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Section: Sustainable Urban Development

## Urban land use changes forecasting

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### Abstract

The development of urban areas largely affects the land situated along the border between urban and rural areas, causing various forms of land use to penetrate and overlap each other. Called a “transitional” zone between the town and country due to its specificity and character, the area is characterised by a high variability of function in time and changes in the forms and ways of use of particular pieces of land. These are so-called city adjoining areas, with loosely built-up areas, horticultural and pomicultural farms, incomplete communal development, scattered industrial and storage facilities, greenery and leisure facilities. The area is treated as a temporary (transitional) form of land use, which precedes the phase of more intensive development. An object of research was the area of the fringe area of the city and the village and parameters characterizing it, definite on the ground analyses of current forms of the land use with the utilization of foundations of the fuzzy sets theory. The article aim is analyzing of changes in land use on the fringe areas of the Olsztyn city. Changes has been analyzed that have occurred since 1999, in the southern part of the city. The study also contain forecast of transformations that may occur in the future, in the study area. On the basis of changes, the scenario of land use in the near future was created. The evaluation of a degree to which a piece of land belongs to a city and a possibility of designing the width of transition zones enables the planning of the development of the transition zone between urban areas and landscape protected areas (e.g. forests, lakes). Such a plan seems necessary both because it makes it possible to determine the optimum way of land use and also to adapt it to the natural conditions. Detailed analysis of the forms of land use and its use enables the shaping of an urban landscape with the developed models.

**Keywords:** development of urban areas; fringe areas of the city and the village; degree of membership.

### 1. Introduction

Rational space use consistent with the needs of the society obtained by transformation of the existing situation into the desired one is the main objective of spatial management. In this context the system is noticed in which the society is the subject, the space is the object and satisfying the basic human needs is the target. Spatial development for which assuring spatial order while maintaining the elements present within the space and appropriate relations between them should be the goal represents the outcome of the system understood in that way.

Spatial development may also be interpreted as widely understood spatial analysis because space, first of all, in its diversified states: mathematical, physical, environmental, economic, and mainly planning space is the subject of its interest [1]. Hence, spatial development covers mainly the studies on the past, current and future statuses of space use, particularly the planning space, while the space use status is the representation of the socioeconomic development level currently accomplished by the society occupying the analysed space [1]. Development requires certain changes in the space surrounding us, which is reflected in the spatial analyses conducted. With the passage of time new and larger areas are subject to transformation processes to satisfy the needs of residents, which is visible particularly well in the areas influenced directly by the urbanisation pressure. Change in the form of development (use form) has significant influence on the methods of delimitation of landscape units, particularly in the urban and rural landscape style. The border formed is characterised by large diversity of shape, extent and pace of changes.

### 2. Transition zone between the urban and rural area

Transformations in land use accompanying development of towns generate formation of the so-called transition which, because of the complicated and unspecified land use cannot be allocated clearly either to town or to rural area at the border of urban and rural use. To avoid incidental form of the planning and development process, it should be carried out in

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planned way with observation of the spatial order principles creating the harmonious whole taking into account all the functional, socioeconomic, environmental, cultural as well as compositional and aesthetic conditions and requirements.

Socioeconomic development is influenced, among others, by migrations of population from rural to urban areas and the resulting spatial development of the urban area at the expense of the rural areas, construction of industrial and service enterprises as well as the infrastructure. Exclusion of land from use typical for rural areas is a consequence of that process. Quantitative, qualitative and structural transformations in land use taking place within the specified time and space represent a manifestation and measure of town development. That development is governed by the processes of spatial diffusion progressing from the town centre towards the peripheral zones. Those processes are linked to human activities in a given area within a specified time. As concerns spatial development, they are represented by replacement of less intensive land use forms by more intensive forms [2–3]. Development of urban areas has significant influence on the areas situated at the contact point between the urban and the rural land use causing penetration and overlapping of the different space use forms within the peripheral zone. The development takes place at the expense of the food producing zone because urban infrastructure ‘cuts off’ certain areas from typical rural use and includes them into a specific spatial structure. That area, because of its specific characteristic is referred to as the transition zone between the town and the rural area and it is characterised by high rate of changes in function over time as well as changes in the forms and methods of use of the individual fragments of the area [4].

