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The assessment of the suburbanisation degree of Warsaw Functional Area using changes of the land development structure

Abstract
The paper presents the analysis of spatial suburbanization using a multi-indicator method. Based on features related to geodetic areas (according to the directions of their use) such as built-up areas, urbanised lands, arable lands, residential, recreation and leisure areas, road transport areas as well agricultural and forest areas transformed into local land development plans - six suburbanization indicators were developed. After the standardisation of such indicators, a summary index was obtained making it possible to determine the suburbanization degree. The validation of the proposed method was made by comparing individual municipalities with the unit type determined using the Webb method. The analysis made it clear that the only four units with spatial features of the city lying in the proximity of Warsaw, for which Polish capital could be enlarged are: Piastów, Pruszków, Marki, Józefów and possibly Sulejówek.

Keywords
Suburbanisation • land use structure • municipality • urban sprawl

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Introduction

The increasing urban tendency, most often reflected in the absorption of arable land into city areas, is an inevitable but ongoing process. According to the French Alliance for Cities and Territorial Development (PFVT 2019), between now and 2030, cities will be inhabited by 80% of the earth's population, which is over 4 billion dwellers. The growth of cities is, therefore, inevitable; hence, the process of appropriate urban planning takes on significance. Around cities, there are temporary developing areas – specific zones between the city and agricultural land where the ongoing change in land use related to the proximity of cities is clearly visible (Sorensen 2016). The way in which the suburban areas are transformed is very diverse and difficult to generalise. In part, this is also a process dependent on the nature and size of the core city itself, but it is largely caused by physical features, natural barriers, transport accessibility and economic – including land production – value. The transformation of the suburban area may take on a chaotic form, called urban sprawl, but can also represent a precise orientation, e.g. in wedge-shaped form along transport corridors. It is not uncommon that within the city structure, areas that are not entirely urbanised are included; however, outside its administrative areas, one can find fully urbanised villages (Heffner 2011).

Nowadays, it is considered desirable to develop compact city structures with a higher intensity of their spatial use which can be called 'inward development' (Sołtys 2010). In this context, the city should primarily absorb the areas with the greatest 'degree of urbanity'.

The historical development of Warsaw took place in stages. Its northern and southern quarters were incorporated in the early 18th century. This process has progressed over centuries. The most intensive enlargement of the city borders took place in 1951 when the largest of the current districts were joined to the city structure.

The development of Warsaw has always been formed by economic, demographic and spatial determinants. Never before has there been a proposal for a dynamic, one-off enlargement of Warsaw from 517 km^2 to about 1,500 km^2. Such a solution appeared in the draft legal act concerning the capital city of Warsaw, dated January 30, 2017 (Draft Act on the Constitution of the Capital City of Warsaw 2017). Increasing the Polish capital by 32 municipalities would triple its total area. In terms of area, and compared to other European cities (Demographia, 2018), Warsaw is currently located in 31st place, whereas if it had been enlarged, it would have been in 4th position right after Paris (2,723 km²), Essen/Düsseldorf (2,642 km²) and London (1,623 km²).

It should be obvious that the legislative process related to the delimitation of the area to grant a settlement city status or incorporate it into the city area is only the effect or the consequence of in-depth analyses during which the given area is considered in the urban-shaping context including:

- urbanisation, suburbanisation and so-called 'rurbanisation' processes;
- endogenous and exogenous functions;
- many natural, historical, demographic, social, economic and infrastructural factors.

The studies of urbanisation processes that take place around cities are needed both in a theoretical and practical

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sense, considering the specificity of processes occurring in a given suburban area. The analyses undertaken by the authors may apply in both cases.

Features and properties of suburbanisation

Urbanisation and suburbanisation have still been the ongoing processes shaping the contemporary look of the world. Due to the diverse nature of these phenomena, as well as the variability in time and space, we encounter many problems in the research and regular assessment of their intensity, choice of measures or administrative and investment decisions (Śleszyński 2009; Czarnecki 2010). In the relevant subject literature, the diversity of urbanisation of suburb areas is widely described, considering demographic, economic, socio-cultural, natural landscape and spatial factors (Kutkowska et al. 2010; Małek 2011; Zegar et al. 2016; Mikołajczyk & Raszka 2016; Harasimowicz 2018). The set of variables used in the study of the urbanisation level and dynamics is extensive, considering:

