Article

CORINE Land Cover Data and Actual Arrangement of Buildings in Research on Processes of Concentration and Dispersion of Settlement: Example of Poland

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Abstract: The article describes the results of comparison of occurence of buildings (and address points) in Poland with delimitations of land use belonging to particular classes in the CORINE Land Cover (CLC) 2018 dataset. Large discrepancies have been identified, which reach on average approx. 34% of addresses and 35% of buildings located outside class 1 (artificial surfaces), mainly on terrains of class 2 (agricultural areas). Among single-family buildings it was 37% and among new addresses (forecasted or 'under construction' buildings) – as much as 50%. This puts a question mark over the possibility of using CLC data with resolution of 25 ha for monitoring of spatial planning and development in Poland for purposes of the diagnosis and assessment of the scale of dispersion of built-up areas. It is worth carrying out similar analyses in other countries, known for the deconcentration processes and a relatively large share of dispersed settlement e.g. other CEE countries, Spain, Portugal, Italy.

Keywords: CLC 2018 level of detail; comparison of remote sensing and geodetic data; settlement; land use monitoring; urban sprawl

1. Introduction

The uses of remote sensing materials and databases derived from them - in particular CORINE Land Cover, for examination of changes in land use, including 'urban sprawl', are numerous. The CLC data was tested for the needs of monitoring of urbanization and land use on the national and regional scales, i.a. in Germany [1] and Romania [2,3], in coastal areas of Portugal [4,5], in the metropolitan regions of Rome [6], Athens [7] and Madrid [8,9]. There are also a number of comparative studies between different countries among which there is Poland too [10,11]. The research studies reveal numerous spatial conflicts between housing, urbanization, industrialization, agriculture, forestry, nature protection, including i.a. the curbing of food-zones in the metropolitan areas [12].

CORINE Land Cover includes data sets of Pan-European coverage. Therefore, they are used in research on the monitoring of urban growth and urban sprawl having the character of comparisons between different countries, regions and cities [13,14], in combination, inter alia, with population data [7, 15-18]. Results of the research studies, showing large diversity of the examined phenomena, suggest that they are affected by factors not only connected with demographic pressure and economic transformations but also specifically local conditions.

However, a part of the mentioned studies exhibits a high level of errors with the use of CLC datasets compared with other spatial data, in particular in dynamic analyses or while distinguishing

various types of land use and land cover [19]. This makes a guideline for planners and decision-makers to exercise caution while using this data source for analyses of the use of urban lands and their dynamics in the local scale. It is a serious research problem. The research whose results are presented in this study was aimed at verification, within what scope the aforementioned observations of inconsistency are true with regards to data for the area of Poland.

Against this background, the main goal of the article is the comparison of consistency of location of buildings in Poland, including in particular residential single-family, in relation to the CLC 2018 delimitations i.e. the most up-to-date CORINE dataset. This research is of very high importance due to strong processes of dispersion of settlement and uncontrolled urbanization. Detailed objectives may be indicated as methodological, cognitive and practical ones. The methodological objective is most significant and aims at obtaining an answer to the question, in what degree and in which areas of Poland the CLC 2018 data may be useful for analysis of land use, including in particular housing settlement. A hypothesis is made that due to the identified strong processes of dispersion of built-up areas, in principle in all regions of the country [20-25], the CLC data is not fully useful for this type of research and the biggest discrepancies concern suburban zones and tourist areas. The cognitive objective is identification of the inconsistency degree of the locations of address points and buildings in relation to class 1 in CLC 2018 (artificial surfaces) in the spatial structure of the country. The practical objective is formulation of conclusions and recommendations for the monitoring of land use.

The following structure of the article was proposed for the foregoing goals. First, the specific character of Polish settlement and land use is presented. Getting to know the historical background and contemporary processes will allow, further, to draw conclusions, related to regional differences in location of buildings and address points in relation to the CLC 2018 cover classes. Afterwards, the specific character of topographic databases and methodology of the CLC 2018 classification in Poland will be discussed in short. After these explanations, the used sources of data and research methods will be presented.

The essential empirical part of the article includes comparisons of existence of inconsistencies in locations of the address points and buildings in relation to the class 1 in CLC 2018. Taking account of the rationales arising from chapter 2 (historically and functionally specific character of Polish settlement and land use), the analyses will be conducted in comparative manner, taking into consideration this specific character (historical, functional and landscape types of the areas, detailed analysis for the suburban zones). At the end, methodological, cognitive and practical conclusions are presented.

2. Specific character of Polish settlement and land use

As a result of the historical and economic conditions, such as in particular the period of Partitions of Poland and large shifts of borders, contemporary regions of Poland developed, in a high degree, independently of each other, which allowed several big cities to form [26]. Eventually, the system of cities which is referred to as polycentric, was formed after the World War II. On the one hand, it means that the cities located in the country territory are of various size. The second characteristic of Polish polycentrism is quite regular geographical arrangement of big cities (above 200 thousand residents).

A different situation applies to the rural settlement, however historical processes also had an enormous influence on this system. In the times when European countries underwent the industrial revolution and intensive urbanization, Poland was a country divided between partitioners (The Kingdom of Prussia and later German Empire, Austrian Empire and afterwards Austrian and Hungarian Empire, Tsarist Russia) which carried out a different policy in this respect. Nowadays, Poland includes three former partition zones with urbanization processes developed on different degree, as well as historically industrialized (Silesia) and peripheral lands (Lubuskie, Pomerania) belonging in the partition period (1795-1918) or in part of this period to German countries. Several regularities arise from this. Firstly, the area with the highest population density has the shape of a triangle the base of which is the south of the country and the apex is located in Gdańsk [27]. Secondly,

in Poland there are different types of rural settlement. In the south, big and quite densely arranged villages dominate and in the north - small and rare. Thirdly, as a result of the settlement and social and economic policies of the partitioners, in the eastern and partially central and southern part of the country there is the so-called urbanization delay [28].

After about 1995, in Poland the process of centrifugal dispersion of built-up areas and settlement deconcentration has been pending. The built-up areas "sprawl" considerably outside administrative borders of cities as well as on many rural areas, in particular those attractive in terms of tourism. Dispersion of built-up areas and deconcentration of the settlement networks directly increases costs of their functioning [29,30], so that the costs of spatial chaos in Poland have been estimated recently for not less than 20 billion EUR per year [31].

The development processes of suburban zones in Poland had been taking place for many decades but after 1989 their particular intensification has been noticed. It has been an effect of society growing rich and development of motorization, with simultaneous deterioration of environmental living conditions within administrative borders of cities – absolute or relative in relation to other locations, in particular in centres and in residential districts of large blocks of flats. The effect of this is the relative deconcentration of urban centres, also resulting in numerous problems and challenges of practical nature.

The spatial diversity of urbanization in Poland has to be investigated in the context of changeability of land cover and land use. The natural (physical and geographical) units which allow to present in an accurate and fair manner this diversity in the scale of the whole country are mesoregions. The most detailed research on the changeability of land use in this context based on CORINE Land Cover data for the periods 1990-2000 and 2000-2006, along with preparation of typology of the mesoregions, was carried out by D. Łowicki and A. Mizgajski [32]. The authors referred to the hierarchical system of physio-geographical regionalization of Poland [33], however the new typology took into account the effects of the anthropogenic pressure on the environment. The typically agricultural mesoregions were mainly identified in central Poland (Mazovia, Wielkopolska), and in some areas (e.g. in Kujawy) there was over 90% of the coverage of agricultural terrains. The mesoregions with diverse and mixed land use are present in the whole country. Mountainous mesoregions are outstandingly woody, as well as the mesoregions of Pomeranian Lakelands have large woodiness (above 90% of forests).

