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ANALYSIS OF TEMPORAL CHANGES IN THE SPATIAL DEVELOPMENT OF THE CITY WITH USING GIS TECHNOLOGY

In this article the analysis of spatial development of the Prague city with use GIS technologies is carried out. The dynamics of land use change in the city is discussed. For the analysis the vector land use plans of Prague at four periods of 1986, 1994, 1999 and 2012 were used. Legends of land use plans have contained different classification systems of land use, therefore the unified classification system was created. The land use types were divided in eight categories: residential areas, production areas, recreation areas, traffic areas, other areas, forests, water bodies, agricultural land. The analysis was performed using software package ArcGIS 10.0, using tool «overlay». The land use changes over time were assessed between periods: 1986–1994, 1994–1999, 1999–2012. The relationship between land use changes and changes in population of the city during the considered period is established.

land use changes, overlay analysis, changes in population, areas

PROBLEM STATEMENT

In the modern world as a result of a number natural factors (population growth, high mobility of labour and financial resources), the urbanization and intensive development of city territories is occurs. However, due to the inefficient use of urban land or because of uncontrolled expansion of urban areas it contributes occurrence of negative economic, environmental and social implications for people.

Land is a nonrenewable resource, the amount of which is limited, therefore we must ensure its reasonable using [7]. Because of the intense urbanization, the modern cities face a number of problems such as environmental problems, problems of unhealthy living environment of the population – the noise, air pollution, consolidation of built up area, transport problems, etc. All these aspects indicate that in process of development of city territories should be considered not only the factors of economic benefits, first of all it is necessary to create comfortable living conditions for all levels of population. And this, in turn, is not possible without a detailed analysis of the temporal land use changes in urban areas. This analysis will allow to assess the dynamics of urban development, and also to identify the relationship between changes of different classes of territories in certain time periods. Application of GIS technology for this purposes helps to conduct analytical researches, as well as to carry out a control over the development of city territories.

OVERVIEW OF THE LAST RESEARCHES AND PUBLICATIONS

Researches in the field of the spatial development of the city with using GIS technology today carried out by Prof. H. Delden, A. Hagen, Prof. J. Vliet, Prof. R. Frondoni, Ass. Prof. L. Halounova, K. Szentesiova, Prof. G. Capotorti, Prof. Y. Liu and etc.

Analysis of the above discussed literature has shown that the existing studies do not involve a spatial component of land use changes. First of all it is caused to the fact that basically for the analysis of urban development using remote sensing images, which do not fully describe the changes in the urban areas.

The overall **objective** of this work is to identify the temporal and spatial pattern of land use change and also to establish the relationship of these changes with the change in the population of city.

STUDY AREA

The study area is the capital of the Czech Republic – Prague. It is the fourteenth largest city in the European Union. Situated in the north-west of the country on the Vltava river, in the Central Bohemian Region. Prague

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is also the largest city in the Czech Republic. It covers an area of 496 km², which is only 0,6 % of the country territory, but with the population of 1 246 780 inhabitants as at 31 December 2012 [4] it represents 11,9 % of the total population of the state. Prague then markedly dominates the population structure in the Czech Republic as its second largest city, Brno, makes one third of the Praguees population. At the beginning of the 20th century the territory of Prague consisted of only 8 parts with the area of approximately 2000 hectares which is about 4 % of its present area. The Act of 6 February 1920 established the Great Prague when other 39 nearby municipalities joined to the existing eight Prague neighbourhoods. Further territorial growth took place in 1960 (attachment of three municipalities and two cadastral areas), in 1968 (attachment of 21 municipalities of the former Central Bohemian Region, in 1970 (modification of the territorial borders of Prague, particularly in relation to the surroundings of the Prague-Ruzyne airport) and finally in 1974 when other 30 municipalities of the former Central Bohemian Region were attached to Prague. From 2001 Prague is divided to 22 administrative districts, from the point of view of self-government it consists of 57 autonomous city sections [4].

MATERIALS AND METHODS

The analysis was performed with using software ArcGIS 10.0 and was based on four vector land use maps for the years: 1986, 1994, 1999 and 2012 (fig. 1). These maps were provided by the City development Authority Prague [5] in vector form, at scale 1:10 000. These vector maps represent a database in which stores information about polygons, that are the closed sequence of lines. Each of the polygons represents a certain class of land use and contains attributes characterizing its property, color, type, name, etc. The data about population of the Czech Republic for different periods were taken on web page of the Czech Statistical Office [4].