- the demographic aspect – these include a natural increase, the migration attractiveness ratio, the percentage of the population of working age, the fertility rate of women of reproductive age or number of marriages (Kutkowska et al. 2010; Spórna 2018);
- the economic aspect – parameters including the number of private non-agricultural economic entities per 1,000 people of working age, the percentage of working women among women of working age (Kutkowska et al. 2010), the percentage of population whose livelihood comes from non-agricultural sources, the number of economic entities (Sokołowski 2015), demand per citizen, share of GDP in an administrative unit (Śleszyński 2012), GDP per citizen, gross value added in PLN per citizen, added value of market services per citizen, the number of companies per 1,000 citizens, unemployment rate, municipality budget incomes, investment expenses (Kutkowska et al. 2010);
- the social aspect – inter alia, the number of employees in industry and services, the average living area or the intensity of using cultural and leisure facilities (Małek 2011), the number of citizens utilising treatment plants, net schooling rate for children of preschool age, number of pharmacies per 1,000 citizens (Kutkowska et al. 2010), the ratio of workplaces to residential addresses (Sokołowski 2015), the number of flats per 1,000 citizens, usable floor area (Śleszyński 2012);
- the infrastructural and spatial aspect – inter alia, the character of functional domination, changes of arable land area in cadastral units (Jaroszewicz et al. 2018), the level of technical and infrastructural equipment, implementation of a spatial structure and built-up areas characteristic of a city structure, as well as an enacted spatial development plan (Sokołowski 2015), the increase in residential areas (Śleszyński 2012) but also the population density per 1 km^2, the density of water pipelines per 1 km^2, the ratio of new flats to overall residential resources, the number of sewage water connections per 1,000 flats (Kutkowska et al. 2010);
- the sociological aspect expressed by lifestyle changes – changes in the forms of dwelling, living, nutrition, dress, organising working and free time, leisure, as well as changes in the family structure, social relations in local environments or mentality (Gutowski 2006).

Regarding the assumed analysis, the most interesting is the spatial aspect. In suburbanisation studies, the indicators mostly considered related to the number of local land development plans, as well as the changes they provide to land use (Mrozik & Wiśniewska 2013, Podawca 2015, Podawca & Mrozik 2019). The parameters related to the spatial structure in the suburbanisation context, such as the share of urbanised areas, the share of residential areas unrelated to agriculture, and the relation of residential areas to farm buildings constitute the basis for assessing the urbanisation processes (Degórska 2012; Zydroń & Szczepański 2012; Mrozik, Bossy; Zaręba 2012). The authors also believe that the immanent feature of the urban area is the existence of public spaces (Gyurkovich 2007). In suburbanisation, there are particularly important recreational and leisure areas, which should co-exist with residential areas, increasing their attractiveness. Enlarging the village and changing its character due to the reduction of arable land and its allocation for housing, leisure, public or industrial purposes is also associated with the increase in building density, the improvement of transport infrastructure or the emergence of other service functions (Małek 2011).

In the subject literature, there are also variables used in the spatial aspect such as population density, the density of the water supply network, number of sewers per 1,000 dwellings or the percentage of newly completed flats in general housing resources (Kutkowska et al. 2010). The problem is so vibrant, that the above variables could also be applied in demographic, economic or social aspects, and are directly dependent on the spatial structure which is superior in this case. The discussed problem is currently the research subject for urban sprawl worldwide, concerning the European cities of Barcelona (Roca et al. 2004), Rome (Di Zio & Montanari 2010), the capital of South Korea – Seoul (Woo 2014), Moscow (Brade & Rudolph 2004) and metropolitan areas in the USA (Huang et al. 2017).

Regarding domestic conditions, the analysis of the Polish Academy of Sciences showed that the suburbanisation process is most advanced in the metropolitan area of Gdańsk-Gdynia-Sopot, Poznań, Lublin, Radom, Szczecin and, of course, the capital city of Warsaw (Lisowski and Grochowski 2008, Parysek 2008, Podawca & Mrozik 2019). Despite the fairly obvious urbanisation process of rural, suburban areas, it takes on a much greater significance considering the sprawl of cities, increasing their areas and the process of urbanisation (Mitchell 2008; Bhatta 2010; Tivari & Goel 2010; Karakayaci 2016).

Research purpose and methodology

It is commonly recognised that changes in suburban areas are caused by suburbanisation, defined as the sprawl proceeding from city centres outwards (Nijman & Clery 2015). The authors assumed that the background for the decision on an administrative city enlargement should be, among other things, the assessment of the urbanisation level of the areas located within the range of socio-economic impact of a core city. The progressive processes of urbanisation mean that a clear division between the city and the village is blurred and the distinction between what is 'urban' and what is 'rural' becomes difficult. Thus, the authors set up the following research goal:

- to develop a set of spatial indicators representing characteristic features of urban areas;
- to develop a method for classifying areas in terms of the degree of their urbanisation.

At the same time, the authors formulated the thesis that Warsaw could be administratively enlarged while maintaining the features of the concentric system.

Due to the nature of the problem, a research procedure was sought that would consider a significant number of variables, with the simultaneous possibility of clarifying and grouping analysed objects. It was assumed that these conditions would be fulfilled by multi-indicator analysis, one of the fundamental multilevel methods playing a vital role in the spatial information system and is now a widely used tool (Borys 2005, Madsen et al. 2010, Hoła & Nowobilski 2017). It was decided that the dominant

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aspect of urbanisation would be the spatial level that focuses on the methods of utilising areas included in the category '*Territorial division*' in the '*National Geodetic Area*' group (data from Geodesy and Cartography Head Office) collected in the Local Data Bank.