The most anthropogenic areas are characteristic of the Tri-city (Gdańsk, Gdynia and Sopot) along with the Kashubia shoreland, the conurbation of Upper Silesia, agglomerations of Warsaw and other cities in the Central Vistula Valley, as well as the agglomeration of Łódź. In total, the vast majority of the regions have a stable spatial structure and only in approximately 30% of the units in the country there were significant changes in the land cover in the investigated period. In the scale of the whole country, 80% of the changes in the entire period 1990-2006 consisted in urbanization, as well as forestation at the expense of agricultural terrains. These both processes were of similar importance since e.g. for the sub-period 2000-2006 in 39 mesoregions among 316 there was significant urbanization, also in 39 mesoregions – forestation, and in 6 mesoregions - these both processes in parallel. The mesoregions with a considerable increase of artificial surfaces were, inter alia, on the Warsaw Plain and in the Warsaw Basin (extension of the Warsaw metropolis) or in Wielkopolska – Greater Poland (Poznań and Gniezno Lakelands, environs of Poznań), in addition – in the regions of Tri-city or Wrocław. However, this increase does not fully involve terrains of residential built-up areas, since it also arises from realization of transport infrastructure and sometimes from industrialization. In general, in Poland in 2000-2006 the artificial surfaces increased by 261 km2. While examining the results of the calculations, it is, however, necessary to take into account the level of spatial aggregation of the CORINE Land Cover data, including the fact that small areas of low-scale changes (less than 25 ha) were not registered [34].

In the context of the changes in the spatial development in Poland it is worth paying attention to the map of landscape diversity based on changeability of the Shannon diversity factor. It presents the spatial arrangement of ecosystems and land use forms [35]. The calculations were conducted in the layout of municipalities (communes) based on the CORINE Land Cover 2012 data. In general,

fragmentation of the landscape and diversity of the land use forms are the largest in southern Poland (in particular, pre-partition Galicia and, secondly, the Congress Kingdom), which arises from historical factors - both agricultural land partitions and structure of settlement. Towards the north and west (formed Prussian partition) this diversity is on the decrease. There are also clear contemporary factors having an influence on the landscape diversity, such as diversity of rural settlement organization and defragmentation of the landscape as a result of urbanization, construction of roads and processes of division of agricultural lands. The influence of urbanization is particularly visible in the suburban zones of the largest agglomerations, including Warsaw, Poznań and Tri-city (Gdańsk-Sopot-Gdynia).

The urban sprawl in Poland is most often discussed in the case of Warsaw [20,36] and other big urban centres such as Poznań [37], Wrocław [38] or Kraków [21], as well as smaller ones, such as e.g. Olsztyn [39]. Research studies show that suburbanization in Poland also refers to the medium-sized urban centres, including district towns – capitals of poviats [40,41]. As opposed to the West European urban sprawl, the specific character of Poland consists in the fact that the built-up areas incoherently "drip" and "splash" along fields and arterial roads. This is particularly attributable to agricultural land divisions on which the built-up areas are planned and realized without prior land consolidation and reparcelling, as well as abandonment of construction of new public roads [42]. Characteristic of post-socialist countries, including Poland, is also the phenomenon of 'inner suburbanization', taking place within administrative borders of cities [43]. It is the most noticeable, based on an analysis of the land cover, in the case of the Upper Silesia polycentric agglomeration [44], where it is impossible to distinguish one core, which has an influence on methodological and analytical difficulties in the examination of this type of processes [45]. In general, the social and economic changes connected with the transformation after 1989 led to acceleration of the changes in the landscape, related to the suburbanization processes, occurrence of new spaces used i.a. for recreation, devastation of the historical spatial layouts, and in the micro-scale i.a. elimination of roadside trees and alleys [46]. This had an influence on serious changes in the flow of the matter and energy in the natural environment, in particular on areas with highly diverse topography (relief) [47].

Other phenomena which occur in Poland, with different intensity, include the functional transformations and urbanization of villages, outside the suburban zones. On the one hand, it is noticeable that a lot of villages are depopulated and some towns shrink, which is related to depopulation [48-52], and on the other hand, popularization of the phenomenon of second homes [53], increasingly brave entering of large-surface trade into rural areas [54], or even direct "revival" of some villages [55]. After the economic and political transformation, urban and rural regions were shaped, and within their limits "town-village" transition zones, i.e. periurbanization zones [56].

In rural areas after the transformation the urban growth were taking place at the expense of agricultural function and partial loss of food-zones around cities. This process took place regardless of the quality of soils in these terrains. This was, and is often, a result of abandonment of preparation, by municipalities, of local spatial development plans at the expense of issuing ad hoc decisions on building and land development conditions. It is worth emphasizing that such changes in the period after the transformation were also activated in other countries of Central and Eastern Europe [57]. Furthermore, a part of the agricultural land remained abandoned or was afforested. The number of large farms increased at the expense of smaller farms. The increase also referred to the area of meadows and grazing lands [32].

3. Specific features of remote sensing and geodetic data in urbanization research in Poland

The basis for conducting the research on the range of urbanization and dispersion of built-up areas on remote sensing materials are aerial photographs and satellite images. Within the scope of digital vector spatial data it is, necessary to indicate in Poland the country-wide data from the Topographic Object Data Bank (BDOT)[1], being a generalized version of the Register of Lands and

[1] The structure of the database is described in the document: Description of the topographic and general-geographic database and technical standards for creation of maps. Appendix to the Regulation of the Minister

Buildings (made accessible in counties – poviats) or data from the address points database [2]. Compilation of both types of data may lead to interesting conclusions.

In Poland there is the Geoportal.gov.pl national portal, consistent with guidelines of the European INSPIRE Directive. It shares geo-spatial data not only for the needs of public and self-government administration but also individual users. Remote sensing data (contemporary and archive) is made accessible in the service but also data from the BDOT complemented with cartographic symbology is accessible there. The BDOT database is the basis for creation of topographic maps in the scale of 1:10 000, and, in particular, it contains the layer of buildings. This data may be acquired via the Chief Geodesy and Cartography Office (GUGiK). Sharing of data from the Register of Lands and Buildings (EGiB) is a bit more complex, however they are partially available on the said geoportal managed by the GUGiK, but also in the "geoportal of open spatial data" by Geo-System (http://polska.e-mapa.net).

With regard to the remote sensing data, a lot of collections may be acquired free of charge from suppliers of geo-IT technologies, but paid data forms a part thereof. This particularly refers to high-resolution satellite images from such satellites as WorldView, GeoEye, QuickBird, SPOT, Ikonos. This is data which allows to monitor the land use in detail because its spatial resolution comes to approx. 1 m or less. Aerial photographs offer comparable quality. In particular, they allow for inventory of buildings, large objects of ground infrastructure or for determination of the species characteristics and health condition of tree stand.

The free of charge data includes the medium-resolution images from Landsat satellites (with spatial resolution of 15-30 m) which were the basic material for preparation of the database on the land cover and ground use – CORINE Land Cover (CLC) [58,59]. So far, 5 editions of this database have been published, for the years: 1990, 2000, 2006, 2012, 2018. The coordinator of the works on the CORINE Land Cover and the main administrator of the database is the European Space Agency (ESA), however in each country a different institution deals with preparation of these datasets. In Poland, it is the Institute of Geodesy and Cartography (IGiK).

The minimum mapping unit of CORINE Land Cover is 25 ha, whereas the minimum width of the linear object represented in the database is 100 metres. The areas that are smaller in terms of surface or narrower linear objects are not identified. The complementary data collections – CLC-Change have higher spatial resolution – the minimum mapping unit has the area of 5 ha. These datasets identify only the areas on which the form of land use / land cover changed in particular periods: 1990-2000 and in the next 6-year sub-periods for 2000-2018. It must be noted that the CLC data is characterized by a high level of generalization but thanks to this it is useful for analyses on the regional scale and even comparisons between countries.

