GEODESY AND CARTOGRAPHY
Vol. 68, No. 2, 2019, pp. 245–260



DOI: https://doi.org/10.24425/gac.2019.128466

*Research paper*

# On the use of Global Urban Footprint to the Polish settlement vector database development

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Received: 6 June 2019 / Accepted: 2 September 2019

**Abstract:** Urbanization has a far-reaching impact on the environment, economy, political and social processes. Therefore, understanding the spatial distribution and evolution of human settlements is a key element in planning strategies that ensure the sustainable development of urban and rural settlements. Accordingly, it is very important to map human settlements and to monitor the development of cities and villages. Therefore, the problem of settlements has found its reflection in the creation of global databases of urban areas. Global settlement data have extraordinary value. These data allow us to carry out the quantitative and qualitative analyses as well as to compare the settlement network at a regional, national and global scale. However, the possibility of conducting both spatial and attribute analyses of these data would be even more valuable. The article describes how to prepare raster data so that they can be implemented into a vector database. It answers the questions whether it is possible to combine these data with databases available in Poland and what benefits it brings. It presents the methods of data generalization and the optimization of time and disk space. As a result of the study, two vector databases with GUF data were developed. The first database resolution is similar to the original (~12 m resolution) database, the second database contains less detailed (~20 m resolution) data, generalized using mathematical morphology. Both databases have been enriched with descriptive data obtained from the National Geodetic and Cartographic Resource.

**Keywords:** settlement, GUF (Global Urban Footprint), generalization, mathematical morphology

## 1. Introduction

The development of Earth observation technologies (EO) as well as software and tools for data processing, causes increasing availability of these data, and their dissemination for various types of research (Gamba et al., 2012; Politis et al., 2019). New sensors and methods deliver new products, and the availability of HR/VHR resolution imagery results in more spatially detailed maps (Florczyk et al., 2016).

According to UN data, in recent decades the world has been urbanizing rapidly. In 1950, only 30 per cent of the world's population lived in urban areas, a proportion that grew to 55 per cent by 2018 (DESA UN, 2018). By 2050, all but five countries or areas in Europe are projected to be at least 60 per cent urban, and three of the remaining five – Bosnia and Herzegovina, the Faroe Islands, and the Republic of Moldova – will be more than 50 per cent urban. All of Northern America and half of the 48 countries or areas in Europe are expected to be at least 80 per cent urban in 2050 (DESA UN, 2014).

Urbanization has a far-reaching impact on the environment, economy, political and social processes. Therefore, understanding the spatial distribution and evolution of human settlements is a key element in planning strategies that ensure the sustainable development of urban and rural settlements. Accordingly, it is very important to map human settlements and to monitor the development of cities and villages. Therefore, the problem of settlements resulted in the creation of global databases on urban areas. There are already a lot of available global databases, at different resolutions, that concern human settlements (Melchiorri et al., 2018; Potere et al., 2009; Schneider et al., 2009). Table 1 contains an overview of the selected available urban or urban-related datasets in Europe and in the world. However, the most relevant global products providing a static snapshot of the status on human settlement presence (and therefore built-up areas) at a decametric scale are the Global Urban Footprint (GUF) (Esch et al., 2013) and the Global Human Settlement Layer (GHSL) (Pesaresi et al., 2013). These two new initiatives promise to be capable of mapping fine-scale and complex human settlement patterns at unprecedented spatial resolutions and global scales (Klotz et al., 2016; Melchiorri et al., 2018). Such products as GUF and GHSL will extend their applicability way beyond global analysis of core urban areas. In fact, they lay the foundation for monitoring the growth of cities as well as the regional evolution of peri-urban and rural settlement patterns in high spatial detail, independently and at global scales (Klotz et al., 2016). Other settlement databases are highly accurate on a global scale, while for local use, e.g. the country, are no longer sufficient.

Global Urban Footprint is available in the form of a raster, where the values 0 are assigned to 'land surface' and 255 to 'urban areas'. Apart from displaying and 'visual' analyses, it is not possible to perform advanced spatial-attribute analyses. For this reason, it is important to try to combine these raster data with vector databases, and thus with all information stored in the attribute tables.