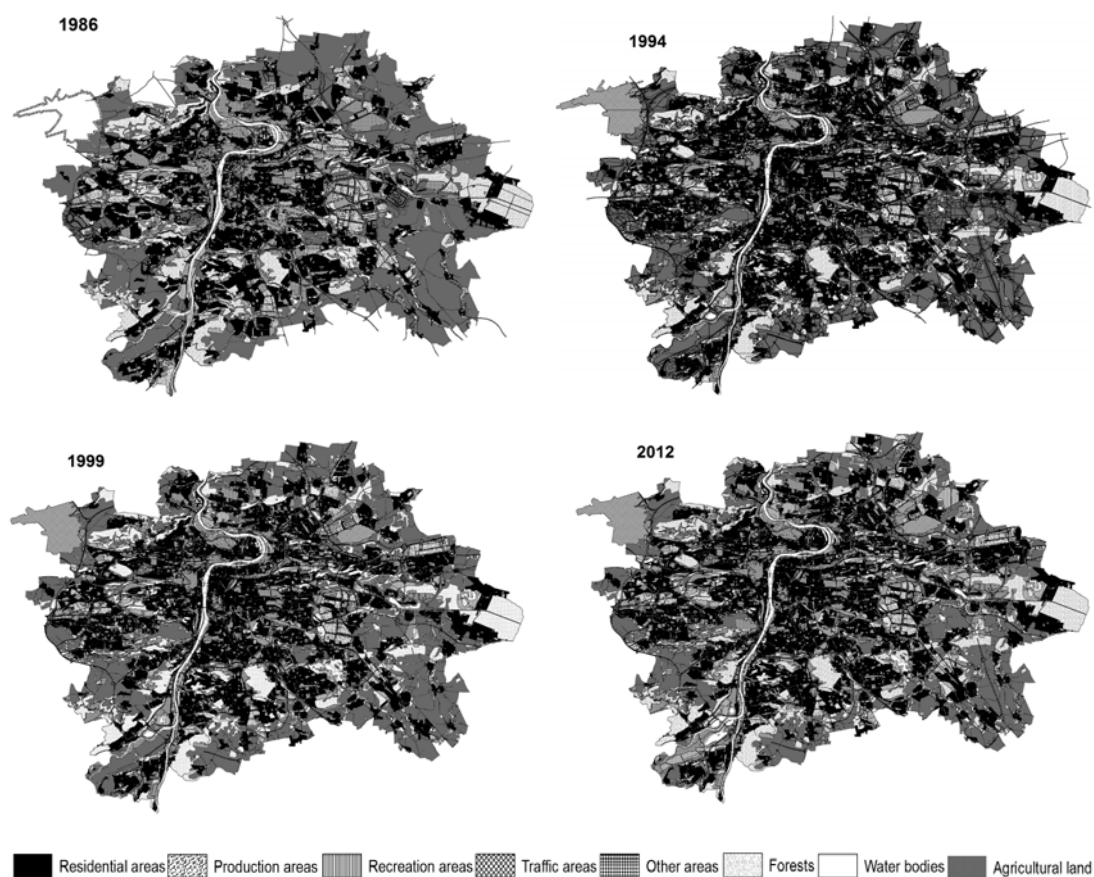


Figure 1 – The land use plans of the city of Prague.

Because of different classification level of land use plans at four periods, the unified legend of land classification was created, which contains the following eight categories of land use: residential areas, production areas, recreation areas, traffic areas, other areas, forests, water bodies, agricultural land.

Analysis of land use change was performed with using tool «overlay» in ArcGIS software. Overlay analysis are one of the most powerful and widespread analytical methods used in the GIS environment. These operations are based on the overlay of two or more dissimilar cartographical layers and the creation of derived objects arising at their geometrical overlay. In particular the overlay analysis allows to identify the major «sources» and «destinations» of appearing and disappearing land [2]. ArcGIS offers several Overlay tools at working with polygons. In this paper the «union» tool is used, which Computes a geometric intersection of the input features. All features will be written to the output feature class with the attributes from the input features, which it overlaps [1].