As a result of different phenomena taking place within the area of urban and rural influence, the specific character of the transition zone between the town and the rural area develops and that area can also be defined as the area positioned at the border of the urban and the rural use of space that, because of the diversified (unclear, unspecified) way of use cannot be allocated clearly either to urban or to rural area [5].

The forms of land use can be defined as sets of certain properties (features), which create the multidimensional character of the planning space. The fuzzy nature of the planning space makes it possible to assign a certain fuzzy measure to each event or state of the space, which will determine the degree of its belonging to a category which is of interest to us, which, when the fuzzy sets theory is applied, can help determine the degrees of belonging of particular types of land use to the corresponding functions in the interval [1]. Spatial analyses require that the existing forms of land use be identified and located, especially those situated on the border between urban and rural areas. For practical reasons, it is the easiest to define and determine the spatial range of the urban use of land since the forms of land development, in this case, are more distinct. According to the fuzzy sets theory, a rural area is a complement of the vanishing urban area, as its opposite.

In order to determine whether an analysed area belongs to an urban or rural area, fuzzy logic can be used determine the degree of belonging of the area to urban or rural type of land use. If the fuzzy measure of land for the urban type of use amounts to 0.9, it is equal to 0.1 for the rural type of use, which means that the area is clearly more urban than rural and can be designated as part of a city. The area whose degrees of rural and urban belonging are close and which cannot be assigned to either of the functions is proposed to be called a “transition” zone. The zone is created in the intersection of fuzzy measures for rural and urban types of land use, as presented in the following diagram:

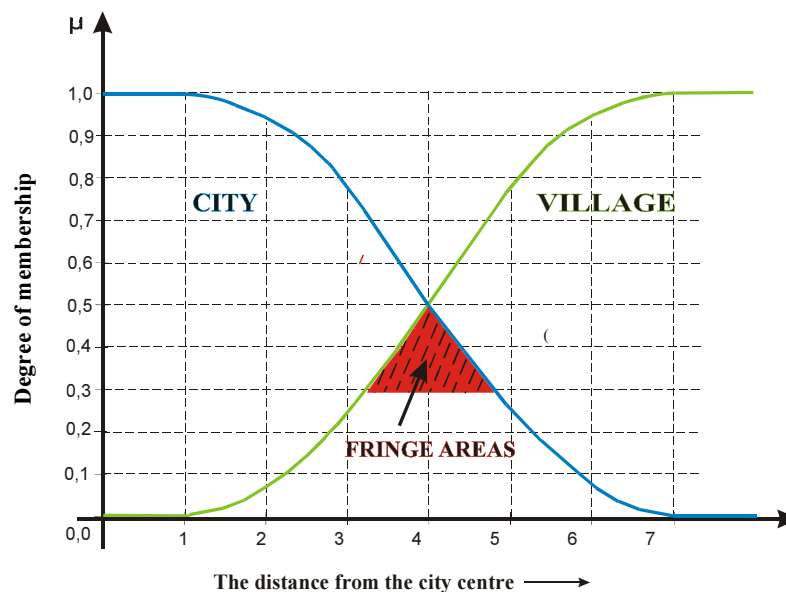


Fig. 1. A graph of the membership function for urban or rural use and rescaled fringe areas. Source: [6]

By shaping the spatial structure of a city, particular forms of space use are identified with it to various extents. The perception of an urban with the use of the fuzzy sets theory enables the determination of fuzzy measures for particular forms of land use, which determine the degree of belonging of a given study field to the urban type of use.

