

Article

The Problem of Mismatch between the CORINE Land Cover Data Classification and the Development of Settlement in Poland

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Abstract: The main goal of the article is the evaluation of usefulness of CORINE Land Cover (CLC) data—acquired predominantly by visual interpretation of Landsat satellite imagery—for monitoring of changes in settlement development and land use. This has been done by comparison of occurrence of buildings (and address points) in Poland with delimitations of land use belonging to particular classes in the 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 a 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 use 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.e., 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, i.e., the curbing of food-zones in the metropolitan areas [12].

CORINE Land Cover includes datasets 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 a 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 incompatibility 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 a residential single-family, in relation to the CLC 2018 delimitations, i.e., the most up-to-date CORINE dataset. The hypothesis is that these data are not suitable for monitoring of socio-economic development, land use, and spatial organization in Poland because the new buildings and built-up areas are too scattered. 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 the 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 that the biggest discrepancies concern suburban zones and tourist areas. The cognitive objective is identification of mismatch between the locations of address points and buildings in relation to class 1 of land cover in CLC 2018 (artificial surfaces) in the spatial structure of the country. We have identified significant development outside of the urban fabric (class 1 of CLC 2018). Building permits suggest greater change in the future that still may not be captured by the CLC data acquisition methodology. The development is occurring below the spatial resolution associated with the CLC data. The practical objective is formulation of conclusions and recommendations for the monitoring of land use.

In light of the research problem and objectives presented above, the following questions appear. Is the problem one of scale CORINE Land Cover data—meaning that some buildings are not enough to change classification of particular areas, due to the spatial resolution of the CLC datasets? Is the problem misclassification of land cover—meaning that the CLC classification rules are simply incorrect (e.g., agricultural classification when it should be urban)? Is the problem one of classification categories—meaning that some relevant categories are lacking (e.g., “low density residential”)? The authors attempted to answer these questions.

2. Study Area

The research area is the whole territory of Poland, which has been analyzed according to several classification methods (Figure 1). First, all communes (municipalities) have been assigned to the four historical regions, mostly in line with divisions from the Partitions of Poland period (1795–1918), i.e.,

- the Congress Kingdom or Congress Poland (along with the Białystok District), which is the former Russian partition,
- Galicia, which is the former Austrian partition,
- Greater Poland (Wielkopolska) along with Upper Silesia and part of Pomerania (including Kashubia), which formed the former German (Prussian) partition,
- Western and Northern Lands (along with Opole Silesia), being the former German territories which Poland regained after World War II.

This division is quite frequently used, since the historical conditions still have a significant impact on the land use structure in Poland. A detailed delimitation has been conducted recently by P. Łysoń [26].

Second, the functional typology of communes by P. Śleszyński and T. Komornicki [27] has been applied. It was drawn up specially for the needs of monitoring of the spatial planning, therefore its use in this study seems to be particularly useful. In this classification, 10 types of communes were distinguished based on administrative and settlement hierarchy of cities, socio-economic functions, and dominating land use. Third, with regard to the 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 [28] and described, i.e., in the study of P. Korcelli et al. [29] (p. 23). This delimitation, based on population density indicators and land use structure, included 151 suburban zones of all towns and cities over 20 thousand residents. Fourth, the natural regions classification according to the latest physio-geographical regionalization of J. Solon et al. [30] has been applied.