Overlay analysis of land use plans are carried out consistent between periods: 1986–1994; 1994–1999; 1999–2012.

CHANGES IN POPULATION OF PRAGUE SINCE 1986

Because the population changes is a main driving force of land use changes, it is necessary to estimate the population development in the city during the considered period.

At present, in the city live 1 246 780 people [4]. Prague as a single city with a million population in the Czech Republic represents the largest concentration of urban population (2 444 people per km²). Population changes in the city from 1986 to 2012 are shown in figure 2.

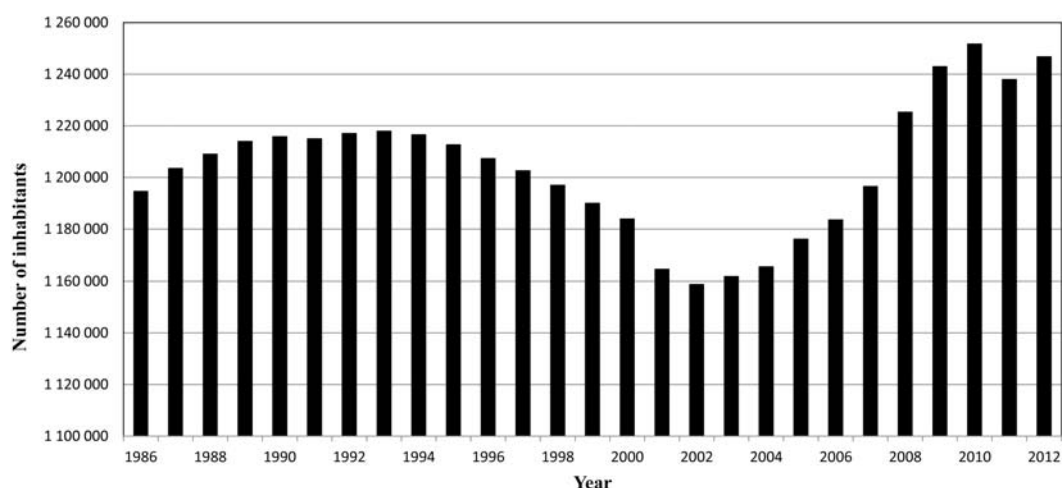


Figure 2 – Development of the Prague's population from 1986 to 2012.

The main trend in the development of Prague population (fig. 2) until 1993 is the uniform growth, which is associated with the beginning in 1968 accession to the city of Central Bohemia Region territories. However, from 1993 to 2002 appears decreasing trend. According to the 2001 Population and Housing Census, the number of inhabitants was even lower than in 1980, it is 1 164 682 people [4]. In this period the population in absolute expression was decreasing. It was due to the fact that in Prague wasn't already building large residential areas. The number of emigrants from Prague exceeded the number of immigrants, that related to suburbanization tendencies in Prague and its surroundings. Only in 2002 the population started to increase again, mainly due to a positive migration balance of people from abroad [5].

DEVELOPMENT OF PRAGUE CITY TERRITORY

The distribution of land use areas from 1986 to 2012 in Prague are illustrated in figure 3.

Significant changes seen in the increase of residential areas with the primary 11 468 ha in 1986 to 13 660 ha in 2012, that makes increase on 2192 ha. Development of residential areas corresponds to an increase of the city population (fig. 2) during the periods 1986–1994 and 1999–2012.

The insignificant changes in the land use classes from 1994 to 1999 are caused by decrease of the city population, due to the development of Central Bohemia Region in this period and construction of satellite residential units in Prague's surroundings [6].

The development of recreation areas is also appreciable, that is directly related to an increase of residential areas. But there is a significant reduction of agricultural land on the general background of the land use development. Carrying out of overlay analysis in ArcGIS will allow to establish the relationship between the changes in the various classes of land use.