After analysing the relevant legal regulations and the literature on the subject, 18 forms of land use have been adopted in the studies into the identification and location of a transition zone between rural and urban areas. For each of the 18 forms of land use, a fuzzy measure, i.e. the degree of belonging to the urban type of land use, was determined with the use of questionnaires. Degrees of belonging to the urban type of land use for the 18 forms of land use are presented in Table 1:

Table 1. Degrees of membership for the urban way of land use – results from inquiries. Source: [6]

Forms of the planning land use	Rescaled values of degrees of appurtenant for the urban way of land use
1. Areas of the residential. single-family	0.69
2. Areas of the residential. multi-family	1.00
3. Areas of the service- building	0.92
4. Areas of the sport and the recreation	0.66
5. Areas of productive facilities . depots and stores	0.97
6. Areas of farm building	0.16
7. Special areas – the army. the police	0.76
8. Areas of the transport. the technical infrastructure	0.82
9. Areas of water buildings	0.51
10. Facilities under of the realization	0.64
11. Areas of the appointed green	0.68
12. Areas of the natural green	0.35
13. Areas of allotments	0.45
14. Areas of pomiculture and horticultural tillages	0.30
15. Cemeteries	0.51
16. Forests	0.20
17. Agricultural areas	0.13
18. Areas of inland surface waters	0.20

Determining the levels to which individual fragments of space belong to urban or rural use it is possible to determine the borders of urban and rural development (as complement  $\mu = 1$  to urban use) as well as the spatial scope of and level of belonging to the transition zone.

### 3. Urban land use changes

Spatial development of towns causes continual spreading of that zone over areas outside towns. The direction and dynamics of that development depend mainly on the number and significance of natural, demographic, economic, social and organisational barriers present. In the areas under direct pressure of urbanisation, mixing takes place of typical urban areas with the areas that are residues of the old rural forms and devastated areas that are in the process of change of use. Agricultural functions are substituted mainly by housing, industry, communication and transport functions as well as areas for rest and recreation. Transition zoned develop and are positioned in different ways in the surroundings of different towns. This results mainly from the specific characteristics of topography in the surroundings of different towns as well as the characteristics and dynamics of their development. The borders formed are lines or zones separating neighbouring areas differing in at least one characteristic. The vast majority of spatial borders do not have the form of sharp lines but they assume the form of wider or narrower transition zones within which the characteristics of the separated zones are transformed [8]. According to Widacki [9], the borders can be divided according to the level of complexity into simple and complex ones. Among complex borders, connecting borders with characteristics of both neighbouring units, separating borders, i.e. different from both units that are similar to each other as well as diversifying borders separating two different units may be identified.

Maintaining proportions of elements within the space system, e.g. the town – rural area system, refers to maintaining the interdependence between components of the structure. Sometimes the town spreads across the neighbouring or even peripheral areas. Domański [10] identifies many causes for the phenomenon of urbanisation of the areas in the closest vicinity of towns that can include, among others, prices of land more attractive for the investors or less stringent planning requirements.

The studies conducted aimed at the analysis of changes in the forms of land use in peripheral areas of the city of Olsztyn, presentation of the projection of changes that will occur in the nearest future as well as identification and location of the ecotone as the transition zone between urban and rural areas.

The influence of the town reaches deep into the rural areas forming a characteristic area of such influences that is called the suburban zone. With the increase in the distance from the town a decrease of “urban character” and increase of the “rural character” of the suburban zone can be noticed. The study encompassed the southern part of the city of Olsztyn and the areas neighbouring its southern border. The Study of Conditions and Directions of Spatial Development of Olsztyn of 2009 qualifies the studied areas as the residential zone.

The studies aimed at conducting the analysis of changes in the form of land use in the peripheral areas of the town and presentation of a forecast of changes that will take place in the nearest future. The studies were based on topographic maps of 1999 and 2012 as well as data obtained from site examination. The area encompassed by the study was divided into 247 squares with side length of 250 m each meaning that the area of each square was 6.25 ha while the entire area was 1543.75 ha. Using the method of identification and location of the transition zone [5–7] individual squares were classified as belonging to the individual forms of land use determining their urban, rural or transitional character in 1999 and in 2012. Fragments of 1999 and 2012 maps showing the analysed land use forms are presented in Figure 2.