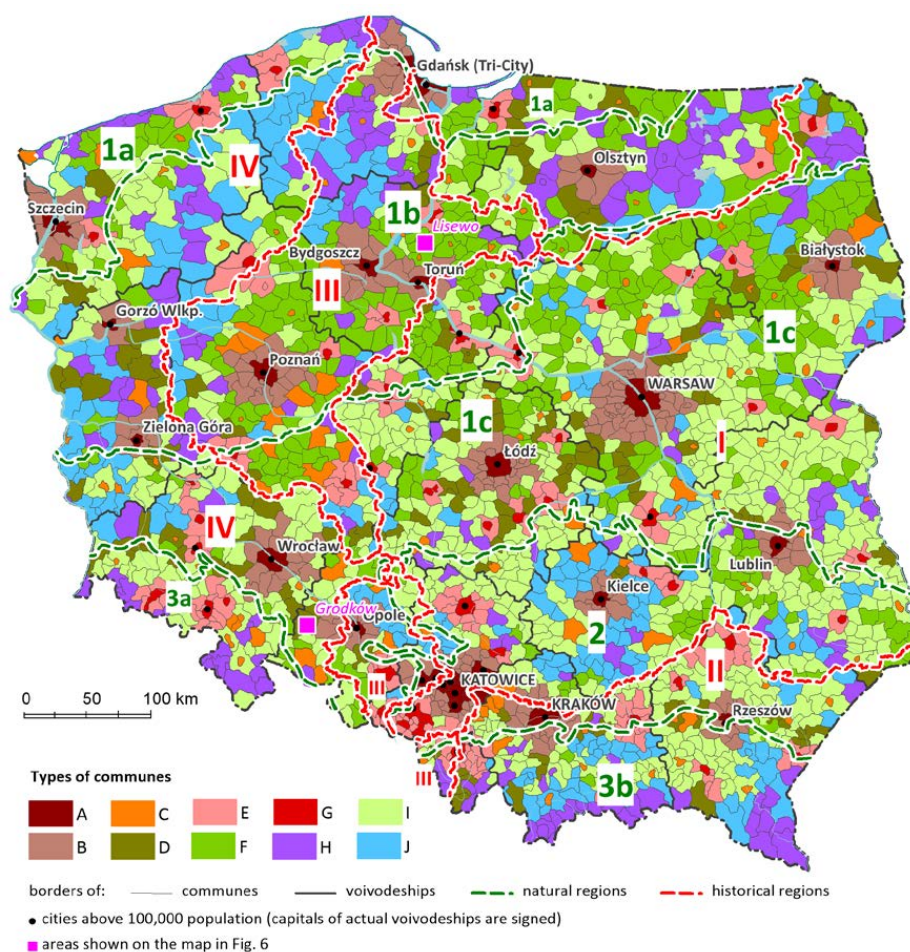


Figure 1. Division of Poland into natural regions, historical regions, and types of communes, used in the study. Explanations: Types of communes according to the classification of P. Śleszyński and T. Komornicki [27]. A—functional urban areas of voivodeship capitals; B—their external zones; C—functional 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). Types of natural regions according to the latest physio-geographical regionalization of J. Solon et al. [30]. Abbreviations on the map: 1a—lowlands: Coastlands; 1b—lowlands: Lakelands; 1c—other lowlands; 2—uplands and Northern Subcarpathians (including basins); 3a—mountains—Sudetes; 3b—mountains—Carpathians. Historical regions: I—Congress Kingdom (with district of Białystok); II—Galicia; III—Greater Poland, Gdańsk Pomerania (Kashubia), and Upper Silesia; IV—Western and Northern Lands.

3. Materials and Methods

Within the scope of digital vector spatial data it is necessary to indicate in Poland the existence of country-wide data from the Topographic Object Data Bank (BDOT) [31,32] (being for a large part a generalized version of the Register of Lands and Buildings, made accessible in counties—poviats), or data from the address points database PRG [33]. A 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 created on the basis of geodetic measurements. 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>).

The free of charge remote sensing data available worldwide includes, i.e., the medium-resolution images from Landsat satellites (with a spatial resolution of 15–30 m) which were the basic material for preparation of the database on the land cover and land use in Europe—CORINE Land Cover (CLC) [34,35]. So far, five editions of this database have been published, for the years: 1990, 2000, 2006, 2012, 2018. The coordinator of the works on the CLC and the main administrator of the database is the European Space Agency (ESA), however in each country a different institution deals with the preparation of these datasets. 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 minimum mapping unit of CLC is 25 ha, whereas the minimum width of the linear object represented in the database is 100 m. The areas that are smaller in terms of surface or narrower linear objects are not identified. The complementary data collections—CLC change have a 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 six-year sub-periods for 2000–2018. The CLC database has been designed as a basis for the creation of medium-scale (1:100,000) maps of land cover, particularly useful for the interregional comparisons.

In Europe, higher resolutions have Urban Atlas maps—a project developed as part of GMES (Global Monitoring for Environment and Security) which circumvents the 1:100,000 (25 ha) scale limit [36]. Here, however, maps are created only for selected areas around large cities, so they do not cover the entire EU territory, while changes in buildings are observed and should be monitored everywhere. Another example of the increase in the spatial resolution are the “fourth-level” CLC maps, however, they were prepared only in some countries and classifications used in them are inconsistent with each other [37].

CORINE Land Cover in general has three-level classifications of areas. It must be noted that the third level of 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. Special attention in the research was paid to the following classes from the CLC ([19], pp. 75–79):

111—continuous urban fabric—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, 112—discontinuous urban fabric—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 an 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,

211—arable land—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 the size of the plots is of no importance here,

242—complex cultivation patterns—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.

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:

- 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 areas of CLC, according to the divisions into: (1) Historical regions, (2) natural regions, (3) functional types of communes, (4) suburban zones of cities.

The basic calculations were conducted in the QGIS (Quantum GIS ver. 2.14.3 Essen, QGIS ver. 3.4 Madeira) software. In particular, operations were carried out of joining the attributes (according to location in the ETRS89/LAEA Europe (EPSG: 3035) coordinate system) of the following vector layers: (1) Centroids of buildings (polygon centroids for the BDOT buildings layer, obtained through geoprocessing), and (2) address points from the PRG database, with the layer (3) containing 150.5 thousand areas (patches) of CLC 2018 and covering the whole of Poland. It is most up-to-date amongst the data collections made accessible by the ESA. Afterwards, the obtained layers were linked with layer (4) of 2478 Polish municipalities from PRG (the smallest is 332 ha of area, the biggest 63,370 ha, median value is 11,671 ha), as well as the aforementioned regional divisions of Poland (historical and natural ones). 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 in the ETRS89/Poland CS92 (EPSG: 2180) coordinate system. Visualization was made with the MapInfo Professional ver. 12.5 software.

4. Results

4.1. Basic Correlations and Co-Occurrences of Buildings and Addresses with CLC Classes

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 Polish BDOT (centroids of buildings, divided into: 1. Residential single-family houses, and 2. other buildings), as well as address points from the PRG database (divided into: 1. Existing, 2. for buildings forecasted for construction, and 3. for buildings under construction). The address point database 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. The number of buildings classified according to the general category “BUBD 1110” in BDOT as “residential single-family” came to 6458.0 thousand objects and in other classes of residential buildings (i.e., “BUBD 1121”—buildings with two flats, “BUBD 1122”—buildings with three or more flats, “BUBD 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 a 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 in BDOT (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. However, only 82.3% of existing addresses in PRG 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 (14.4% of existing, 23.8% during construction, and 22.6% of the forecasted for construction). A 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 information about occurrence 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 for this type of buildings is approximately 4% higher than the number of these buildings. It might seem that these 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 total, the number of buildings in BDOT is, however, much higher (it comes to 14.7 million) than the addresses in PRG, 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 half of the area of the country).

Outside class 1 of CLC 2018—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 of class 1 (including the sub-class 11—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 address points and buildings outside the compact built-up areas were assigned to class 211 (non-irrigated 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 with 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%).