The subject-matter of the research was to juxtapose locations of residential buildings in Poland, identified based on the Topographic Objects Data Bank, with areas of particular land use classes delimited in CORINE Land Cover 2018[3]. It is most up-to-date amongst the data collections made accessible by the ESA. Verification of location of the BDOT objects with reference to the CLC zones allows to assess reliability of the CLC data for the analysis of land use, in particular, to the land associated with residential buildings, as well as to assess the settlement dispersion processes and uncontrolled urbanization. Inconsistencies between the locations of the buildings and the range of

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of the Interior and Administration of 17 November 2011 on the topographic database and general-geographic database as well as standard cartographic documents. Volume I. OJ appendix to No 279, item 1642 27 December 2011. More about creating this database: [60].

[2] The address point database is a part of freely accessible data collection of the national register of borders and areas of units of the country territorial divisions – PRG (made accessible by the National geodetic and cartographic resources (PZGiK)), http://www.gugik.gov.pl/pzgik/dane-bez-oplat/dane-z-panstwowego-rejestru-granic-i-powierzchni-jednostek-podzialow-terytorialnych-kraju-prg (accessed on 2 May 2020) [61].

[3] The CORINE Land Cover 2018 project in Poland has been implemented by the Institute of Geodesy and Cartography and financed from European Union funds. Results of the project were acquired from the website of the Chief Inspectorate of Environmental Protection (GIOŚ).

the urbanized land in the CLC database are evidence of dispersion of settlement and, in the vicinity of urban centres, of the 'urban sprawl' processes.

The most detailed analysis included relations of existence of buildings of the class 1110 (BUBD 01) – residential single-family buildings, with reference to the land cover forms and land use identified in CORINE Land Cover. This class of buildings is particularly associated with settlement dispersion processes. This refers both to houses built by individual investors and by the commercial real estate developers. Special attention in the research was paid to the following classes from the CLC: 111 (continuous urban fabric[4]), 112 (discontinuous urban fabric[5]), 211 (arable land[6]), 242 (complex cultivation patterns[7]). Location of the residential building objects within the boundaries of 111 and 112 classes should be a normal situation. Within the limits of class 242 existence of buildings is acceptable, and it includes in particular built-up areas of rural character, whose width does not exceed 100 m, and they are linked with the housing function and agricultural or holiday resort function. A large share of buildings identified within the class 242 is an evidence of the dispersion of buildings, and even more it is true in case of a large share of buildings identified within the class 211 areas, where, in principle, existence of buildings is not envisaged.

Compilation of the described data sources, i.e. BDOT, address points and CLC 2018 is included in Figure 1. There are examples from two regions of Poland: Kujawsko-pomorskie voivodeship (Lisewo municipality) and Dolnośląskie voivodeship (Grodków municipality). This analysis indicates large co-existence disparities, i.e. consistency of the point databases (addresses, buildings) with the class 1 of CLC 2018 (artificial surfaces). The second municipality is characterized by much better matching.

[4] In view of the specific character of Poland in this and in further footnotes, the CLC 2018 classification and methodological details used in this country were described [62]. Continuous urban fabric (class 111) includes densely built-up areas together with terrains of streets and squares covered by durable surface. In this category, there may also be small green areas or uncovered ground, including parks, cemeteries, squares, however non-built-up areas cannot constitute more than 20% of the class surface. This class mainly includes centres of large cities, as well as old-urban districts (therein, p. 32).

[5] Areas of residential housing estates composed of blocks, tenement houses, single-family houses or public utility buildings (schools, higher education institutions, hospitals). Particular buildings existing in this category are separated by green terrains, squares, parks and even meadows and arable fields. Thus, they are mainly areas not classified to compact built-up areas. Big villages are also included (also 'street' type villages if their width comes to at least 100 m). Within areas of this category, buildings, roads and other hardened surfaces constitute in total from 30 to 80% of the general area. They also include cemeteries with area of less than 25 ha, as well as recreational facilities – only if they exist in direct vicinity of urban fabric and include buildings and transport infrastructure clearly visible in the satellite image (therein, p. 32).

[6] They are mainly areas of cultivation of cereal crops, fodder plants, industrial crops, root crops and vegetables, as well as tree nurseries, greenhouses and under foil crops, flowers, medicinal plants, spice plants, aromatic plants and fallows. In case of high diversity of the land cover, this class includes areas used as agricultural land at least in 75%. It must be emphasized that size of the plots is of no importance here (therein, p. 33).

[7] Small plots, adjacent to each other, used for different crops cultivation, both one-year and durable crops, as well as small meadows and grazing lands. It is particularly important that this class also includes areas of dispersed settlement along with farmstead plots, home orchards and gardens i.e. rural areas (therein, p. 34).