To assess the urbanisation level of the examined administrative units with corresponding variables, the following features were used:

- the total area of urbanised land – P_{gu} [ha], related to:
  - total municipality area – P_{cg}, showing the degree of urbanisation of the municipality X_1,
  - total arable area – P_{gr} [ha], specifying the character of the municipality X_2;
- the area of residential areas P_{tm} [ha] which referred to:
  - the car transportation area of P_{tk} [ha], by showing the level of transportation accessibility of residential areas X_3,
  - the recreation and leisure area P_{trw} [ha], by showing the extent of public and sport terrains X_4 within inhabited areas;
- the total area of arable land for which plans for non-agricultural purposes have been changed P_{grz} [ha], related to:
  - total arable area – P_{gr} [ha], determining the level of a municipality farmland status change X_5;
- the total area of forest land for which the plan was designated for non-forest purposes P_{glz} [ha], which referred to:
  - forest land area – P_{gl} [ha], defining the degree of deforestation of the municipality land X_6.

Each municipality can be described by a vector of indicators I_G:

$$I_G = [X_1, ..., I_n]$$

where G = 1, ..., 39; X_n – an indicator adopted for analysis (n = 1, ..., 6).

The set of municipalities of the Warsaw Functional Area G_{WOF} is characterised by a two-dimensional matrix of indicators, given by the model:

$$G_{WOF} = \begin{bmatrix} X_{1.1} & X_{n.1} & X_{6.1} \\ X_{1.G} & X_{n.G} & X_{6.G} \\ X_{1.39} & X_{n.39} & X_{6.39} \end{bmatrix}$$

The values in the groups of particular indicators significantly deviate from each other. In this regard, as well as the fact that all indicators have the urbanisation stimulating character, the formula was applied to statistical normalisation:

$$S_{nG} = \frac{X_{nG}}{\max X_{nG}}$$

where: X_{ng} – the value of an *n*-indicator in a *G*-municipality; max X_{nG} – maximum value of the *n*-indicator, S_{nG} – normalised value x_{nG}.

As a result of this process, a set of parameters W_{GWOF} was created describing the analysed municipalities, saved in the form of a two-dimensional matrix. Each row contains values of all parameters for one municipality, and each column contains one-parameter data concerning all of them. This matrix is given as:

$$W_{GWOF} = \begin{bmatrix} S_{1.1} & S_{n.1} & S_{6.1} \\ S_{1.G} & S_{n..G} & S_{6.G} \\ S_{1.39} & S_{n.39} & S_{6.39} \end{bmatrix}$$

A synthetic form of the suburbanisation level of municipalities was obtained using data aggregation by applying the non-pattern method. As a result of processing the following formula:

$$W_{sub} = \frac{1}{x}\sum_{n=1}^{x} S_{n.G}$$

where: W_{sub} – a synthetic indicator of spatial suburbanisation of municipalities; n – 1, 2, ..., x; x – the number of indicators included, the values from the range 0–1 were obtained.

A higher value of the synthetic index means a higher degree of suburbanisation in the administrative unit.

The municipality is considered as the basic spatial unit covered by analyses. Such an approach was adopted because municipalities can conduct their local spatial policies, create inter-municipal relations, as well as being obliged to maintain interregional development tasks tied to their position in regional and sub-regional structures (districts, regions, functional areas, agglomerations, metropolises, etc.).

The territorial range was limited to the municipalities of the Warsaw Functional Area (WFA). The purpose of the selection of such a set was the systematically growing urban pressure on the areas near Warsaw and suggestions for incorporating these areas into the Polish capital. The relevant spatial analysis using numerical data was performed in ArcGIS software, version 10.4.1.

From the utilitarian point of view, the evaluation of selected municipalities of the WFA can provide the foundation to make a possible decision on including a given municipality in the capital city of Warsaw.

Municipality indicator characteristics of the Warsaw Functional Area

The sizes of indicators assessed (Table 1) affecting the level of urbanisation are the most diversified in the parameter X_2 which defines the municipality character as more or less agricultural. In this regard, the current division into the type of administrative unit is visible because the highest values are assigned to urban municipalities. In this case, the rural municipalities of Jabłonna and Michałowice, as well as the urban–rural units of Wołomin, Łomianki and Piaseczno in which the ratio of residential and agricultural areas is above 30%, deserve our attention. In other cases, the indicator strongly shows the agricultural character of municipalities. The situation is very similar in the context of the ratio of urbanised land to the municipality area. The exceptions are the municipalities of Izabelin and Zielonka, in which a significant share of forests is visible, limiting the urbanistic features of these areas.

In the case of the density of transportation related to residential areas, contrary to previous expectations, this indicator took on the highest value in non-urban units. The most significant values were observed in the urban–rural municipalities of Karczew, Ożarów Mazowiecki, Błonie, as well as in rural ones like Wiązowna, Wieliszew, Leszno and Czosnów. It proves that in these administrative units there is a transportation network, along which residential development can be implemented.

Considering the attractiveness of residential areas measured by the number of leisure and recreational areas, it was found that it does not depend on the unit type. Examples of a municipality with a small number of such areas are Józefów – an urban municipality, or Lesznowola – a rural village. The opposite, favourable situation can be observed in Żyrardów (urban), Jabłonna (rural) or Radzymin (urban and rural municipality).