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

	Address Points for Addresses of Buildings		Centroids of Buildings	
	Existing	During Construction and Forecasted for Construction	Residential Single-Family	Other
Total number of objects (thousands)	7297	310	6458	538
Structure of location of abovementioned objects according to CLC 2018 classes (%)				
111—continuous urban fabric	0.7	0.3	0.1	6.6
112—discontinuous urban fabric	66.1	50.0	63.0	81.0
12—industrial, commercial and transport units,				
13—mine, dump and construction sites,	1.9	3.1	1.3	3.3
14—artificial, non-agricultural vegetated areas				
211—non-irrigated arable land	13.0	23.4	14.4	3.6
231—pastures	1.8	3.7	2.1	0.4
241—annual crops associated with permanent crops	0.0	0.0	0.0	3.4
242—complex cultivation patterns	10.8	10.8	12.1	0.7
243—land principally occupied by agriculture, with significant areas of natural vegetation	2.6	4.0	3.1	0.0
31—forests	2.4	3.7	3.1	0.9
Other 14 classes	0.6	0.9	0.7	0.1
In total (whole Poland)	100.0	100.0	100.0	100.0
Share of objects outside class 11 (%)	31.3	46.6	35.6	9.2

The share of the addresses and buildings of different types existing outside class 1 is also illustrated on the 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 communes). The addresses during construction of buildings have, however, a more dispersed, irregular pattern of location outside class 1 of CLC. The cartographic analysis did not indicate if the higher shares were related to suburban zones, however, in reality some differences between them do exist. This required a further detailed examination, which has been made in the further part of the study.

With regard to co-existence of particular groups of objects in all 2478 municipalities of Poland, the results of the correlation for the shares of the objects outside class 1 are as presented in Table 2. The strongest correlation is between the address points (PRG) 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.

Table 2. Correlation for the presence of objects outside class 1 patches of CLC 2018 in all municipalities of Poland.

	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 R^2 , 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.

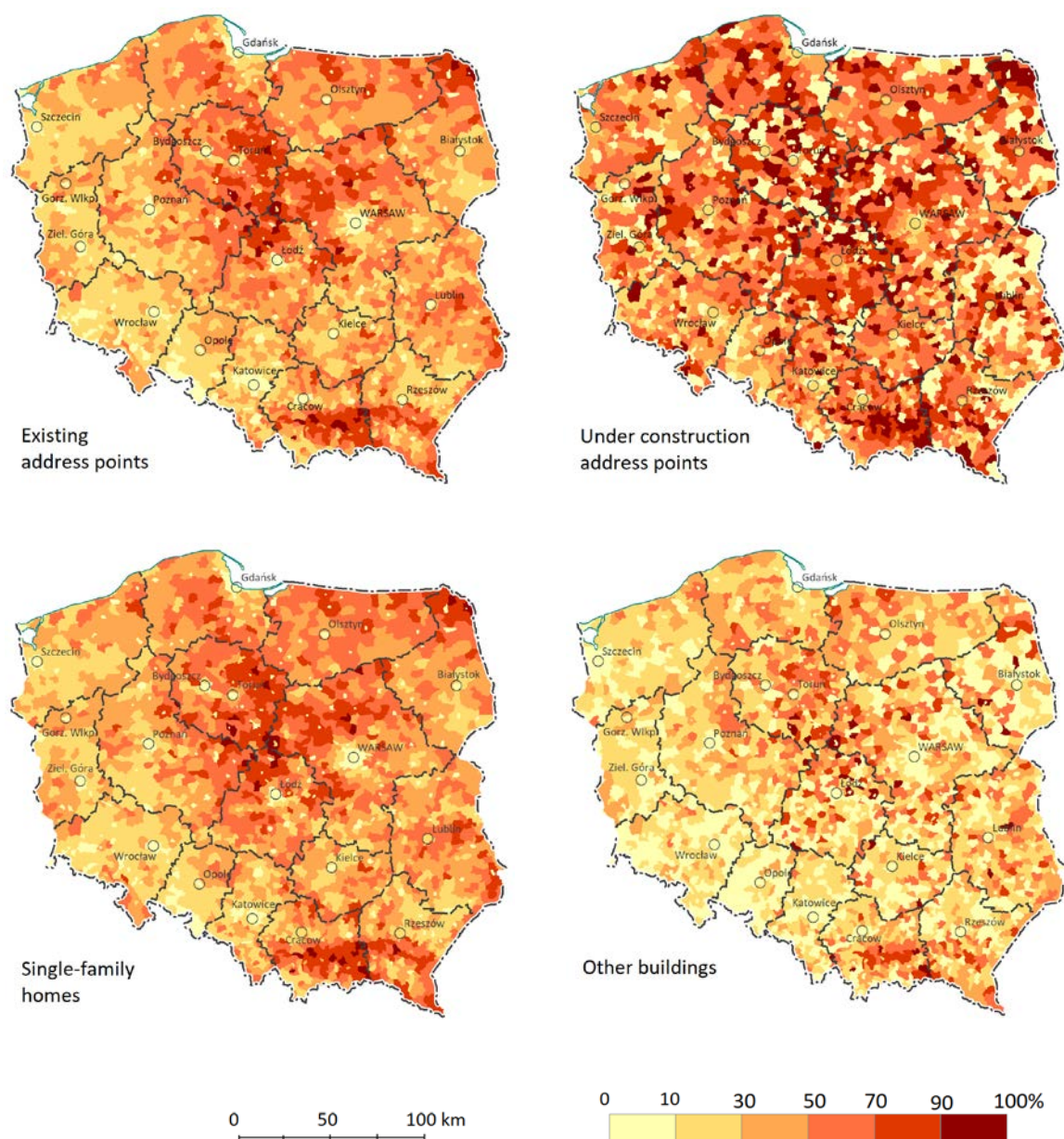


Figure 2. Share of addresses and buildings located outside the patches of class 1 in Poland (CLC 2018—artificial surfaces). Source: Based on CLC 2018 and GUGiK data.

