focus on the areas free from building development.

Satellite imagery is more commonly used material for the purpose of the analysis of changes taking place in space. The proof for this is rich research material available in scientific magazines, which raises the issue of the satellite imagery use for various purposes. Apart from the research quoted in the earlier part of the work, this topic is raised also in the spheres of: spatial planning, farming and sustainable development or agriculture (Wu, Li, Wang, Paulussen, Hec, Wang, Wang, Wang, 2006; Balakeristanan, Md Said, 2012; Torkashvand, Eslami, 2012; Roose, Kull, Gauk, Tali, 2013). This shows an increasingly common use of satellite imagery in the decision-making processes. Significant is the fact that these solutions are promoted by the institutions connected with the European Union, which resulted in the development of CORINE land cover programme. Due to its achievements the European Environment Agency makes available data concerning land development of the European Union countries.

It should be highlighted again that the problem existing in the Polish reality, is the knowledge gap concerning the use of GIS tools and the accompanying elements. that is the satellite imagery. The barrier is not the software because it is possible to find on the market free solutions that may be used in the public sector. Simultaneously, the costs of modern satellite

imagery are affordable for agglomerations such as Łódź. An important element of the land-use policies that are associated with spatial planning is the necessity to use the GIS tools on the day-to-day basis, which will facilitate the decision making process and the analyses connected with spatial planning.

Due to the application of satellite images and spatial information systems, the decisions made by the local authorities, particularly the ones referring to the peripheries where landscape is the least transformed, will allow for taking adequate steps. At the same time, data coming from the images may be used by various departments of City Halls and will be an electronic source. It will also facilitate meeting the recommendations concerning building a Spatial Data Infrastructure (SDI) included in the Directive INSPIRE. It will also allow for the improvement of the quality of services rendered by the local government through the possibility of expansion of e-government services. The availability of data will allow for more effective management and integration in terms of the rendered services (Borzacchiello, Craglia, 2013).

The presented research may be used both by the metropolitan cities as well as by smaller territorial units of NUTS 5 (Nomenclature of Territorial Units for Statistics 5) level. The development of the use of information technology by self-governments will allow for the decrease of costs of these units functioning and the analysis of areas particularly threatened by the anthropogenic impact. It will concern both the peripheries being within the borders of the city as well as the areas that are in their direct neighbourhood (Li, Yeh, 2004).

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