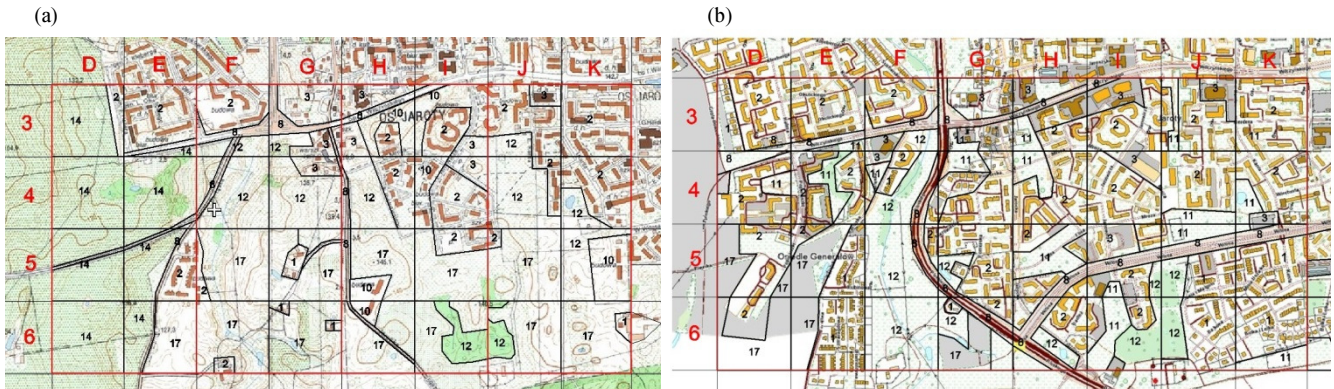


Fig. 2. Analysis of land use form in 1999 (a) and 2012 (b). Source: own elaboration

By determining the percentage of individual land use forms in the individual squares analysed the classification of fields allocating them to the groups of urban use, rural use and transitional use. The results of analyses representing the classification of allocations of the individual squares to the urban or rural use in 1999 and 2012 are presented in Table 2.

Table 2. Comparison of urban and rural forms of land use in 1999–2012

column > line	1999		2012		M2012 - M1999	1999		2012		M2012 - M1999	1999		2012		M2012 - M1999	1999		2012		M2012 - M1999	
	D		D			F		F			H		H			J		J			
	type	use	M	W		M	W	M	W		M	W	M	W		M	W	M	W		M
3		0.42	0.58	0.91	0.09	0.49	0.83	0.17	0.87	0.13	0.04	0.83	0.17	0.89	0.11	0.06	0.82	0.18	0.95	0.05	0.13
4		0.30	0.70	0.92	0.08	0.62	0.20	0.80	0.58	0.42	0.38	0.50	0.50	0.93	0.07	0.43	0.29	0.71	0.94	0.06	0.66
5		0.32	0.68	0.70	0.30	0.38	0.18	0.82	0.47	0.53	0.29	0.28	0.72	0.85	0.15	0.57	0.16	0.84	0.65	0.35	0.49
6		0.30	0.70	0.41	0.59	0.11	0.16	0.84	0.35	0.65	0.19	0.19	0.81	0.74	0.26	0.55	0.17	0.83	0.61	0.40	0.44
column > line	E		E		M2012-M1999	G		G		M2012-M1999	I		I		M2012-M1999	K		K		M2012-M1999	
	E		E			G		G			I		I			K		K			
	type	use	M	W		M	W	M	W		M	W	M	W		M	W	M	W		M
3		0.93	0.07	0.99	0.01	0.06	0.79	0.21	0.87	0.13	0.08	0.81	0.19	0.97	0.03	0.16	0.95	0.05	0.95	0.05	0.00
4		0.30	0.70	0.94	0.06	0.64	0.36	0.64	0.88	0.12	0.52	0.91	0.09	0.98	0.02	0.07	0.85	0.15	0.93	0.07	0.08
5		0.45	0.54	0.45	0.55	0.00	0.19	0.81	0.92	0.08	0.73	0.34	0.66	0.88	0.12	0.54	0.49	0.51	0.71	0.29	0.22
6		0.19	0.81	0.51	0.49	0.32	0.17	0.83	0.45	0.55	0.28	0.20	0.80	0.65	0.35	0.45	0.19	0.81	0.69	0.31	0.50