4.2. Development Patterns in Historical Regions and Functional Types of Communes

The differences in occurrence of address points and buildings according to the historical regions of Poland are presented in Table 3. 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 (south-east Poland, 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 58.5%.

With regard to the functional division of municipalities (communes), the following regularities have been identified. The particularly high share of objects inconsistent in location with class 1 of CLC refers to the municipalities with intensively developed agriculture (type H), and it is as much as 54.5% of single-family buildings, 52.1% of existing addresses, and 31.3% of other buildings (Table 4). With regard to addresses for investments under construction, the most incompatibilities were in the

type of municipalities of “ecological” type J (66.6% of single-family buildings) but in the agricultural types “H” and “I” the shares were also very high (57.4%–63.2%).

Table 3. Occurrence of address points and buildings outside class 1 of CLC 2018 (artificial surfaces) according to the historical regions. Data expressed in percentages. Source: Based on CLC 2018 and GUGiK data.

Historical Region	Address Points for Addresses of Buildings			Centroids of Buildings	
	Existing	During Construction and Forecast for Construction	Difference	Residential Single-Family	Other
Galicia (Eastern Europe)	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 (whole Poland)	31.3	46.6	15.3	35.6	9.2

Table 4. Occurrence of address points and buildings outside class 1 (areas artificial surfaces) of CLC 2018 according to the functional types of communes (Śleszyński and Komornicki 2016 [27]). Data in percentages. Source: Based on CLC 2018 and GUGiK data.

Types of Communes (Śleszyński and Komornicki 2016 [27]) *	Address Points for Buildings			Centroids of Buildings	
	Existing	During Construction and Forecasted for Construction	Difference	Residential Single-Family	Other
	In %				
A	5.5	18.1	12.6	7.5	1.0
B	29.6	48.2	18.6	30.3	12.7
C	8.3	29.3	21.0	9.5	2.6
D	32.2	51.6	19.4	34.3	18.9
E	13.4	34.8	21.3	16.1	3.3
F	38.5	51.0	12.4	41.8	17.0
G	37.4	56.7	19.4	42.7	17.4
H	52.1	57.4	5.3	54.5	31.3
I	42.2	63.2	21.0	45.2	19.3
J	44.0	66.6	22.7	47.6	21.5
In total (whole Poland)	31.3	46.6	15.3	35.6	9.2

* See detailed abbreviations below Figure 1.

Comparisons according to the historical regions juxtaposed with the functional types of communes are presented in Figure 3 (for single-family buildings) and Figure 4 (for addresses for objects under construction), 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 the historical regions of Poland they have the highest share for the observed incompatibilities among all the types.

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

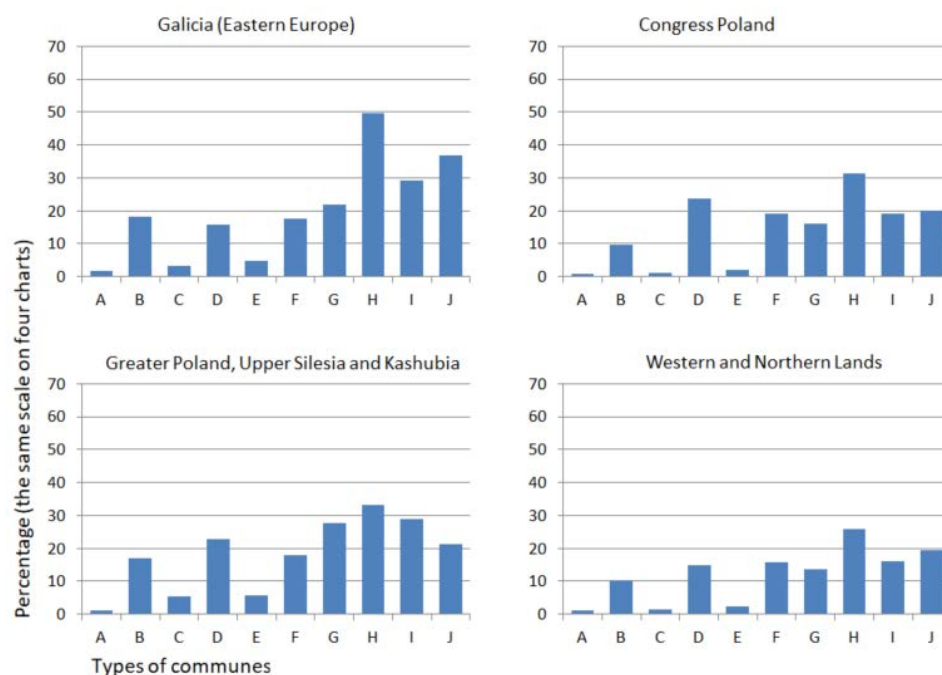


Figure 3. Occurrence of single-family buildings outside class 1 (artificial surfaces) of CLC 2018 according to the historical regions and functional types of the communes. Data in percentages. Source: Based on CLC 2018 and GUGiK data.