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Table 1. Features and spatial suburbanisation indicators of the WFA municipalities (own elaboration)

Municipality	Values of the spatial structure features* [ha]									Spatial urbanisation indicators [-]					
	P_{cg}	P_{gr}	P_{gu}	P_{tm}	P_{tk}	P_{trw}	P_{grf}	P_{glz}	P_{l}	X_1	X_2	X_3	X_4	X_5	X_6
Milanówek	1 344	445	762	506	126	7	126	5	86	0.56696	1.71236	0.24901	0.01383	0.28315	0.05814
Podkowa Leśna	1 013	34	190	118	54	1	0	34	773	0.18756	5.58824	0.45763	0.00847	0.00000	0.04398
Grodzisk Mazowiecki	10 740	7 322	2 153	916	640	21	3 210	0	775	0.20047	0.29405	0.69869	0.02293	0.43840	0.00000
Jaktorów	5 530	4 135	792	362	201	2	857	36	429	0.14322	0.19154	0.55525	0.00552	0.20726	0.08392
Legionowo	1 354	80	1 045	644	173	12	0	59	173	0.77179	13.0625	0.26863	0.01863	0.00000	0.34104
Jabłonna	6 480	2 138	820	409	224	80	147	25	2 833	0.12654	0.38354	0.54768	0.19560	0.06876	0.00882
Nieporęt	9 604	3 356	921	408	267	31	421	59	4 163	0.09590	0.27443	0.65441	0.07598	0.12545	0.01417
Wieliszew	10 609	5 754	1 006	249	369	10	0	31	2 896	0.09483	0.17483	1.48193	0.04016	0.00000	0.01070
Halinów	6 309	4 106	801	391	261	5	840	37	1 062	0.12696	0.19508	0.66752	0.01279	0.20458	0.03484
Sulejówek	1 931	495	780	477	146	27	41	90	525	0.40394	1.57576	0.30608	0.05660	0.08283	0.17143
Nowy Dwór Mazowiecki	2 821	680	1 280	178	144	8	0	0	207	0.45374	1.88235	0.80899	0.04494	0.00000	0.00000
Czosnów	12 845	7 123	729	193	334	3	1 475	11	3 593	0.05675	0.10234	1.73057	0.01554	0.20708	0.00306
Józefów	2 391	316	1 029	616	197	0	0	231	619	0.43036	3.25633	0.31981	0.00000	0.00000	0.37318
Otwock	4 731	1 091	1 393	679	339	17	353	357	1 871	0.29444	1.27681	0.49926	0.02504	0.32356	0.19081
Karczew	8 150	4 574	674	203	267	5	46	0	1 907	0.08270	0.14735	1.31527	0.02463	0.01006	0.00000
Wiązowna	10 212	5 816	845	267	348	11	172	1	3 212	0.08275	0.14529	1.30337	0.04120	0.02957	0.00031
Góra Kalwaria	14 412	8 643	1 223	419	388	19	1 845	183	2 940	0.08486	0.14150	0.92601	0.04535	0.21347	0.06224
Konstancin-Jeziorna	7 858	4 718	1 080	511	294	20	852	267	977	0.13744	0.22891	0.57534	0.03914	0.18058	0.27329
Lesznowola	6 930	4 884	1 028	493	328	1	3 345	194	912	0.14834	0.21048	0.66531	0.00203	0.68489	0.21272
Piaseczno	12 826	6 267	2 598	1 365	593	19	1 583	122	3 626	0.20256	0.41455	0.43443	0.01392	0.25259	0.03365
Piastów	576	71	505	286	95	5	34	0	0	0.87674	7.11268	0.33217	0.01748	0.47887	0.00000
Pruszków	1 919	549	1 295	514	321	60	164	1	14	0.67483	2.35883	0.62451	0.11673	0.29872	0.07143
Brwinów	6 926	4 779	1 409	691	369	14	625	27	510	0.20344	0.29483	0.53401	0.02026	0.13078	0.05294
Michałowice	3 473	2 049	976	524	273	12	898	0	269	0.28103	0.47633	0.52099	0.02290	0.43826	0.00000
Nadarzyn	7 345	4 757	1 046	474	341	8	317	54	1 335	0.14241	0.21989	0.71941	0.01688	0.06664	0.04045
Raszyn	4 391	2 808	815	450	244	9	0	0	653	0.18561	0.29024	0.54222	0.02000	0.00000	0.00000
Błonie	8 558	7 570	843	197	257	22	715	0	16	0.09850	0.11136	1.30457	0.11168	0.09445	0.00000
Izabelin	6 501	578	523	311	160	3	95	55	5 036	0.08045	0.90484	0.51447	0.00965	0.16436	0.01092
Leszno	12 508	6 424	438	150	239	12	352	15	5 214	0.03502	0.06818	1.59333	0.08000	0.05479	0.00288
Łomianki	3 883	1 721	937	546	213	3	184	12	595	0.24131	0.54445	0.39011	0.00549	0.10691	0.02017
Ożarów Mazowiecki	7 127	6 124	851	202	290	6	2 896	0	55	0.11941	0.13896	1.43564	0.02970	0.47289	0.00000
Stare Babice	6 342	4 443	559	267	216	2	1 755	5	1 227	0.08814	0.12582	0.80899	0.00749	0.39500	0.00407
Kobyłka	1 964	574	821	464	139	5	133	35	394	0.41802	1.43031	0.29957	0.01078	0.23171	0.08883
Marki	2 615	315	1 212	569	224	4	315	115	915	0.46348	3.84762	0.39367	0.00703	1.00000	0.12568
Ząbki	1 098	203	556	319	102	5	0	0	325	0.50638	2.73892	0.31975	0.01567	0.00000	0.00000
Zielonka	7 948	257	659	269	113	13	0	129	6 166	0.08291	2.56420	0.42007	0.04833	0.00000	0.02092
Radzymin	12 946	7 321	1 991	618	474	161	950	26	2 885	0.15379	0.27196	0.76699	0.26052	0.12976	0.00901
Wołomin	6 166	3 530	1 439	746	320	2	0	38	940	0.23338	0.40765	0.42895	0.00268	0.00000	0.04043
Żyrardów	1 435	362	939	379	196	50	96	0	71	0.65436	2.59392	0.51715	0.13193	0.26519	0.00000