M – urban type use. W – rural type use.   – transition zone between the town and the rural area  
M2012-M1999 – increase in belonging to the urban function during the years 1999–2012

The landscape in the southern peripheries of the city of Olsztyn changed significantly during the last several years. The increase in area of the land representing the urban type use means progressing urbanisation of the given area. That process manifests first of all by development of land with open forms characteristic for urban use. This influences at the same time a significant increase in the value of the given space. Development characteristic for urban areas, rural areas and the transition zone in 1999 and 2012 is presented in Figure 3.



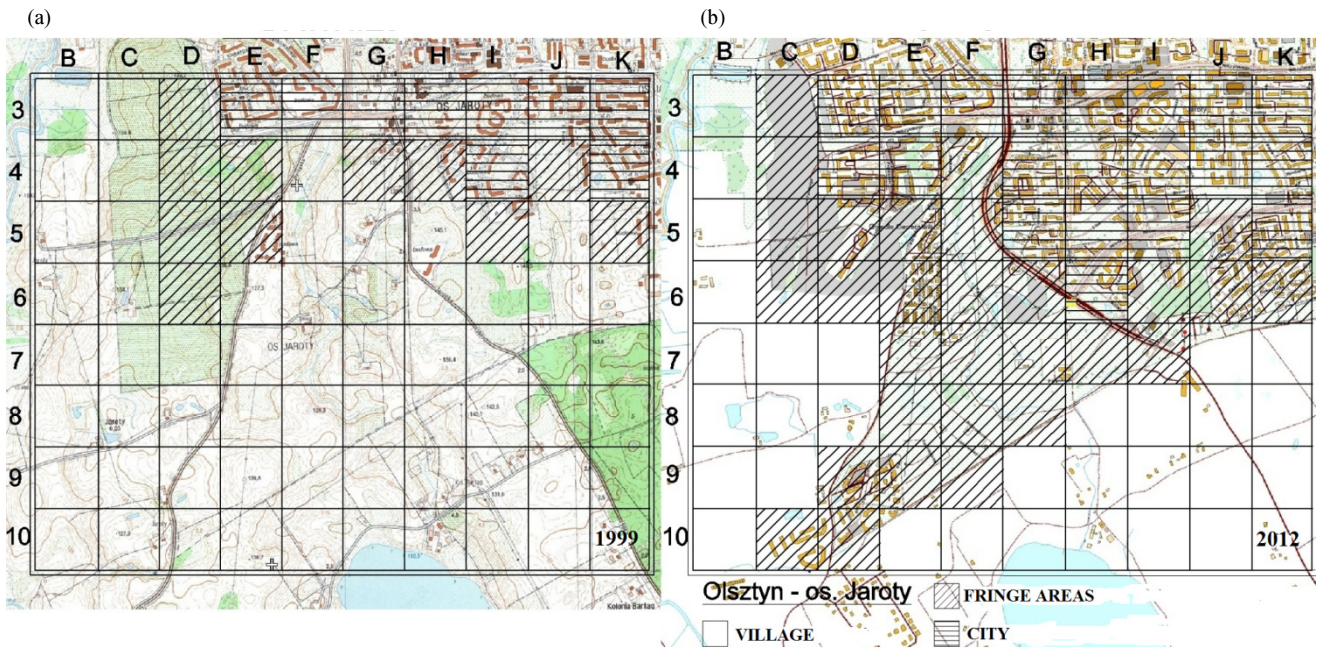


Fig. 3. Development characteristic for urban areas, rural areas and the transition zone in 1999 (a) and 2012 (b). Source: own elaboration

Changes that occurred during the recent years result from the continual pressure of urbanisation on suburban areas. During 14 years, typical urban development increased by 14% and the use characteristic for the transition zone increased by over 22%. At the same the rural use decreased by 36%.