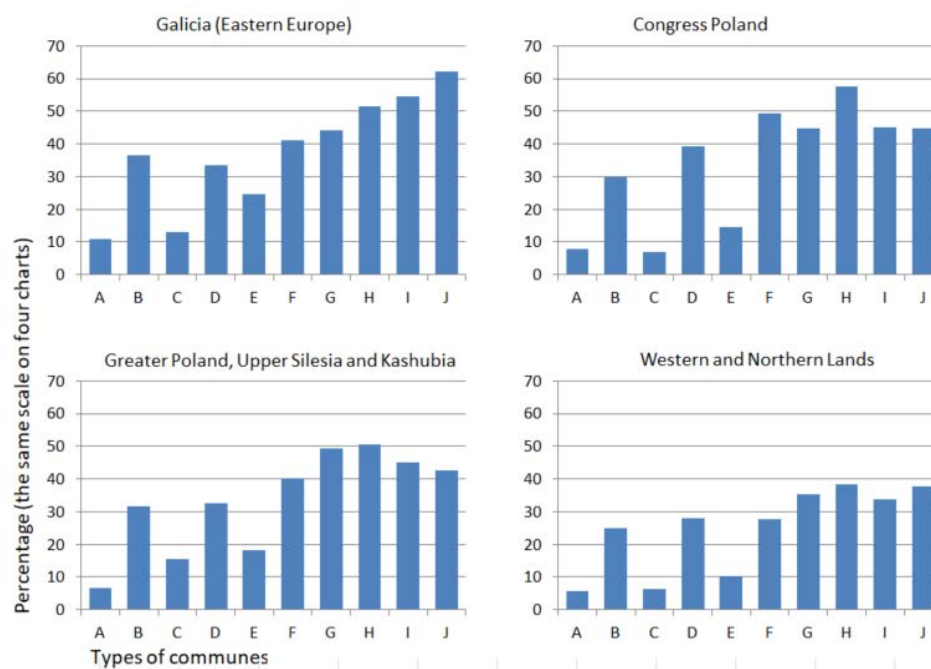


Figure 4. Occurrence of address points for addresses of objects during construction and forecasted for construction outside class 1 (artificial surfaces) of CLC 2018 according to the historical regions and functional types of the communes. Data in percentages. Source: Based on CLC 2018 and GUGiK data.

4.3. Spatial Incompatibilities according to Suburban Zones of Cities

Further, the analyses concerned incompatibilities with class 1 in 151 suburban zones of cities and towns. The diversities noticed were very large (Figure 5). 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). Moreover, in the case of these analyses it is proven that the biggest incompatibilities 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 abovementioned centres).

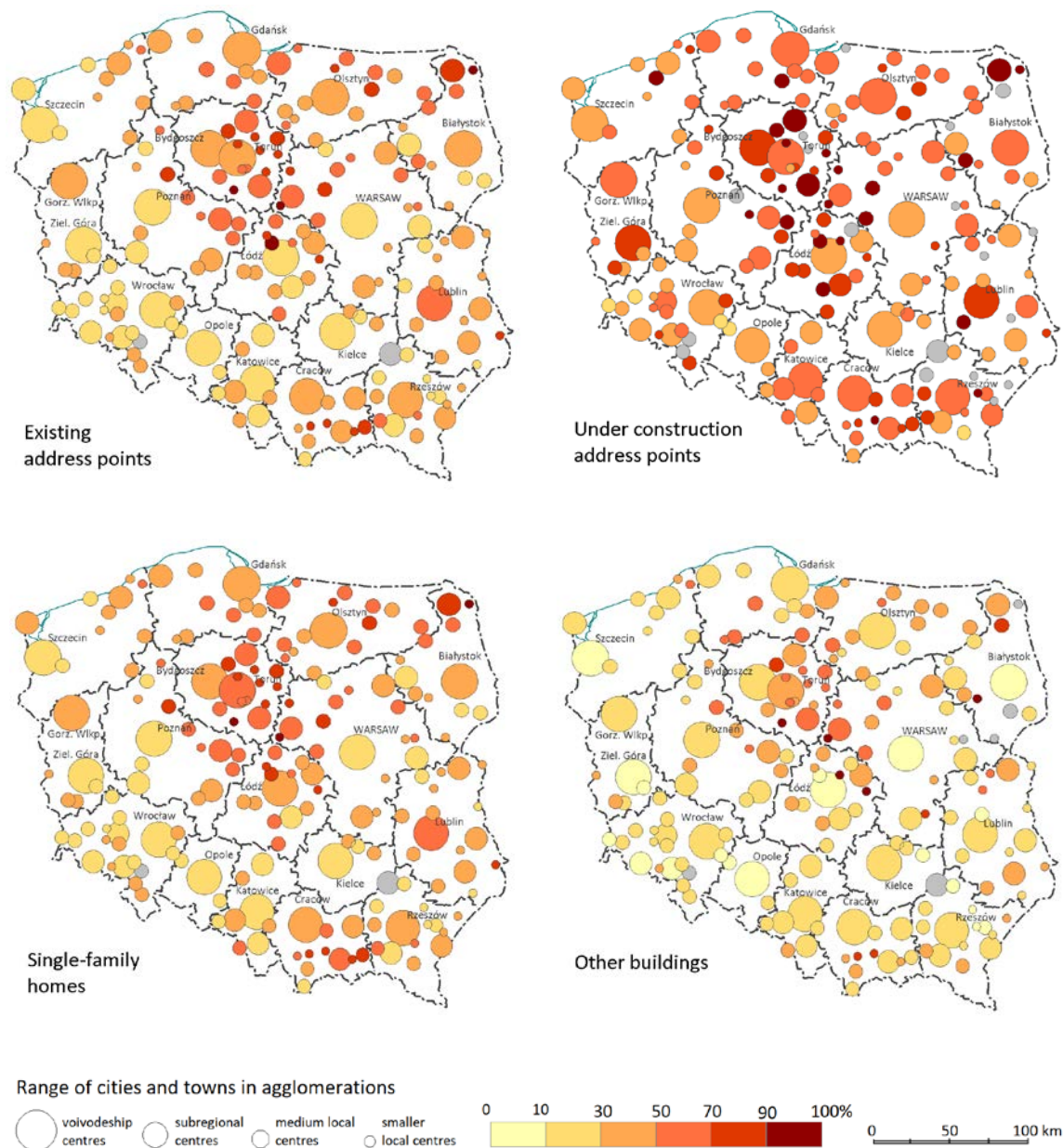


Figure 5. Share of addresses and buildings located outside patches of class 1 of CLC 2018 (artificial surfaces) in suburban zones of cities and towns (151 urban centres in Poland with a population above 20 thousand). Source: Based on CLC 2018 and GUGiK data.