Legend

Minimum values
Maximum values

** data provided by the Local Data Bank for the year 2014; in the case of the parameters P_{grf} and P_{glz}, maximum value concerns the period 2013–2016*

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The progress of suburbanisation is immanently tied to the change in function of a terrain. In such cases, the most common process is the change of farmland status (from agricultural to residential) or its deforestation. Regarding the size of agricultural and forest areas allocated in local land development plans, the municipalities of Piastów and Marki are leading the way to assigning another function. This is the inevitable result of a small amount of arable land. The most significant planning level of the suburbanisation of rural areas occurs in Lesznowola, Ożarów Mazowiecki and Grodzisk Mazowiecki, while the smallest – excluding cities – is in Wołomin, Raszyn and Wieliszew (Table 1).

While analysing the normalised indicators presented in Table 2, it is possible to observe how individual municipalities compare with the maximum value of a given indicator. Indeed, the municipality data groups are analogous with the division involving X_n indicators. The municipalities with the most agricultural structure of land use (parameters S_1, S_2) in which the values do not exceed 10% of the overall maximum are Leszno, Czosnów, Izabelin, Karczew and Wiązowna. One can also see how the comparison of geodetic built-up and agricultural areas with a large share of forests, can give a rural character to the urban unit – as is the case of Zielonka. Of course, the maximum values prevail in urban municipalities with Legionowo and Piastów as the most dominant ones.

What is more, the density of the transportation network related to residential areas is not the highest in urban municipalities. Comparing maximal values of the whole set, the lower ratio can be observed in Milanówek, Legionowo, Kobyłka, Sulejówek, Ząbki, Józefów and Piastów (below 20%); however, the most advantageous are Ożarów Mazowiecki, Wieliszew, Leszno and Czosnów (over 80%). Such a situation in rural units is affected by the small surface of residential terrain. Nevertheless, this value has a significant impact on the prospects of creating new urban areas.

One of the most interesting aspects we can consider is the level of the change in use of farmlands by giving them other purposes, which – compared to the municipality of Marki – is higher than 40% in the municipalities of Michałowice, Grodzisk Mazowiecki, Ożarów Mazowiecki, Lesznowola and Piastów. The most surprising observation is the lack of transformation of arable land for other purposes during the spatial planning process in municipalities: Wołomin, Raszyn and Wieliszew. The analysed factor does not indicate a complete lack of such a process. It is difficult, however, to judge ift due to the lack of data on the potential to change the status of farmlands at the request of individual farmers.

Research results

Regarding the assessment of the WFA municipalities based on six suburbanisation indices and – at the same time – diversification in the context of their possible inclusion in the capital city of Warsaw, a division into typological groups was used (Komornicki & Śleszyński 2009, Kutkowska et al. 2010) following the principle:

- group I (high degree of spatial suburbanisation) – municipalities: Legionowo, Marki, Piastów, Pruszków, Żyrardów and Józefów, in which the value of the synthetic indicator exceeds the mean and standard deviation $W_{sub} \geq W_{sub(mean.)} + s_{Wsub}$, i.e. greater than 0.31199;
- group II (average degree of spatial suburbanisation) – municipalities: Lesznowola, Radzymin, Otwock, Konstancin-Jeziorna, Ożarów Mazowiecki, Sulejówek, Milanówek, Błonie, Czosnów and Leszno, in which $W_{sub(mean.)} + s_{Wsub} > W_{sub} \geq W_{sub(mean)}$, i.e. within the range of <0.22232; 0.31199);
- group III (low degree of spatial suburbanisation) – municipalities: Jabłonna, Nowy Dwór Mazowiecki, Kobyłka, Góra Kalwaria, Michałowice, Grodzisk Mazowiecki, Wieliszew, Podkowa Leśna, Wiązowna, Ząbki, Stare Babice, Karczew, Nieporęt, Jaktorów, Brwinów, Piaseczno, Halinów and Nadarzyn, where the synthetic indicator fulfils the condition $W_{sub(mean.)} > W_{sub} \geq W_{sub(mean.)} - s_{Wsub}$, i.e. <0.13265; 0.22232);
- group IV (very low degree of spatial suburbanisation) – municipalities: Zielonka, Łomianki, Izabelin, Wołomin and Raszyn, in which the synthetic indocator is smaller than 0.13265 – i.e. $W_{sub} < W_{sub(mean.)} - s_{Wsub}$.