#### 4. Urban land use changes forecasting

Changes in space related to land use that took place during the recent years provide the base for elaboration of the forecast of urban space development during the nearest decade. Assuming a similar pace of changes in the development of the suburban space and the average percentage dynamics of changes, the forecast of changes in the land use in the analysed space can be developed. The probable distribution of the individual forms of development is presented in Figure 4.

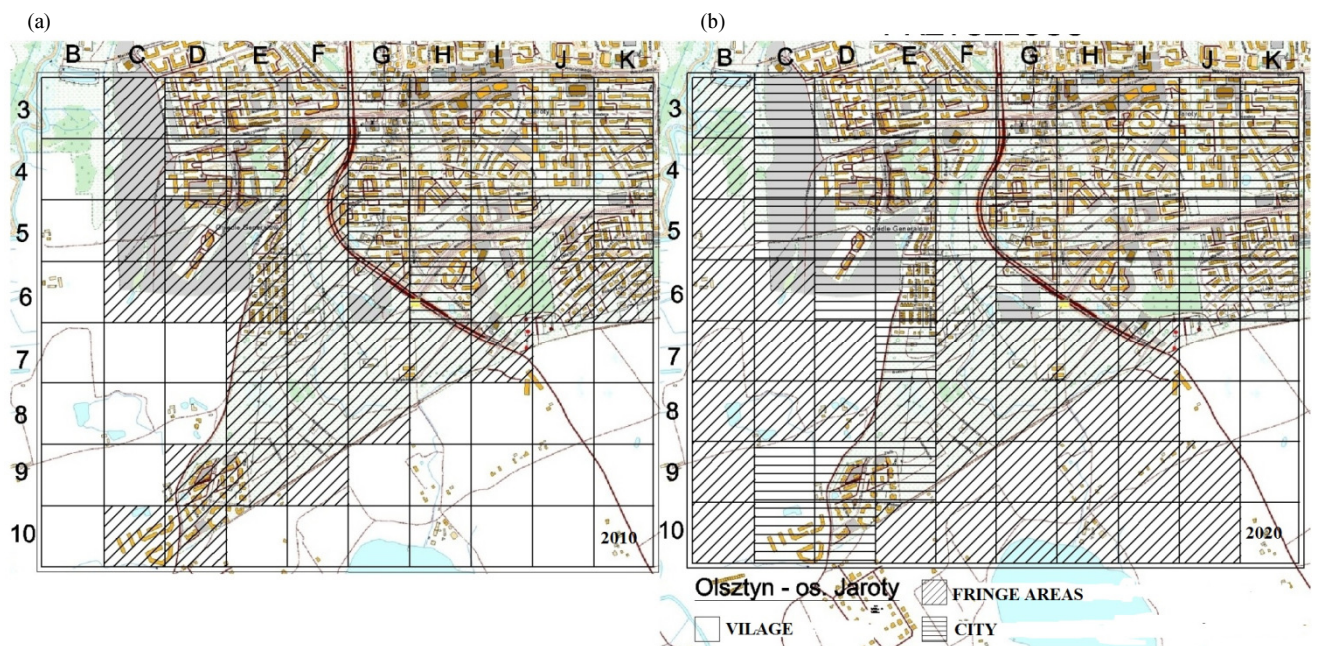


Fig. 4. Forecast of changes in the land use form: (a) – 2010, (b) – 2020. Source: own elaboration

During the nearest 10 years, the land use in the transition zone will change significantly. The forecast based on the analysis of planning documents, location of possible barriers and the pace of the investment process permits estimating the magnitude of changes in space. Development of the town will cause 38% increase of the development typical for urban

areas. The use characteristic for transition zones will develop on the area covering almost 58% of the analysed land while less than 4% of the land will remain under rural use. Those numbers, however, should be subject to certain adjustments because in some fields the entire change of use will not occur as a consequence of the natural barriers present within them such as forests or surface waters. Nevertheless, this does not change the conclusions from the analysis of that fragment of land. Urban areas will absorb a part of areas currently belonging to the transition zone while a relatively large part of south-eastern peripheral areas will transform from the rural form of use into the transition zone of the city of Olsztyn.