In Poland, settlement datasets are collected as one of the layers of the Database of Topographic Objects (BDOT10k) at the scale of 1:10,000 in the form of individual buildings and built-up areas and made available free of charge only for scientific purposes (Dz.U. 2011 nr 279 poz. 1642, 2011). On the other hand, in the fully available General Geographic Objects Database (BDOO) at the scale of 1:250 000 localities are presented as points, whereas the built-up areas are heavily generalized (Dz.U. 2011 nr 279 poz. 1642, 2011). For this reason, the latter base is not suitable for the detailed analyses of the development of the urbanized coverage. It is therefore essential that regional or global maps of urban land use not only show the point location of cities or the spatial

Table 1. An overview on the selected available urban or urban-related datasets (source: own work based on (Klotz et al., 2014; Melchiorri et al., 2018; Potere et al., 2009; Schneider et al., 2009)

| Extent | Name of the dataset | Thematic resolution | Spatial resolution | Year(s) | Original data source |
|---|---|---|---|---|---|
| WORLD | Global Land Cover 2000 | 22 classes, 1 – artificial surface | 30″ (~1 km) | 2000 | SPOT4-VGT |
| | GlobCover | 22 classes, 1 – artificial surface | 300 m | 2004–2006, 2009 | MERIS |
| | Global Human Built-up and Settlement Extent (HBASE) | % impervious surface | 30 m | 2010 | Landsat |
| | MODIS Urban Land Cover | Urban / Non-urban | 1 km, 500 m | 2001–2002 | MODIS |
| | Global Human Settlement Layer | Built-up / population grids / settlement model | 38 m / 250 m / 1 km | 1975, 1990, 2000, 2015 | ENVISAT ASAR |
| | Global Urban Footprint | 3 classes (urban areas, water, land surface) | 12 m (non-commercial use), 84 m | 2010–2013 | TerraSAR-X, TanDEM-X |
| EUROPE | European Settlement Map 2016 | Percentage built-up (pixel 10 × 10 m) | 10 m | 2010–2013 | SPOT5, SPOT6 |
| | European Settlement Map 2017 | 12 classes, 1 – built-up | 2.5 m | 2010–2013 | SPOT5, SPOT6 |

distribution of population, but also provide up-to-date information regarding the extent, growth, and physical characteristics of urban land (Schneider et al., 2009). BDOT10k is very detailed, but there is still the question of spatial and time accuracy. It is very important to maintain a compromise between these two resolutions (Potere et al., 2009) and keep in mind the timeliness of the data and the time span of obtaining these data. BDOT10k is manually vectorized, among others, from orthophotomaps, and the update takes place (not regularly) for the selected areas.

Satellite imagery has significant potential to provide more timely statistical outputs, to reduce the frequency of surveys, to reduce respondent burden and other costs and to provide data at a more disaggregated level for the decision making (Big Data UN Global Working Group, 2017). Satellite data have already been successfully used to update vector databases (Ceresola et al., 2005; Mayer, 1999). GUF has already been used as reference dataset, e.g., to compare with 20 m Global Building Map from Sentinel-1 SAR Data (Chini et al., 2018) or for regionalizing the population in administrative units (Merkens et al., 2018). The use of remote sensing data and spatial analyses is a reliable solution for urban mapping and monitoring over large areas (Taubenböck et al., 2012).

Taking the above into consideration, research was undertaken on the use of data that were obtained in 100% from satellite images to enrich databases in a vector form. Nowadays, there is a lack of a comprehensive and up-to-date spatial data of the range and spatial distribution of both urban and rural settlements in Poland. In this context, the purpose of the undertaken research was to develop an up-to-date and coherent map of the settlement network in Poland using GUF data. However, it should be stressed that GUF are raster data and in order to be able to carry out more advanced analyses, not only spatial, but also attribute ones in future, it would be useful to convert them to vector form and combine these sets with available descriptive data.