Considering the spatial distribution of particular municipalities, it should be noted that in the first ring from Warsaw, only the municipalities of Piastów, Pruszków, Marki and Józefów are characterised by significant urban features (i.e. urban, from the perspective of the land use structure). For rural and urban–rural units, among those located directly near the borders of Warsaw, there are Ożarów Mazowiecki, Konstancin-Jeziorna and Lesznowola. From the remaining municipalities with a high total spatial degree of suburbanisation, there are two rural ones: Leszno and Czosnów, two urban–rural: Błonie and Radzymin as well as two cities: Milanówek and Otwock. They are situated in the second centralisation ring within the Warsaw Functional Area. One can also observe four administrative units – Raszyn, Łomianki, Zielonka and Izabelin – neighbouring directly with Warsaw that present a low degree of spatial suburbanisation. In this case, particular attention should be paid to urban–rural municipalities (Łomianki and Raszyn), which despite the apparent urban character, considered as a whole, fall below expectations. In this regard, one may attempt to state that the suburbanisation is not unequivocally related to the distance and transport connections with Warsaw. The incorporation of municipalities with a high degree of urbanisation located in the proximity of Warsaw is in line with one of the development principles, i.e. the law of minimising effort (the maximum use of existing available resources and then the less accessible resources) (Chmielewski 2001).

In the case of the municipalities (mainly urban) with a high degree of spatial suburbanisation and located a greater distance from Warsaw, including them into the area of Warsaw, apart from the problem of urban sprawl, is associated with the need to overcome the so-called development thresholds of the city (mainly infrastructural and economical). Overcoming such problems requires significant financial resources although, in the long term, it may create individual development potential. At the same time, one can consider a very probable scenario in which some of the analysed units, more distant but well connected with Warsaw, have a chance for further multifunctional development as 'satellite centres' (sub-centres) of the Polish capital, preserving their administrative autonomy.

In order to verify the proposed method of suburbanisation assessment, the results were compared with the most frequently used demographic plane of the suburbanisation process (Zegar et al. 2016, Śleszyński 2012). It turned out that the indicators – mainly population growth – used during the assessment of social suburbanisation levels provide quite similar but not identical results as the indicators used to evaluate the land suburbanisation. Considering the suburban division of municipalities according to the Webb method, it can be concluded that major municipalities of WFA are characterised by a positive real increase (types A–D). In most cases, the relationship between demographic and spatial parameters can be observed among municipalities belonging to groups I and II (Table 3). In several units, despite the population increase, the degree of spatial suburbanisation is diversified (Figure 1). The most significant contrast between the demographic and spatial sphere is visible:

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Table 2. Values of normalised indices of suburbanisation in WFA municipalities (own elaboration)