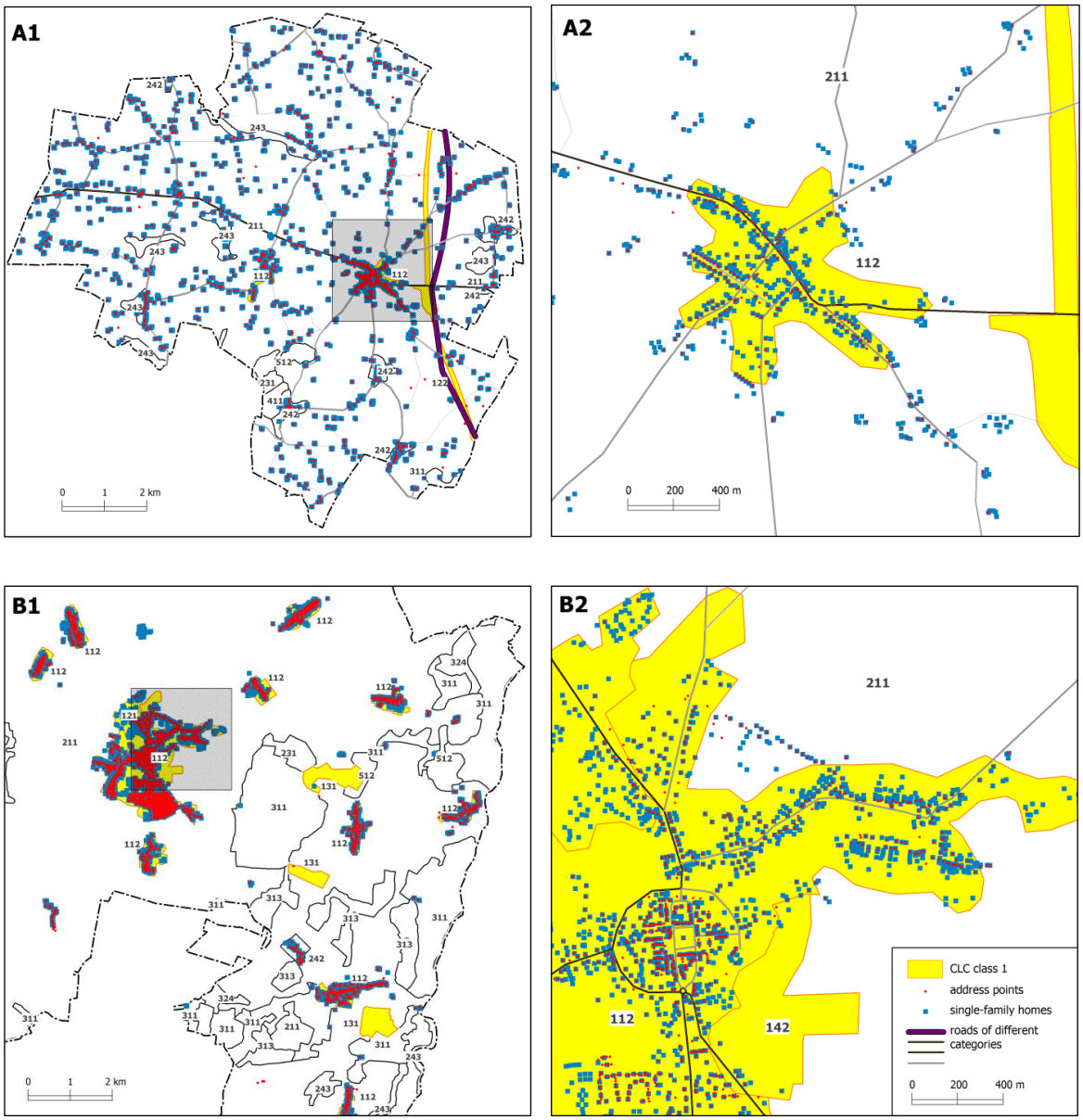

Figure 1. Co-existence of centroids of single-family houses, address points and CLC 2018 delimitations: **(a1, a2)** Lisewo municipality (Kujawsko-pomorskie voivodeship); **(b1, b2)** Grodków municipality (Dolnośląskie voivodeship). Source: based on data of CLC 2018 (IGiK) and BDOT (GUGiK).

4. Materials and Methods

For the analyses the following datasets were used: CLC 2018 land cover map, as divided into patches according to the classification of level 3 (33 classes for Poland), data from the BDOT (centroids of buildings, divided into: 1. residential single-family houses, and 2. other buildings) as well as address points (divided into: 1. existing – with "ist" mark, and 2. forecasted for construction and under construction - with "prg" and "wtb" marks). The address point database (c) in the category "existing" amounted to 7297.3 thousand objects and in the categories "during construction of buildings" and "forecasted for construction" – in total 310.1 thousand. Whereas, the number of buildings classified according to the general category 1110 as "residential single-family" came to 6458.0 thousand objects and in other classes of residential buildings (i.e. 1121 – buildings with two flats, 1122 – buildings with three or more flats, 1130 – collective accommodation buildings) amounted to 538.0 thousand.

Residential detached buildings formed a dominant group among buildings classified as "residential single-family" (96.5% of them). The general category of residential single-family buildings was complemented by holiday resort houses (3.4%) and forester's lodges (0.1%). The group of other residential buildings included mostly buildings with three and more flats (forming 2.8% of all buildings; but in large cities percentage of these buildings often came to over 10%). Buildings with two flats and collective accommodation buildings were of complementary importance (both these categories forming in total 0.7% of all buildings, and 1,6% of residential buildings). It must be noted that in Poland residential buildings are the second, in terms of number, class of buildings, and their number is slightly smaller in relation to agricultural and utility buildings.

Buildings of both these categories (residential, and agricultural and utility) are most often located at a quite small distance from each other [23], forming the basis for separation of the so-called built-up areas[8]. However, only 82.3% of existing addresses are located in these terrains. Among addresses of buildings during construction only 69.2% are located in areas of this type, and among addresses of buildings forecasted for construction it is a bit more (73.0%). Other addresses are mainly located on terrains classified to the category of pastures or arable land[9] (14.4% of existing, 23.8% during construction and 22.6% of the forecasted for construction). Considerable percentage of addresses in the areas classified in the BDOT as areas other than built-up areas justifies the use of this source of information as well in the presented analysis.

The basic calculations were conducted in the QGIS (Quantum GIS) software. In particular, operations were carried out of combining the attributes (according to location) of layers of: 1) centroids of buildings, and 2) address points, with the layer of 150.5 thousand areas (patches) of CLC 2018. Afterwards, the obtained layers were linked with the layer of 2478 Polish municipalities (the smallest is 332 ha of area, the biggest 63 370 ha, median value is 11 671 ha). Information on what share of the address points and buildings is located in particular classes, including the points located outside class 1 (artificial surfaces) was received in this manner. The results were presented on maps.

With regard to co-existence of particular groups of objects in 2478 municipalities, the results of the correlation for the shares of the objects outside class 1 are as follows:

	A1	A2	B1	B2
A1	1.00	0.43	0.99	0.66
A2	0.43	1.00	0.43	0.29
B1	0.99	0.43	1.00	0.65
B2	0.66	0.29	0.65	1.00

Coefficient of the Pearson linear correlation, value R2, confidence level >0.95. Clarification of the abbreviations: A1 – existing address points, A2 – address points for buildings during construction and forecasted for construction, B1 – residential single-family buildings, B2 – other buildings.

The strongest correlation was between the address points and single-family houses, which indicates the latter ones as the main reason for discrepancy in locations of CLC 2018 patches and single objects, which cannot be classified in "their" CLC class mainly due to the surface limit of 25 ha, adopted for the smallest delimitation in this dataset.

In order to answer the question asked in the introduction, connected with usefulness of CLC 2018 data for analyses of dispersion of buildings (and wider – for the monitoring of land use) and in order to find some regularities, the following analyses were carried out:

[8] Built-up areas formed by residential buildings, industrial buildings, warehouse buildings, agricultural production buildings, etc. along with small terrains and devices, functionally related to them - such as backyards, squares, yards, passageways, crossings, adjacent game and play grounds etc. [63] (p. 79).

[9] Areas covered with grasses, i.e. meadows, grazing lands, forest glades, landing-fields with grassy surface, sports sites, grassy areas on terrains of parks and housing estates, as well as arable lands and permanent fallows, etc. [63] (p. 75).

- correlation of the percentage of the shares of address points and buildings with selected social and economic indicators, which may be connected with dispersion of buildings i.e.: population density, coverage of spatial development plans, and character of spatial planning (share of residential areas in planning documents, intensity of localization decisions, changes in intended purpose of land) as well as population inflow and outflow;
- comparison of location of address points and buildings outside class 1 according to the divisions into:
    - historical regions (according to the epoch of Partitions of Poland),
    - functional types of municipalities,
    - 151 suburban zones of cities (all towns and cities over 20 thousand residents),
    - landscape types of lowlands, uplands and mountains (according to the latest physio-geographical regionalization of J. Solon et al. [64]).

With regard to the historical types, their identification consisted in assigning the municipalities to one of 4 areas, in line with divisions after partitions, i.e.: the Congress Kingdom (along with the Białystok District), Galicia, Greater Poland (Wielkopolska) along with Upper Silesia and part of Pomerania (including Kashubia), as well as Western and Northern Lands (along with Opole Silesia). This division is quite frequently used in Poland, and its detailed delimitation has been conducted recently by P. Łysoń [65]. Whereas, with regard to the functional typology, the classification of P. Śleszyński and T. Komornicki [66] was applied, drawn up specially for the needs of monitoring the spatial planning, and the use of which in this study seems to be particularly useful. In this classification, 10 types of municipalities were distinguished based on administrative and settlement hierarchy of cities, socio-economic functions and dominating land use. With regard to suburban zones, delimitation drawn up during the ESPON 1.4.3 project "Study on urban function" was used, which had been implemented previously in 2005-2007 [67] and described i.a. in the study of P. Korcelli et al. [68] (p. 23).