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 incompatibilities of location of the address points and buildings in relation to 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 with the demographic and migration indicators (registered inflow of people) (Table 5).

Table 5. Results of the analysis of correlation for the dependent and independent variables calculated for 151 suburban zones with a population above 20 thousand. The coefficient of the Pearson linear correlation, value R^2 , confidence level >0.9 . Source: Based on CLC 2018, GUGiK data (2018) and Local Data Bank of Central Statistical Office in Poland (2018) 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 1000 residents in 2004–2018	−0.05	−0.07	−0.07	0.00

4.4. Spatial Incompatibilities according to Natural Regions (Types of Landscape)

The analyses were also conducted based on six types of landscapes, drawn up on the basis of new physio-geographical regionalization of J. Solon et al. [30]. Results are collated in Table 6. The analyses show that the mismatch pertains in particular to the Carpathians region—the mountainous area located in southern and south-east Poland (as much as 45.9% of incompatibilities 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 types of regions with the highest mismatch are the 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 located outside class 1 of CLC 2018. The obtained results show, therefore, the correlation between the investigated incompatibilities and the diversity of the terrain features. It can also be concluded that dispersed buildings and built-up areas are being located in places attractive for tourists, so some part of this dispersion may be attached with the tourist homes and vacation homes, but also with the specificity of investment in these areas (such as scattered residential housing, and possibly splitting of some farms in the Carpathians).

Table 6. Existence of address points and buildings beyond class 1 (anthropogenic areas) according to the landscape types. Data in percentages. Source: Calculations based on physio-geographical regionalization (Solon et al. 2018 [30]).

Types of Communes, according to Physio-Geographical Regions (Based on Solon et al. 2018 [30])	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, Subcarpathians (basins)	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 (whole Poland)	31.3	46.6	15.3	35.6	9.2

5. Discussion

The methodology for creating CORINE Land Cover (CLC) maps has already been discussed in the Remote Sensing journal [38], also in the aspect of suburban development dispersion analysis [39] and analysis of arable land changes [40]. It is also the subject and basis for conducting scientific discussions in various areas of scientific research [41]. However, the limitations of this database for the use in the analysis of changes in the settlement structure were relatively rarely discussed [8,19], especially in the context of reference databases for the whole country (such as PRG or BDOT), which is the subject of this article.

In particular, the subject-matter of the research was to juxtapose locations of residential buildings in Poland, identified based on the BDOT, with areas of particular land use classes delimited in CLC 2018. Verification of location of the BDOT objects with reference to the CLC patches allows assessing the reliability of CLC data for the analysis of land use (in particular, in relation to the land associated with residential buildings), as well as assessing the settlement dispersion processes and uncontrolled urbanization. Incompatibilities between the locations of the buildings and the range of the urbanized land in the CLC database are an evidence for 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 “BUBD 1110” (in BDOT)—residential single-family buildings, with reference to the land cover and land use forms identified in CLC. 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. The location of the residential building objects within the boundaries of CLC third-level 111 and 112 classes (urban fabric) should be a normal situation. Within the limits of class 242 the 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 class 242 (complex cultivation patterns) is an evidence of the dispersion of buildings, and even more it is true in case of a large share of buildings identified within class 211 (arable land), where, in principle, existence of buildings is not envisaged. Especially the ongoing or forecasted construction of many single-family residences in areas with an agricultural classification when there is a lack of population growth (so it is not a driver of land development) is surprising.

A compilation of the described data sources, i.e., BDOT, address points (PRG) and CLC 2018 is shown in Figure 6. There are examples from two regions of Poland: Kujawsko-pomorskie voivodeship (Lisewo commune) and Opolskie voivodeship (Grodzów commune). This analysis indicates large co-existence disparities, i.e., consistency of the point databases (addresses, buildings) with class 1 of CLC 2018 (artificial surfaces). The second municipality is characterized by much better matching. The characteristic pattern of development can be seen and why the CORINE methodology does not capture development along roads because of the scale issue, may be observed.

As can be seen, the results obtained indicate that the use of CLC maps in Poland faces a number of difficulties. First of all, they are associated with non-adjustment of the smallest separation in the shared database (25 ha). This unit is too large to capture not only individual investments, but even larger clusters of buildings. In Poland, 25 ha is on average about 125–250 plots (with an area of 1 to 2 thousand m²). For example, to change the CLC classification of an area having this surface from a non-irrigated arable land (211 CLC) to complex cultivation patterns (242 CLC), investment along with other changes in land use/cover would have to apply jointly to 25% percent of this area (6.25 ha), while for the discontinuous urban fabric at least 30% (7.5 ha). Such changes, in the context of the six-year change period, can only be demonstrated in areas with the strongest settlement pressure or large development investments, which is relatively rare in Polish conditions. For comparison, a low-density residential area in the United States accounts for 0.7–2.2 dwelling units/net residential acre (0.45 to 1.43 acre lots and single family farm residences) [42,43], and therefore accounts for a smaller area and a lower building density. Secondly, it has been shown that the scale and nature of

discrepancies are influenced by many features related to the functional and settlement location and the influence of the historical past. This requires a more detailed interpretation in the context of the results of the research presented in Section 3. A relatively small quantitative change in the building locations can lead to a change in the cell classification category and to a sudden change in visualization of the morphological system, which has often been shaped for centuries.