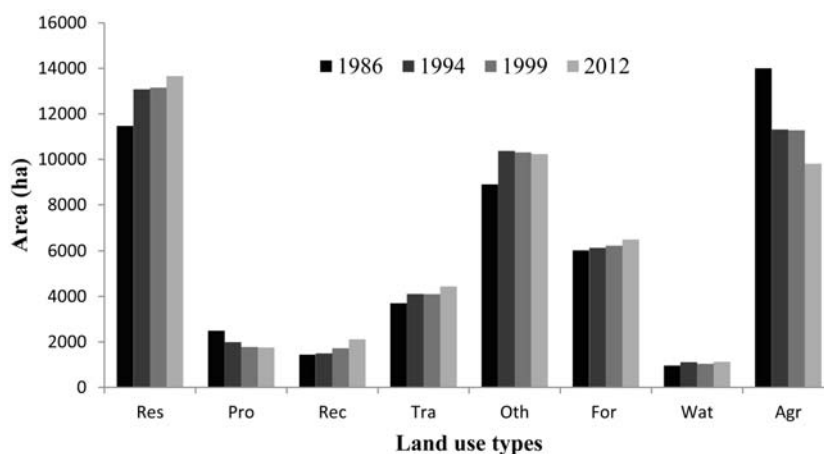


Figure 3 – Area distribution of land use in Prague: Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.

OVERLAY ANALYSIS

At the analysis of land use changes it is important to establish the structure of functional areas replacement, another words, to analyze the total area of certain land uses that appeared or disappeared [3]. Overlay analysis has been carried out to define at the expense of which land there was a development of certain land use classes. The results of overlay analysis are shown in tables 1, 2, 3.

Table 1 – Changes in land use for the period of 1986–1994 (ha)

Areas	Res	Pro	Rec	Tra	Oth	For	Wat	Agr	1994
Res	10 033	130	101	351	966	106	4	603	12 296
Pro	28	2 043	58	138	144	9	0	57	2 477
Rec	10	9	623	12	168	227	9	91	1 150
Tra	145	59	35	2 777	278	55	4	124	3 477
Oth	1 092	223	534	314	6 236	374	52	667	9 490
For	72	13	21	65	470	4 960	8	194	5 802
Wat	13	6	13	14	153	22	850	32	1 103
Agr	75	12	60	31	484	272	34	12 241	13 207
1986	11 468	2 495	1 445	3 701	8 899	6 025	961	14 009	

Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.

In these tables columns show the sum of land use areas for older year, and row show the sum of areas for the modern year. On a diagonal specified value of the areas which have remained without changes during research period. Because the historical structure of city center doesn't allow the further development of the functional areas, the main land use changes occurred in the outer zone of the city. The greatest changes occurred in the periods of growth of Prague population. The analysis allows to allocate two periods of the city territory development.

The first period from 1986 to 1994, 10 % (4 413 ha) of the entire study area underwent a land use change. The outer zone, lying between the border of compact city and the border of Prague, in this period represented land with a high share of undeveloped areas of natural or agricultural character. These land have offered the areas for building, that enabled the development of formerly independent settlements. Each of the 57 newly created city districts wanted to realize their ambitions for population growth. The gradual development of these formerly small settlements have begun. As a result, residential areas have increased by 1 612 ha, at the expense of agricultural land.

Table 2 – Changes in land use for the period of 1994–1999 (ha)

Areas	Res	Pro	Rec	Tra	Oth	For	Wat	Agr	1999
Res	12 132	167	11	117	519	31	8	64	13 050
Pro	19	1 548	0	72	134	3	0	4	1 780
Rec	28	18	1 223	5	364	28	3	55	1 725
Tra	283	43	11	3 648	182	25	10	18	4 219
Oth	432	197	93	213	8 592	205	107	444	10 283
For	40	6	100	22	216	5 699	23	134	6 241
Wat	6	2	12	4	51	14	948	32	1 069
Agr	140	12	45	26	316	135	12	10 559	11 244
1994	1 3080	1 993	1 495	4 109	10 374	6 139	1 112	11 311	

Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.

Table 3 – Changes in land use for the period of 1999–2012 (ha)

	Res	Pro	Rec	Tra	Oth	For	Wat	Agr	2012
Res	12 959	80	29	49	250	11	1	281	13 660
Pro	25	1 638	0	22	31	2	1	43	1 761
Rec	13	4	1 618	1	80	6	16	375	2 114
Tra	76	18	9	3 932	268	18	3	116	4 439
Oth	69	39	32	83	9 536	49	16	409	10 234
For	1	4	5	7	59	6 142	1	258	6 477
Wat	0	0	22	1	21	2	997	82	1 126
Agr	9	0	7	9	62	4	1	9 711	9 804
1999	13 152	1 782	1 722	4 104	10 308	6 234	1 036	11 276	

Note: Res=Residential areas, Pro=Production areas, Rec=Recreation areas, Tra=Traffic areas, Oth=Other areas, For=Forests, Wat=Water bodies, Agr=Agricultural land.