5. Occurence of buildings and addresses in CLC classes

The basic information about occurence of address points and buildings has been compiled in Table 1. The number of the analyzed objects varies in the whole country from 310 thousand (address points during construction and forecasted for construction) to 7297 thousand (existing address points). It is worth noting that in Poland the vast majority of residential buildings are single-family houses (6.5 million, which equals to 92%) and that the number of existing addresses is by approximately 4% higher than the number of these buildings. It might seem that this results, inter alia, from rare instances where several addresses are assigned to the same large building, as well as from physical liquidation of buildings (demolition, pulling down) without loss of address.

In reality, the number of buildings is, however, much higher (it comes to 14.7 million) than the addresses, due to assigning one address to, most frequently, several buildings in agricultural farms (the number of agricultural buildings and utility buildings themselves is higher than the number of residential buildings) and on terrains occupied by industry and services. With regard to the first case, in Poland in 2018 there were 1.4 million agricultural farms, carrying out their activities on the area of 16.4 million ha (a bit more than a half of the area of the country).

Table 1. Occurence of address points and buildings in CLC 2018 classes of different levels. Source: based on CLC 2018 and GUGiK data.

Land cover classes	Address points for addresses of buildings		Centroids of buildings	
	existing	during construction and forecasted for construction	residential single-family	other
Number of objects (thousand)	7297	310	6458	538
Structure of location according to CLC 2018 classes (%)				
111	0.7	0.3	0.1	6.6
112	66.1	50.0	63.0	81.0
121-142	1.9	3.1	1.3	3.3
211	13.0	23.4	14.4	3.6
231	1.8	3.7	2.1	0.4
241	0.0	0.0	0.0	3.4
242	10.8	10.8	12.1	0.7
243	2.6	4.0	3.1	0.0
31	2.4	3.7	3.1	0.9
Other 14 classes	0.6	0.9	0.7	0.1
In total	100.0	100.0	100.0	100.0
Share of objects outside class 11 (%)	31.3	46.6	35.6	9.2

Outside class 1 CLC 2018, i.e. outside the areas artificial surfaces there were 33.9% of the existing address points, 46.6% of those for buildings during construction and forecasted for construction, 35.6% of single-family houses and 9.2% of other buildings. Thus, the differences are very large, especially for new investments under construction. It means that in a very large degree they are built outside the compact built-up areas. Even if some share of new buildings (with a new address) is "adjacent" to the CLC 2018 patches class 1 (including the sub-class 11 – the urban fabric), then the scale of dispersion is still very high. The fact that over 1/3 of existing single-family houses remains beyond class 1 in a very suggestive manner illustrates the extremely problematic structure of Polish settlement.

The vast majority of the address points and buildings outside the compact built-up areas were assigned to class 211 (non-irigated arable land) and 242 (complex cultivation patterns) areas. In the first case, this referred to 13.0% of existing addresses and in the second one – 10.8% of their number. It is worth paying attention to the much higher share of addresses under realization (buildings under construction) on arable land (as much as 23.4%), whereas with regard to the class of complex cultivation patterns both shares were not only much lower but even the same (10.8%).

The share of the addresses and buildings of different types existing outside the class 1 is also illustrated in maps (Figure 2). It turns out that most of such address points and single-family houses are located in the Kujawsko-pomorskie voivodeship, in north-eastern Mazovia and in the Carpathian Mountains (usually above 50% of all objects in municipalities). The addresses during construction of buildings have, however, a more dispersed, irregular pattern of location outside the class 1 of CLC. The cartographic analysis does not indicate if the higher shares were related to suburban zones, however, there are differences between them. This required a further detailed examination, which has been made in the further part of the study.

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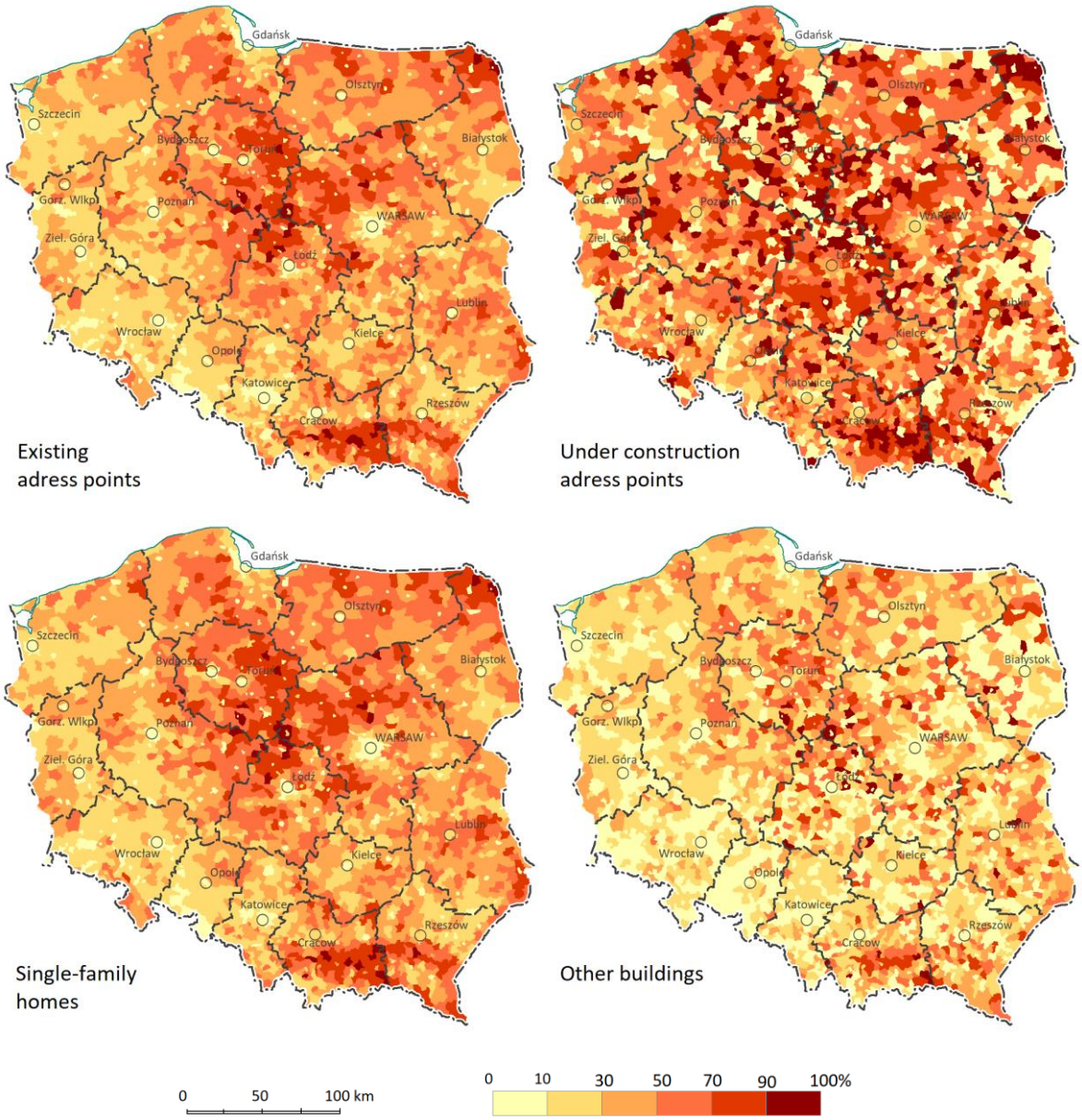

Figure 2. Share of addresses and buildings located outside the patches of class 1 (CLC 2018 – artificial surfaces). Source: based on CLC 2018 and GUGiK data.