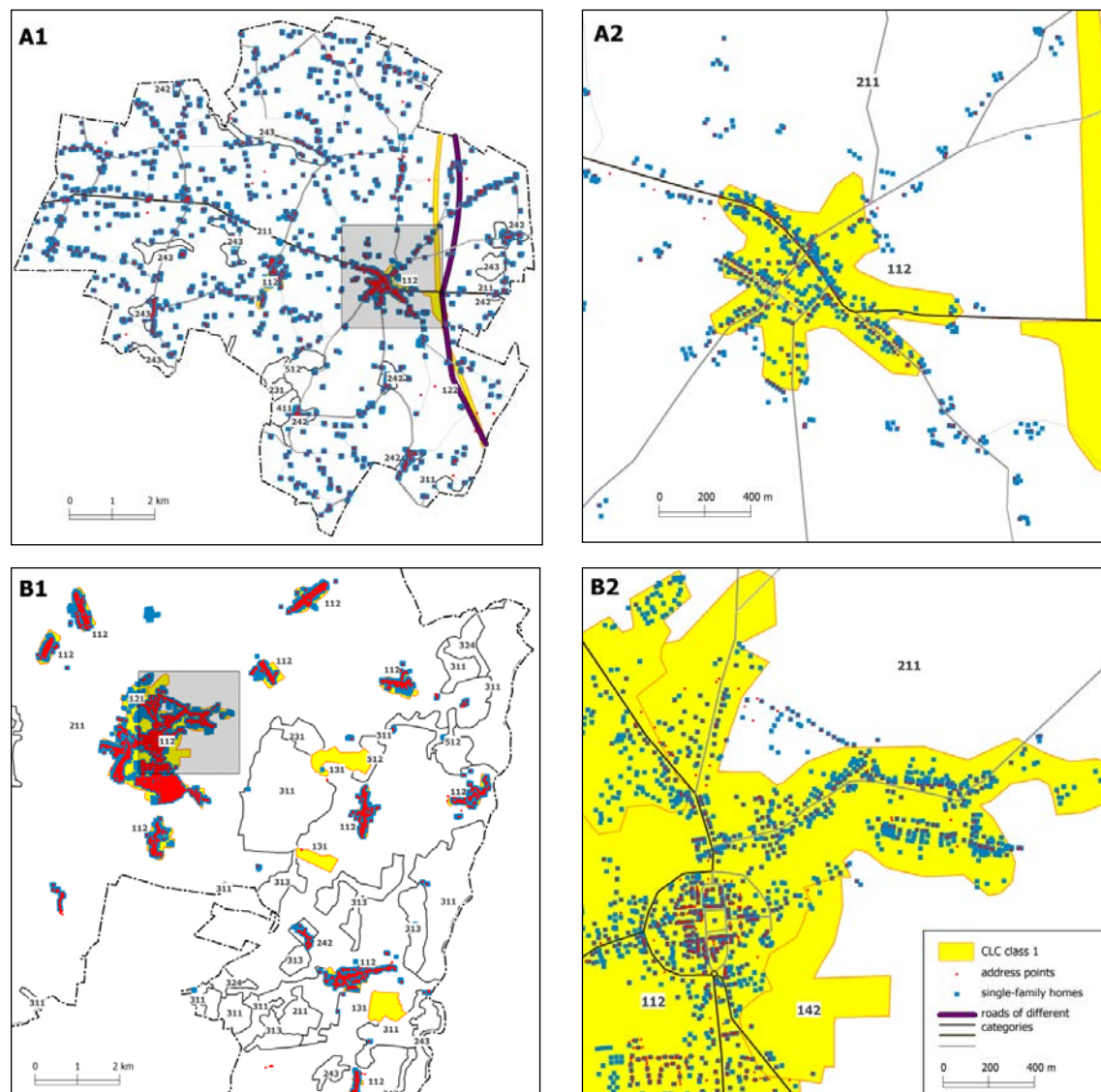


Figure 6. Co-existence of centroids of single-family houses, address points, and CLC 2018 delimitations: (A1, A2) Lisewo municipality (Kujawsko-pomorskie voivodeship); (B1, B2) Grodzów municipality (Opolskie voivodeship). Source: Based on CLC 2018 data (acquired from GIOŚ), BDOT, and PRG (acquired from GUGiK).

As a result of the historical and economic conditions which are spatially diverse, such as those resulting from the period of Partitions of Poland (1795–1918) and large shifts of state borders, contemporary regions of Poland developed, in a high degree, independently of each other, which allowed several big cities to form [44]. Eventually, the system of cities which is referred to as polycentric, was formed after World War II. On the one hand, it means that the cities located in the country's territory are of various size. The second characteristic of Polish polycentrism is quite a regular geographical arrangement of big cities (those above 200 thousand residents).

Historical processes also had an enormous influence on the rural settlement 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 degrees, as well as historically industrialized (Silesia) and peripheral lands (Lubuskie, Pomerania) belonging in the partition period or in its part to the 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 [45]. 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 [46].

Following many decades of urbanization of the country's territory, after about 1989 the process of centrifugal dispersion of built-up areas and settlement deconcentration in Poland has been pending with a particular intensity. It has been an effect of society growing rich after the economic transformation, including results of development of motorization, with simultaneous deterioration of environmental living conditions within administrative borders of cities (in particular in city centres and in the neighborhoods of obsolete blocks of flats). 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 [47,48], so that the costs of spatial chaos in Poland have been estimated recently for not less than EUR 20 billion per year [49].

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 presenting 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 CLC 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 [50]. The authors referred to the hierarchical system of physio-geographical regionalization of Poland [51], 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. Both these 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 six mesoregions—both these 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 the 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 CLC data, including the fact that small areas of low-scale changes (less than 25 ha) were not registered [52].

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 [53]. The calculations were conducted in the layout of municipalities (communes) based on the CLC 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-Gdynia-Sopot).