The reconfigurable areas had a high potential during this period, especially formerly industrial areas and unused areas of railway station. It were areas which in connection with new economic conditions disappeared or became ineffective. That caused the reduction of production areas by 502 ha. For example, transformation of production areas of Tatra Smichov plant, where a new city district appeared [6].

Increase of other areas by 1 475 ha occurred due to the construction of commercial spaces, public facilities for social services, public health facilities, etc.

The second period from 1999 to 2012, 4 % of the entire city territory underwent a changes in land use, and it is 1 568 ha. As can be seen from table 4, the greatest change occurred in the agricultural lands (reduction by 1 472 ha). The development of residential areas, recreation areas, other areas and forest has occurred at the expense of agricultural lands.

From 2002 the city population has started to increase (fig. 2). Residential areas have increased by 508 ha. New residential locations have often implemented at the edges of compact urban core and different settlements on the developing areas, in the spans between existing buildings or transformation of suburban settlements.

The development of recreation areas (increase by 394 ha) was due by commercially based initiatives, such as golf courses or other sports facilities, as well as areas for recreation, parks, bicycle paths, which implemented by public funds.

CONCLUSIONS

The analysis carried out in this work is allowed to reveal the dynamics of temporary land use changes in Prague. Two main periods of urban development are allocated: 1986–1994 and 1999–2012. During these periods the population growth of the city is observed, that was one of the causes of residential areas and other areas development. From 1994 to 1999 there was a period of suburbanization and decrease of city population. It was the reason of minor changes in land use. Only 0,6 % of the city territory (394 ha) have undergone a land use changes. Carrying out of overlay analysis has allowed to reveal the tendency of changes in land use. As a result of ongoing development of urban areas, there is a reduction of agricultural lands, which located in the outer zone or near the city borders.

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АНАЛИЗ ВРЕМЕННЫХ ИЗМЕНЕНИЙ ПРОСТРАНСТВЕННОГО РАЗВИТИЯ ГОРОДА С ИСПОЛЬЗОВАНИЕМ ГИС

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В данной статье проведен анализ пространственного развития города Праги с использованием ГИС технологий. В частности выполнен анализ динамики изменений в землепользовании города. Для анализа использовались векторные земельные планы города Праги за четыре периода: 1986, 1994, 1999 и 2012 годов. Легенды используемых земельных планов содержали разные системы классификации использования земель, поэтому была создана единая система классификации. Типы использования земель были разделены на 8 классов: жилые площади, производственные площади, рекреационные площади, площади транспорта, другие площади, леса, вода, сельскохозяйственные земли. Анализ был выполнен с помощью программного комплекса ArcGIS 10.0 с использованием инструмента «overlay». Были оценены временные изменения в периоды: 1986–1994, 1994–1999, 1999–2012. Также была установлена связь между изменениями в землепользовании и изменениями количества населения города в рассматриваемые периоды.

изменения в землепользовании, операция наложения, изменения количества населения, площади

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АНАЛІЗ ЧАСОВИХ ЗМІН В ПРОСТОРОВОМУ РОЗВИТКУ МІСТА З ВИКОРИСТАННЯМ ГІС

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У поданій статті проведено аналіз просторового розвитку міста Праги з використанням ГІС технологій. Зокрема виконано аналіз динаміки змін у землекористуванні міста. Для аналізу використовувалися векторні земельні плани міста Праги за чотири періоди: 1986, 1994, 1999 та 2012 років. Легенди використовуваних земельних планів містили різні системи класифікації використання земель, тому була створена єдина система класифікації. Типи використання землі були розділені на 8 класів: житлові площі, виробничі площі, площі відпочинку, площі транспорту, інші площі, ліси, вода, сільськогосподарські землі. Аналіз був виконаний за допомогою програмного комплексу ArcGIS 10.0 з використанням інструменту «overlay». Були оцінені часові зміни в періоди: 1986–1994, 1994–1999, 1999–2012. Також був встановлений зв'язок між змінами в землекористуванні та змінами кількості населення міста в розглянуті періоди.

зміни у землекористуванні, операція накладення, зміни чисельності населення, площі