6. Inconsistencies with regard to occurence of patches of land in CLC 2018 as well as address points and centroids of buildings

6.1. Historical regions and functional types of municipalities

The differences in occurence of address points and buildings according to types of the historical areas are presented in table 2. With regard to existing addresses and single-family houses it turns out that higher indicators of the share of objects outside class 1 (in practice it mainly refers to subclass 11) pertain to Galicia (i.e. in the vast majority this region is the area of current Małopolskie and Podkarpackie voivodeships). For the address points it is 37.0% and for investments under construction – as much as 58.6%. Areas of the former Congress Kingdom and Western and Northern Lands are next as regards the presence of addresses and buildings outside class 1. With regard to the Western and Northern Lands, the percentage of the objects outside class 1 is nearly twice lower than in Galicia. Indirectly, this is an evidence of the historically shaped structure of dispersed settlement,

which is strong in Galicia. According to B. Domański et al. [69], in this area the following factors were responsible for the settlement and agricultural fragmentation:

- since 1945 – equal division of the land between offspring, overpopulation of rural areas, fragmentation of ownership and fragmentation of farms, poverty in villages and necessity to search for sources of work outside agriculture, emigration;
- in the years 1945-1989 – socialist industrialization, commuting to work and the "farmer-workers" phenomenon, development of residential buildings in the countryside, possibility of building a house in any place of an abode;
- after 1989 – high cost of municipal infrastructure, spatial chaos, environmental degradation, increase in construction activities, shortage of investment terrains, attractiveness of plots.

The particularly high percentage of the addresses outside class 1 granted to objects during construction and forecasted for construction is symptomatic. This percentage being relatively higher than the percentage for the addresses of existing objects indicates the contemporary processes of dispersion of built-up areas. It is worth noting that the difference between the existing addresses and the addresses under realization is highest in Galicia and lowest in the Western and Northern Lands and in the former Congress Kingdom (respectively 21.5, 14.8% and 12.7% of the difference).

Table 2. Occurence of address points and buildings outside class 1 (areas artificial surfaces) of CLC 2018 according to the historical regions (according to the epoch of Partitions of Poland). Data expressed in percents. Source: based on CLC 2018 and GUGiK data.

Historical region (according to the epoch of Partitions of Poland)	Address points for addresses of buildings			Centroids of buildings	
	existing	during construction and forecast for construction	difference	residential single-family	other
Galicia	37.0	58.5	21.5	41.5	10.6
Congress Kingdom	34.7	47.4	12.7	37.7	7.5
Greater Poland, Gdańsk Pomerania and Upper Silesia	29.0	43.9	15.0	32.9	12.0
Western and Northern Lands	21.0	35.9	14.8	26.1	8.1
In total	31.3	46.6	15.3	35.6	9.2

With regard to the functional division of municipalities (communes), the following regularities have been identified. The particularly high share of objects inconsistent with class 1 refers first to the municipalities with intensively developed agriculture, since in this type of municipalities it is as much as 54.5% of single-family buildings, 52.1% of existing addresses and 31.3% of other buildings (Table 3). With regard to the addresses for investments under realization, the most inconsistencies were in the type of municipalities of so-called: "ecological" type (66.6% of single-family buildings) but in the agricultural types "H" and "I" the shares were also very high (57.4-63.2%). This data quite unequivocally indicates that class 1 from CLC 2018 can poorly be fitted for identification of dispersed built-up areas in Poland.

Table 3. Occurence of address points and buildings outside class 1 (areas artificial surfaces) of CLC 2018 according to the functional types of municipalities (Śleszyński and Komornicki 2016 [66]). Data in percents. Source: based on CLC 2018 and GUGiK data.

Types of municipalities (Śleszyński and Komornicki 2016 [66])*	Address points for buildings			Centroids of buildings	
	existing	during construction and forecasted for construction	difference	residential single-family	other
A	37.0	58.5	21.5	41.5	10.6
B	34.7	47.4	12.7	37.7	7.5
C	29.0	43.9	15.0	32.9	12.0
D	21.0	35.9	14.8	26.1	8.1
E	31.3	46.6	15.3	35.6	9.2
F	37.0	58.5	21.5	41.5	10.6
G	34.7	47.4	12.7	37.7	7.5
H	29.0	43.9	15.0	32.9	12.0
I	21.0	35.9	14.8	26.1	8.1
J	31.3	46.6	15.3	35.6	9.2
In total	31.3	46.6	15.3	35.6	9.2

* Abbreviations: A – functional urban areas of voivodeship capitals; B – their external zones; C – functional urban areas of subregional centres; D – their external zones; E – multifunctional urban centres; F – communes with developed transport functions; G – communes with other developed non-agricultural functions (tourism and large-scale functions, including mining); H – communes with intensively developed agricultural functions; I – communes with moderately developed agricultural functions; J – extensively developed communes (with forests or nature protection areas).

Additional comparisons according to the historical regions and functional types of municipalities are presented in Figure 3 (single-family buildings) and Figure 4 (addresses for objects under realization), maintaining, for comparative purposes, the same vertical scale of 0-70%. Agricultural municipalities (type H) are particularly distinguishing in Galicia but in principle in all of the historical regions of Poland they have the highest share for the observed inconsistencies among all the types. It is also worth to pay attention to the high shares of inconsistencies in suburban zones in the former Congress Kingdom and in Wielkopolska (Greater Poland), Upper Silesia and Kashubia (Gdańsk Pomerania). This confirms findings, known based on other analyses, concerning dispersion of built-up areas not only in large urban agglomerations but also around smaller towns [70].

With regard to the municipalities with tourist profile, the largest inconsistencies of anthropogenic objects with class 1 are in the former Congress Kingdom and in Wielkopolska, Upper Silesia and Kashubia (20-30%). Whereas, in all the historical regions, the smallest values of inconsistencies are connected with the biggest cities (with regard to single-family buildings it is only below 2%).

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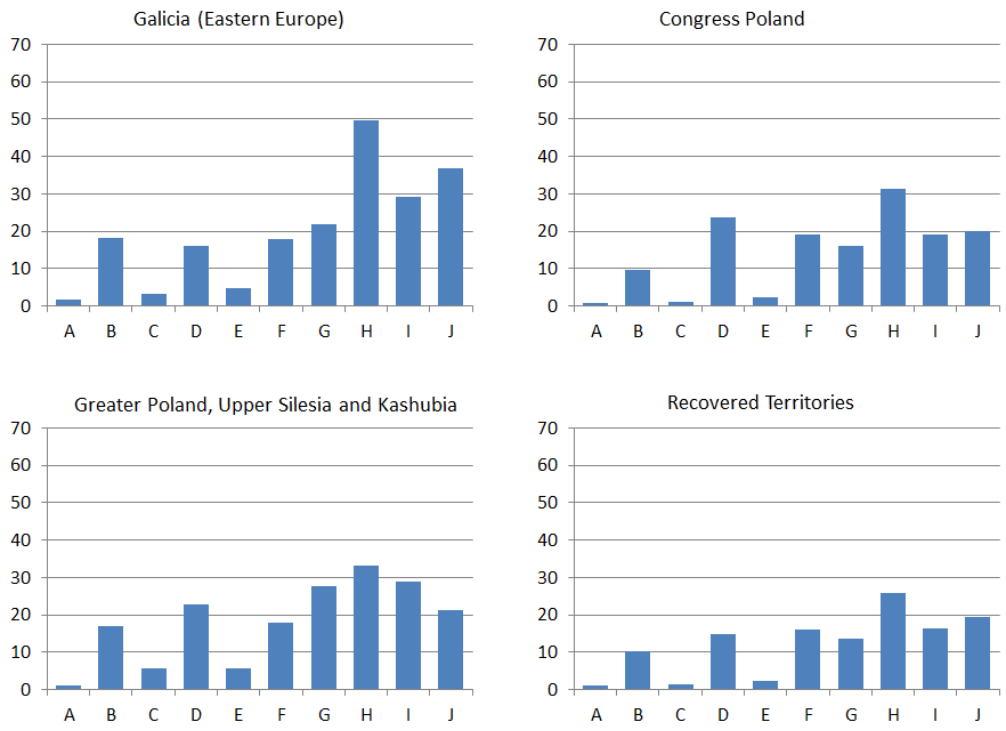

Figure 3. Occurence of single-family buildings outside class 1 (artificial surfaces) of CLC 2018 according to the historical regions and functional types of the municipalities. Data in percents. Explanations: Galicia is the former Austrian partition. Congress Poland is the former Russian partition. Greater Poland, Upper Silesia and Kashubia are the former German (Prussian) partition. Recovered territories are the former German territories which Poland regained after World War II. Source: based on CLC 2018 and GUGiK data.