## 5. Conclusion

Continual changes of land use in the transition zone dependent on the current and future functions of use determine the spatial development directions of the town. The studies indicate that areas with parameters characteristic for transition zone develop around urbanised areas as well as within them, if areas with low values of the level of belonging to the town occur there. Its shape, spatial extent and the values of the levels of belonging of study fields depend first of all on the space use forms present. Evaluation of the level of belonging to the town and the possibility of designing the width of transition areas permits planned development of the transition border between the town and the landscape-protected zones (e.g. forest, lake). Elaboration of such a design seems necessary because of the possibility of determining the optimal use of land as well as adjustment to the natural conditions. Designing the borders of urban development the spatial scope of the transition zone should also be determined to make it as blunt as possible by locating there the forms of land use that represent low burden on the environment representing low level of belonging to town such as e.g. recreational areas, green areas or detached housing. Gradual change of the forms of space use between the intensive urban forms and protective areas in transition zones should mitigate the negative influence of the town on protective areas and assure stability, durability and ability of rapid recovery of the natural system. The skill of planning (projecting) the future states of space requires obtaining knowledge on the current forms of use in the transition areas, development possibilities, needs of residents and the limitations present. Analysis of the level of belonging of the forms of use in Olsztyn and surroundings, the scope of influence of the urban and rural use as well as the area characteristic for the transition zone showed in which direction and at what pace the town will develop.

## References

- [1] Bajerowski, T. 2003. *Podstawy teoretyczne gospodarki przestrzennej i zarządzania przestrzenią*. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn.
- [2] Bajerowski, T.; Bal, A.; Biłozor, A. 2002. *Propozycja zastosowania logiki rozmytej w rozwiązywaniu problemów decyzyjnych z zakresu gospodarki przestrzennej*. Możliwości i ograniczenia zastosowań metod badawczych w geografii społeczno – ekonomicznej i gospodarce przestrzennej. Praca zbiorowa pod redakcją Henryka Rogackiego. Bogucki Wydawnictwo Naukowe, Poznań.
- [3] Hopfer, A.; Żróbek, S.; Żróbek, R. 1987. *Planistyczne i urzędzenioworolne aspekty rozwoju miast*. Wydawnictwo ART, Olsztyn.
- [4] Żróbek, S. 1983. *Zmiany w użytkowaniu gruntów w strefie przejściowej między miastem a wsią w świetle badań i prognoz*. Rozprawa doktorska. Olsztyn.
- [5] Biłozor, A. 2007. Kształtowanie przestrzeni miasta, *Studia i materiały Towarzystwa Naukowego Nieruchomości* (Journal of the Polish Real Estate Scientific Society) 15(3–4). Olsztyn.
- [6] Biłozor, A. 2005. *Zastosowanie logiki rozmytej do identyfikacji i lokalizacji strefy przejściowej miasta i wsi* – ACAT SCIENTIARUM POLONORUM. Administratio Locorum – Gospodarka Przestrzenna 4(1–2) 2005. Wydawnictwo UWM w Olsztynie.
- [7] Renigier-Biłozor, M.; Biłozor, A. 2008. *Zastosowanie teorii zbiorów przybliżonych (rough set) i teorii zbiorów rozmytych (fuzzy set) w gospodarce przestrzennej*. Nowe kierunki i metody w analizie regionalnej. Biuletyn Instytutu Geografii Społeczno – Ekonomicznej i Gospodarki Przestrzennej UAM w Poznaniu, pod redakcją Teresy Czyż, Tadeusza Strykiewicza, Pawła Churskiego. Seria Rozwój Regionalny I Polityka Regionalna nr 3. Poznań.
- [8] Pietrzak, M. 1998, *Syntezy krajobrazowe – założenia, problemy, zastosowania*. Bogucki Wydawnictwo Naukowe, Poznań.
- [9] Widacki, W. 1981. *Klasyfikacja granic geokompleksów*. Zeszyty Naukowe UJ, Prace Geograficzne 53, Kraków, 19–26
- [10] Domański, R. 1989. *Podstawy planowania przestrzennego*. Państwowe Wydawnictwo Naukowe. Poznań.