No.	Municipality	Municipality type *	Values of normalised suburbanisation indicators [-]						
			S_1	S_2	S_3	S_4	S_5	S_6	W_{sub}
	Milanówek	urban	0.64668	0.13109	0.14389	0.05310	0.28315	0.15579	**0.23562**
	Podkowa Leśna	urban	0.21393	0.42781	0.26444	0.03253	0.00000	0.11786	**0.17610**
	Grodzisk Mazowiecki	urban–rural	0.22865	0.02251	0.40373	0.08800	0.43840	0.00000	**0.19688**
	Jaktorów	rural	0.16335	0.01466	0.32085	0.02121	0.20726	0.22487	**0.15870**
	Legionowo	urban	0.88030	1.00000	0.15523	0.07152	0.00000	0.91388	**0.50349**
	Jabłonna	rural	0.14433	0.02936	0.31647	0.75081	0.06876	0.02365	**0.22223**
	Nieporęt	rural	0.10938	0.02101	0.37815	0.29165	0.12545	0.03798	**0.16060**
	Wieliszew	rural	0.10816	0.01338	0.85632	0.15416	0.00000	0.02868	**0.19345**
	Halinów	urban–rural	0.14481	0.01493	0.38572	0.04909	0.20458	0.09336	**0.14875**
	Sulejówek	urban	0.46073	0.12063	0.17687	0.21727	0.08283	0.45937	**0.25295**
	Nowy Dwór Mazowiecki	urban	0.51753	0.14410	0.46747	0.17252	0.00000	0.00000	**0.21694**
	Czosnów	rural	0.06473	0.00783	1.00000	0.05967	0.20708	0.00820	**0.22459**
	Józefów	urban	0.49087	0.24929	0.18480	0.00000	0.00000	1.00000	**0.32083**
	Otwock	urban	0.33584	0.09775	0.28850	0.09610	0.32356	0.51130	**0.27551**
	Karczew	urban–rural	0.09433	0.01128	0.76002	0.09454	0.01006	0.00000	**0.16171**
	Wiązowna	rural	0.09438	0.01112	0.75315	0.15814	0.02957	0.00083	**0.17453**
	Góra Kalwaria	urban–rural	0.09679	0.01083	0.53509	0.17406	0.21347	0.16680	**0.19951**
	Konstancin-Jeziorna	urban–rural	0.15676	0.01752	0.33246	0.15024	0.18058	0.73232	**0.26165**
	Lesznowola	rural	0.16920	0.01611	0.38445	0.00779	0.68489	0.57002	**0.30541**
	Piaseczno	urban–rural	0.23104	0.03174	0.25103	0.05343	0.25259	0.09016	**0.15166**
	Piastów	urban	1.00000	0.54451	0.19194	0.06711	0.47887	0.00000	**0.38041**
	Pruszków	urban	0.76971	0.18058	0.36087	0.44807	0.29872	0.19141	**0.37489**
	Brwinów	urban–rural	0.23204	0.02257	0.30857	0.07777	0.13078	0.14186	**0.15227**
	Michałowice	rural	0.32054	0.03647	0.30105	0.08790	0.43826	0.00000	**0.19737**
	Nadarzyn	rural	0.16243	0.01683	0.41571	0.06478	0.06664	0.10839	**0.13913**
	Raszyn	rural	0.21170	0.02222	0.31332	0.07677	0.00000	0.00000	**0.10400**
	Błonie	urban–rural	0.11235	0.00853	0.75384	0.42867	0.09445	0.00000	**0.23297**
	Izabelin	rural	0.09176	0.06927	0.29728	0.03703	0.16436	0.02927	**0.11483**
	Leszno	rural	0.03994	0.00522	0.92070	0.30708	0.05479	0.00771	**0.22257**
	Łomianki	urban–rural	0.27523	0.04168	0.22542	0.02109	0.10691	0.05404	**0.12073**
	Ożarów Mazowiecki	urban–rural	0.13619	0.01064	0.82958	0.11402	0.47289	0.00000	**0.26055**
	Stare Babice	rural	0.10053	0.00963	0.46747	0.02875	0.39500	0.01092	**0.16872**
	Kobyłka	urban	0.47680	0.10950	0.17310	0.04136	0.23171	0.23804	**0.21175**
	Marki	urban	0.52864	0.29455	0.22748	0.02698	1.00000	0.33679	**0.40241**
	Ząbki	urban	0.57757	0.20968	0.18477	0.06016	0.00000	0.00000	**0.17203**
	Zielonka	urban	0.09457	0.19630	0.24274	0.18550	0.00000	0.05606	**0.12920**
	Radzymin	urban–rural	0.17542	0.02082	0.44320	1.00000	0.12976	0.02415	**0.29889**
	Wołomin	urban–rural	0.26619	0.03121	0.24787	0.01029	0.00000	0.10833	**0.11065**
	Żyrardów	urban	0.74635	0.19858	0.29883	0.50640	0.26519	0.00000	**0.33589**

Legend

Minimum values
Maximum values

** The municipality is the basic unit of administrative division and local government in Poland. It encompasses either a city (urban municipality) or only a rural area (rural municipality) as well as a city with the surrounding rural area (urban–rural municipality). Such division is in accordance with the regulation of the Polish Council of Ministers resulting from the legal act of 8 March 1990 regarding local government (plain text – Dz.U. 2018 pos. 994).*