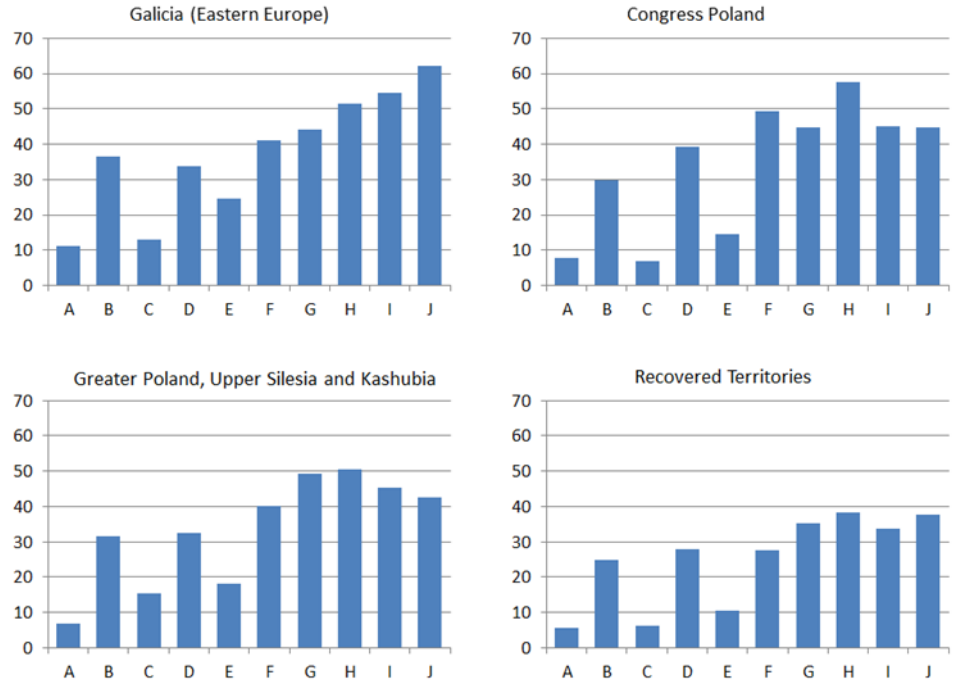

Figure 4. Occurence of address points for addresses of objects during construction and forecasted for construction outside class 1 (artificial surfaces) of CLC 2018 according to the historical regions and functional types of the municipalities. Data in percents. Source: based on CLC 2018 and GUGiK data.

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6.2. Suburban zones of cities

Further, the analyses concerned inconsistencies with class 1 in 151 suburban zones of cities and towns[10]. The diversities noticed were very large (Figure 5). In principle, the general regionally changing regularities, observed in the course of the cartographic analysis of municipalities of the whole country, are confirmed. However, separation of the suburban zones themselves allows to select, more clearly, the ones from among them which are characterized by particularly high percentage of inconsistencies of the occurrence of address points and buildings in relation to the class 1 areas of CORINE Land Cover 2018.

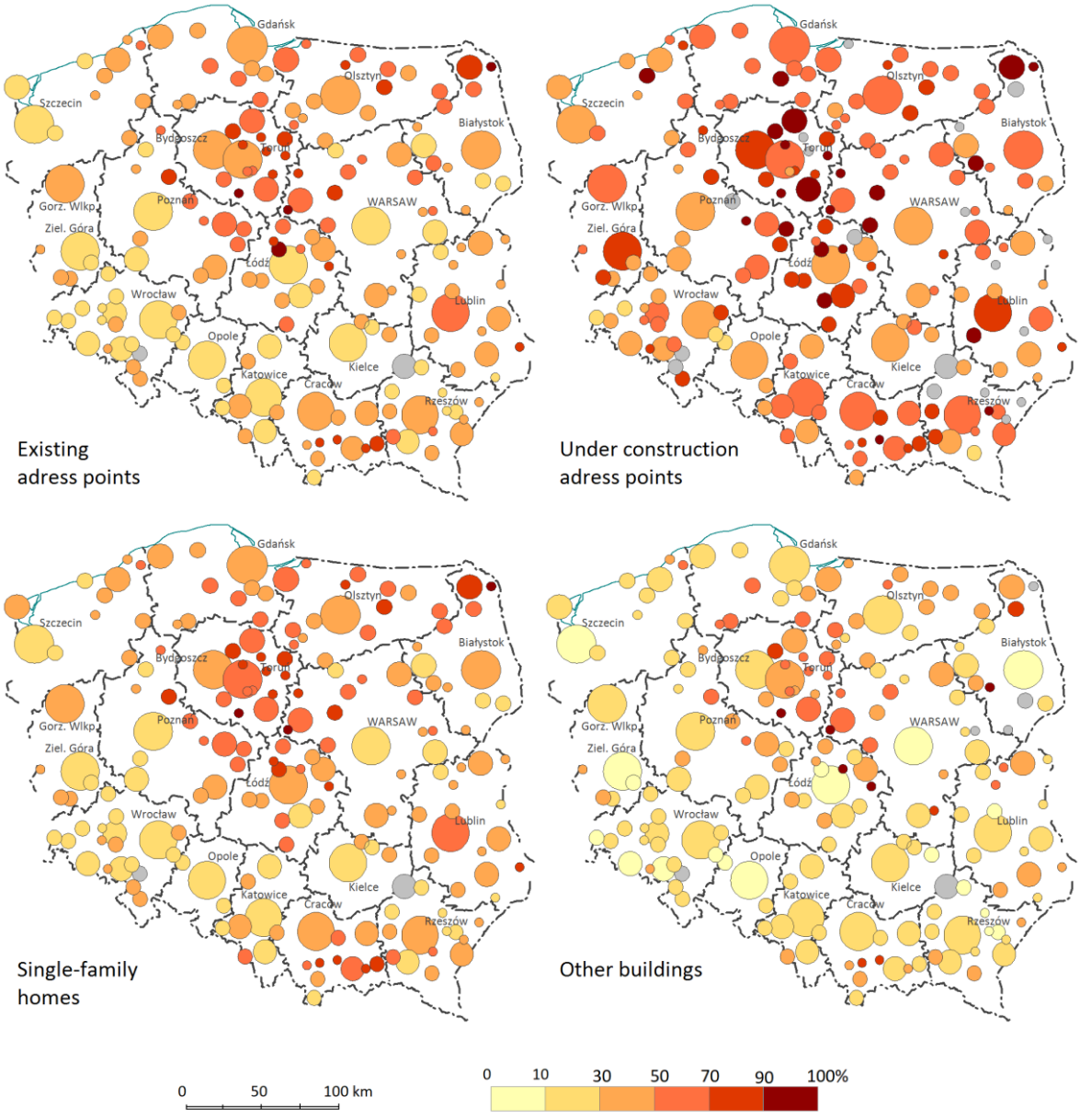

Figure 5. Share of addresses and buildings located outside patches of class 1 of CLC 2018 (artificial surfaces) in suburban zones of cities and towns (151 urban centres in Poland). Source: based on CLC 2018 and GUGiK data.