The urban sprawl in Poland is most often discussed in the case of Warsaw [20,54] and other big urban centres such as Poznań [55], Wrocław [56] or Kraków [21], as well as smaller ones, such as, e.g., Olsztyn [57]. Research studies show that suburbanization in Poland also refers to the medium-sized urban centres, including district towns—capitals of poviats [58,59]. As opposed to the West European urban sprawl, the specific character of Poland consists of 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 [60]. Characteristic of post-socialist countries, including Poland, is also the phenomenon of “inner suburbanization”, taking place within administrative borders of cities [61]. It is the most noticeable, based on an analysis of the land cover, in the case of the Upper Silesia polycentric agglomeration [62], 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 [63]. 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.e., for recreation, devastation of the historical spatial layouts, and in the micro-scale, i.e., elimination of roadside trees and alleys [64]. 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) [65]. It should be noted that these changes are not captured very well by the CORINE dataset because of its spatial resolution.

Other phenomena which occur in Poland, with different intensities, 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 [66–70], and on the other hand, popularization of the phenomenon of second homes [71], increasingly brave entering of large-surface trade into rural areas [72], or even direct “revival” of some villages [73]. After the economic and political transformation, urban and rural regions were shaped, and within their limits “town-village” transition zones, i.e., peri-urbanization zones [74].

In rural areas after the transformation the urban growth was 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. Such processes were often, a result of abandonment of preparation of local spatial development plans at the expense of issuing ad hoc decisions on building and land development conditions. This is associated with agricultural intensification in some areas as well. It is worth emphasizing that such changes in the period after the transformation were also activated in other countries of Central and Eastern Europe [75]. Furthermore, a part of the agricultural land shifted to pastures, remained abandoned, or was afforested. The number of large farms increased at the expense of smaller farms. In parallel to the decrease of farmland an increase of impervious surface covers could be observed. The increase also referred to the area of meadows and grazing lands [50].

Summarizing the results of our study, we may quite unequivocally indicate that class 1 from CLC 2018 can poorly be fitted for identification of dispersed built-up areas in Poland. The character of dispersion of buildings in Poland is durable and the contemporary processes only consolidate this state. The main point here is that the spatial resolution of the CORINE methodology does not capture low-density, dispersed development, nor can it predict where such development will occur. Thus, a sudden shift in land use (agricultural to urban) in the CLC database in reality reflects many years of accumulated change. Moreover, global patterns of development are playing out in Poland, but the spatial patterns of development are culturally and historically constrained.

In the course of the analyses only two weak correlations of dispersed buildings with other variables (Table 5) 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 (positive correlations; both +0.23),
- population density (negative correlations: −0.23 for existing addresses, −0.22 for centroids of single-family buildings, and −0.27 for centroids of other buildings).

With regard to the suburban zones, the study confirmed the general regularities observed in the course of the cartographic analysis for the communes of the whole country and the historical regions. However, the analysis within the suburban zones allowed selecting more clearly those of them characterized by a particularly high mismatch between the occurrence of address points and buildings and class 1 patches of CLC 2018.

It is worth paying attention to the high shares of incompatibilities in suburban zones in the former Congress Kingdom and in Wielkopolska (Greater Poland), Upper Silesia and Kashubia (Gdańsk Pomerania). This confirms findings, known from other studies, concerning dispersion of built-up areas not only in large urban agglomerations but also around smaller towns in Poland [76]. With regard to the Western and Northern Lands, the percentage of the objects outside CLC 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. [77], in this region 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 addresses granted to the objects during construction and forecasted for construction (in PRG) outside CLC class 1 patches 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 of buildings under construction is the highest in Galicia and the lowest in the Western and Northern Lands and in the former Congress Kingdom (respectively 21.5%, 14.8%, and 12.7% of the difference).

6. Conclusions

The analyses made have revealed that the exhaustive examination of the processes of dispersion of built-up areas in Poland based on CORINE Land Cover 2018 data is very difficult or even impossible. Thus, the hypothesis that these datasets are not suitable for monitoring of socio-economic development,

land use, and spatial organization in the case of Poland was confirmed. It results from two major reasons (see the first two points below). The main conclusions are as follows:

- (1) Firstly, a considerable part of the existing buildings is located in the form of single objects distanced from each other (as isolated structures). Therefore, the starting point of the analyses, i.e., subclasses of CLC 2018 class 1—artificial surfaces, are burdened with a large error related to interpretation of the existing land development. The case is that the basic resolution of the CLC, where the minimum mapping unit equals to 25 ha (and 100 m of width in the case of linear objects) is not enough to detect a considerable part of the new development taking place. The problem in Poland is the strong dispersion of investment activities, which rarely takes a sufficiently concentrated spatial form to be able to change the classification of land cover in such a large area. Since many small areas are invested, due to the generalization of maps (and class definitions used) in CORINE Land Cover they are not captured at the level of generalization of 25 ha. This is not simply a problem of incorrect land cover classification. In addition to the data resolution (spatial scale), it also results from the adopted definitions of individual categories of land use.
- (2) Second, 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.
- (3) For the foregoing reasons, also the use of the results from the analyses on the processes of spatial dispersion of built-up areas 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 take place abruptly both in places with a considerable concentration of new buildings (big developers' investments) and in the case of a relatively small extension of the scope of built-up areas in places with an old settlement (in particular rural), which so far has not been indicated in CLC as a part of the complex cultivation patterns (terrains of complex systems of crops and plots, with sparsely located buildings).
- (4) The largest regional differences occur in central and southern Poland, which arise from the specific character of the historical development of Polish lands (partitions, occupation, parceling of lands during the agricultural reform after World War II). The consistency of class 1 CLC patches with the location of buildings increases in particular towards the western direction (it refers, *inter alia*, to the Western and North Lands after World War II).
- (5) It has been proven that the big differences in incompatibility 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.
- (6) It has been confirmed that there is a correlation of the incompatibility 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.
- (7) The research shows that in the scale of the continent it is probably difficult to compare Poland with other countries (however, the mismatch of locations of buildings and the patches of CLC class 1 in other European countries is unknown to the authors). 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.
- (8) 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 the comparison of results of the research conducted based on these sources but also direct juxtaposition of these data.

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