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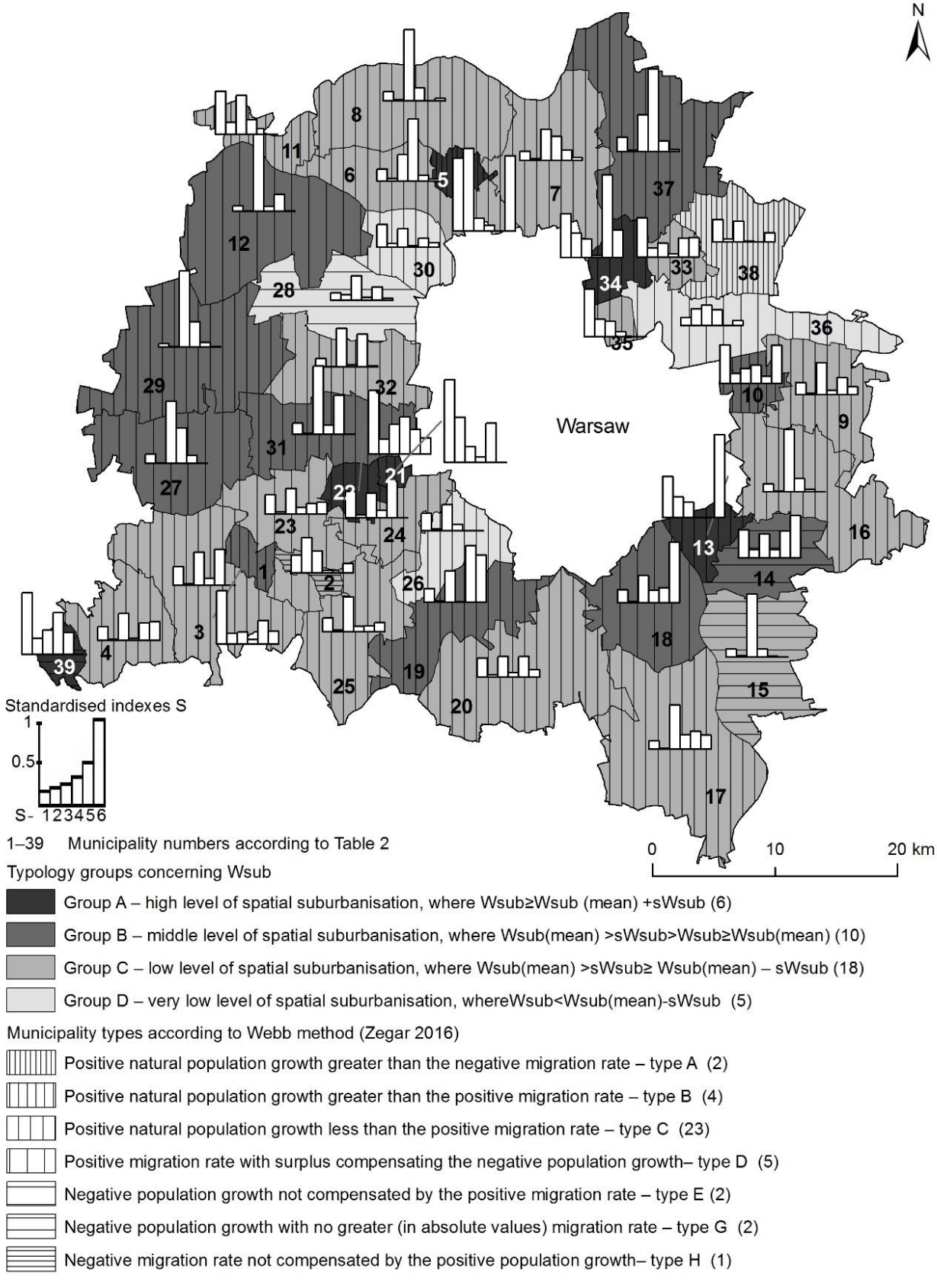

Figure 1. Spatial diversification of WFA municipalities according to suburbanisation level (own elaboration performed in ArcGIS)
Source: Local Data Bank

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Table 3. Distribution of WFA-municipality groups related to the Webb-type units (own elaboration)

		Distribution of territorial units according to types based on the Webb method															
		A		B		C		D		E		F		G		H	
		pcs	%	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%	pcs	%
Municipality groups according to summarised suburbanisation indicator	I	1	2.56	1	2.56	0	0	3	7.69	0	0	0	0	1	2.56	0	0
	II	0	0	2	5.13	3	7.69	4	10.3	1	2.56	0	0	0	0	0	0
	III	0	0	1	2.56	1	2.56	14	35.9	0	0	0	0	1	2.56	1	2.56
	IV	1	2.56	0	0	1	2.56	2	5.13	1	2.56	0	0	0	0	0	0

Source: Local Data Bank

- in the municipality of Żyrardów, in which we observe both negative population growth and migration balance with simultaneous high rates of spatial suburbanisation;
- in the municipality of Wołomin, in which, despite the increase in population growth, we observe a slight degree of spatial suburbanisation.

The above examples of municipalities and the presented summary (Table 3) prove that the suburbanisation process should be considered simultaneously at all levels and not unilaterally (mainly in a demographic context).

Conclusion

Changes in geodetic areas according to the methods of their land use should be regarded as one of the criteria for assessing the urbanisation or suburbanisation processes. This is justified by the results obtained, which are not always relevant to the demographic approach. The possible enlargement of the administrative boundaries of Warsaw in the present land use situation by assessing the changes in geodetic areas, according to how they are used, can be considered only in the case of few municipalities (Piastów, Pruszków, Marki, Józefów or possibly Sulejówek). These municipalities met the examined urban criteria in terms of spatial structure. Hence, it should be emphasised that the formulated assumption was not confirmed. If the administrative boundaries of Warsaw were enlarged, therefore – according to urban theories considering the models of spatial structures of cities – we should apply a multi- or polycentric system developed by Harris and Ullman (Liszewski 2012).

On the other hand, the authors achieved the assumed goals. The proposed methodology for the assessment of spatial units in terms of the degree of urbanisation can also be applied to a different set of municipalities located near a large city. The limitation in applying the method is the maximum value for particular indicators used in the standardisation. This is not a universal value, but it results from the specificity of a given region, country or city. The research aimed to valorise individual spatial units within the area around a given city but not to compare individual agglomerations between them. Regarding the Warsaw Functional Area, the results obtained may be a contribution to further work and analyses on changes in the administrative boundaries of Warsaw.

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