[10] The delimitation of suburban zones was developed much earlier for the needs of the ESPON 1.4.2 project "Study on urban functions". It was based on population density indicators and land use structure.

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This refers in particular to the medium-sized cities of central and northern Poland (Grudziądz, Inowrocław, Suwałki) as well as some big ones in these regions (Bydgoszcz, Toruń). Within this scope, also the suburban zone of Lublin is distinguishing in south-east Poland, as well as some medium and smaller centres in Małopolska (Lesser Poland) – in southern Poland (e.g. Nowy Sącz). Also in the case of these analyses it is proven than the biggest inconsistencies in the scale of the country refer to the address points for buildings under construction. It shows the increasing dispersion of built-up areas in the suburban zones (e.g. Zielona Góra, apart from the above-mentioned centres).

Additional analyses of the correlation in the scale of the whole country carried out in 151 suburban zones did not show almost any statistically significant co-existence of inconsistencies of location of the address points and buildings in relation to the class 1 of CLC 2018 with the spatial diversity of the indicators on realization of the spatial planning policy in the municipalities (spatial development plans coverage, decisions on building conditions, changing the status of farmland) as well as the demographic and migration indicators (registered inflow of people) (Table 4). This must be interpreted in such a way that the character of dispersion of buildings in Poland is durable and the contemporary processes only consolidate this state. Only two weak correlations (positive and negative) were noticed in the case of:

- share of the area of terrains intended for housing in the "studies on conditions and directions of spatial development" of municipalities with address points and centroids of single-family buildings (both +0.23),
- population density (-0.23 for existing addresses, -0.22 for centroids of single-family buildings and -0.27 for centroids of other buildings).

Table 4. Results of the analysis of correlation for the dependent and independent variables calculated for 151 suburban zones. Source: based on CLC 2018 and GUGiK data.

Independent variable	Dependent variables: share of objects existing outside class 1 (artificial surfaces)			
	address points for addresses of buildings		centroids of buildings	
	existing	during construction and forecasted for construction	residential single-family	other
Population density	-0.23	-0.12	-0.22	-0.27
Local spatial development plans (MPZP) coverage	-0.12	-0.09	-0.11	-0.17
Share of residential areas in the Study on conditions and directions of spatial development (SUiKZP)	0.23	0.15	0.23	0.15
Share of residential areas in the Local spatial development plan (MPZP)	-0.03	-0.01	-0.02	-0.07
Number of decisions on building conditions per 100 ha	-0.05	0.06	-0.06	-0.03
Share of changes in the status of farmlands in the area of the MPZP coverage	0.13	0.06	0.13	0.05

Share of changes in the status of farmlands in the area of municipalities	-0.10	-0.07	-0.09	-0.08
Registered inflow per 1,000 residents in 2004-2018	-0.05	-0.07	-0.07	0.00

Coefficient of the Pearson linear correlation, value R^2, confidence level >0.9. Abbreviations: A1 – existing address points, A2 – address points for buildings during construction and forecasted for construction, B1 – residential single-family buildings, B2 – other buildings.

6.3. Types of landscape

The analyses were also conducted based on 6 types of landscape, drawn up on the basis of new physio-geographical regionalization of J. Solon et al. [64] Results are collated in Table 5. The analyses show that the inconsistency pertains in particular to the Carpathian region and, thus, the mountain areas, located in southern and south-east Poland (as much as 45.9% of inconsistencies of the existing address points with CLC 2018 and 66.3% in the case of the forecasted ones, as well as 50.7% of single-family houses). The second ones are lakelands i.e. areas which also have diversified terrain features, mainly of post-glacial genesis. In the lakelands as much as 40.8% of single-family houses are outside the class 1 of CLC 2018. The obtained results show, therefore, the correlation between the investigated inconsistencies and the diversity of the terrain features.

Table 5. Existence of address points and buildings beyond class 1 (anthropogenic areas) according to the landscape types. Data in percents. Source: calculations based on physio-geographical regionalization (Solon et al. 2018 [64]).

Types of municipalities, according to physio-geographical regions (based on Solon et al. 2018 [64])	Address points for addresses of buildings			Centroids of buildings	
	existing	during construction and forecasted for construction	difference	residential single-family	other
Lowland - Lowlands	30.6	42.0	11.4	33.8	5.7
Lowland - Shores	18.6	36.4	17.7	22.2	8.6
Lowland - Lakelands	35.5	47.0	11.4	40.8	15.5
Uplands, Podkarpacie	27.3	47.5	20.2	31.0	7.1
Mountains - Carpathians	45.9	66.3	20.3	50.7	16.0
Mountains - Sudetes	16.6	39.5	22.8	21.8	5.0
In total	31.3	46.6	15.3	35.6	9.2

7. Conclusions

The main methodological, cognitive and practical conclusions are as follows:

1) The analyses made reveal that the exhaustive examination of the processes of dispersion of built-up areas in Poland based on CLC 2018 data is very difficult or even impossible. It results from two major reasons. Firstly, a considerable part of the existing buildings is located in the form of single buildings distanced from each other (as isolated structures). Therefore, the starting point of the analyses, i.e. subclasses of the class 1 of CLC 2018 – artificial surfaces, are burdened with a large error related to interpretation of the existing land development. Secondly, the character of the new building developments is even more dispersed, as a result of which the observed changes in the area of class 1 CLC patches do not contain the sufficient and actual increase of new terrains, in particular, residential areas.

2) For the foregoing reasons, also the use of the results from the analyses on the processes of dispersion of buildings based on CLC 2012-2018 changes (and for the earlier periods) is difficult or sometimes even impossible. Since the changes in classification of the terrains to the artificial surfaces (urbanized areas) take place abruptly both in places with considerable concentration of new buildings (big developers' investments) and in the case of relatively small extension of the scope of built-up areas in places with old settlement (in particular rural), which so far has not been indicated in CLC as the built-up areas but as complex cultivation patterns (terrains of complex systems of crops and plots, with sparsely located buildings).
3) The largest regional differences occur in central and southern Poland, which arises from the specific character of the historical development of Polish lands (partitions, occupation, parceling of lands during the agricultural reform after the World War II). The consistency of class 1 CLC patches with location of buildings increases in particular towards the western direction (it refers, inter alia, to the lands recovered after the World War II).
4) It was proven that the big differences in inconsistency of the addresses and buildings with delimitations (patches) of class 1 pertain in Poland not only to suburban zones but also to a large part of typically rural areas. This shows the need for construction of more precise systems for land cover registration than those which are presently available for the whole country, following e.g. the Urban Atlas databases of Copernicus program available so far only for the environs of selected cities.
5) It was confirmed that there is a correlation of the inconsistency of the actual built-up areas with CLC 2018 classes on terrains with diverse terrain features i.e. in particular on mountain terrains (Carpathian Mountains) and lakelands. At the same time, the existing settlement is more concentrated in the area of the Sudetes.
6) The research shows that in the scale of the continent it is probably difficult to compare Poland with other countries (however, the inconsistencies of locations of buildings and patches of artificial surfaces of CLC class 1 in other European countries are unknown). This shows the need for carrying out comparative research in different countries. Results of the research may be of key importance from the perspective of assessment of the urbanization processes.
7) There are considerable differences in terms of definitions between categories of land use and land cover in CLC and classes of the terrain used in national registers, reference data and metadata, including the BDOT (Topographic Objects Data Bank) in Poland - which highly hinders not only comparison of results of the research conducted based on these sources but also direct juxtaposition of these data.

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