Satellite data have the advantage of being more consistent in terms of timeliness of data in large areas. BDOT data are updated but not simultaneously for the whole country. The Study does not aim to discredit BDOT data, but to present the possibility of using GUF data for thematic maps or other analyses that do not require high level of detail.

The article discusses the answers to the following research questions: Is it possible to use GUF raster data to develop a vector database? How to enrich the database being developed with descriptive data (characteristics of the settlement network)? What methods and data generalization could be used at the same time optimizing time and disk space?

## 2. Data and methods

### *2.1. Data*

In Poland, data concerning urbanized areas and their borders are made available to all users for free:

- selected layers of General Geographic Objects Database (BDOO) (level of detail corresponding to the 1:250,000 scale maps), no city boundaries available only centroids (class of objects: ADMS_P) (Dz.U. 2011 nr 279 poz. 1642, 2011);
- data from the State Register of Geographical Names (PRNG) – all named places are presented as centroids;
- data from the State Register of Borders and the Area of Territorial Division of the Country (PRG) – boundaries of units define the boundaries of cities and basic units of settlement.

The boundaries of the cities, towns and other localities are available as a layer (class of objects: ADMS_A) in the Database of Topographical Objects 1:10,000 (BDOT10k) and can be used free of charge only for scientific or educational purposes. ADMS_A contains descriptive attributes such as, among others: the official name of a locality, type of locality, ID from PRNG, ID TERC of voivodship, county and commune where the locality is situated (TERC – System of identifiers and names of territorial division units), ID TERYT of locality (TERYT – National Official Register of the Territorial Division of the Country), population, information whether the locality is the seat of the commune office, remarks. Attributes mentioned above appear to be relevant for further analysis, because they concern description of the localities and their connections to the state registers.

In the project the raster data from Global Urban Footprint (GUF) and BDOT10k vector data were employed to extract boundaries of each locality.

Global Urban Footprint (GUF) is a worldwide map of urban areas, which shows the full global spatial range of settlements with a unique spatial resolution of ~12 m and ~84 m. A total of 180,000 TerraSAR-X and TanDEM-X scenes were processed to create the GUF. The resulting map shows the Earth in three colors only: black for "urban areas" class, white for "land surface" and grey for "water". This reduction emphasizes the settlement patterns and allows for the analysis of urban structures, and hence the proportion of settled areas, the regional population distribution and the arrangement of rural and urban areas (Global Urban Footprint, 2012). GUF data for the whole globe were collected during 2-year period (2011–2012). With its spatial resolution of 12 m, the Global Urban Footprint dataset currently represents the most detailed and consistent global inventory of human settlements (Esch et al., 2018).

The Database of Topographical Objects (BDOT10k), is a spatial database of level of detail corresponding to the topographic map at the scale of 1:10,000. This base was created in 2012–2013 according to the technical guidelines enclosed in Regulation of the Minister of Internal Affairs and Administration of November 17, 2011 regarding the Database of Topographic Objects and the Database of Geographic Objects, as well as standard cartographic studies (Dz.U. 2011 nr 279 poz. 1642, 2011). It covers the following topics, contained in several layers: water network, communication network, land utilities network, land cover, buildings, structures and equipment, land use, protected areas, territorial division units, other objects.

### *2.2. Methodology*

The basis of the adopted methodology was to use data from the National Geodetic and Cartographic Resource as well as mathematical morphology operators for the development of vector database of Polish settlements based on Global Urban Footprint data. It has been assumed that vector database with various levels of detail will be developed:

- a database that retains 100% source data, without interfering with its structure, requiring only the transfer of raster into vector data enriched by descriptive attributes (~12 m);
- a less detailed database, requiring – apart from the same activities as in the first case – also generalization of the source data (in a raster form). This quantitative generalization will require removal of the smallest polygons, while qualitative generalization will cause the attachment of small surfaces to larger polygons by aggregation and removal of small holes inside larger surfaces (~20 m).

In both cases, the converting of GUF raster data into a vector form, extracting of the areas belonging to individual settlements, and then enriching the geometry of each of them with descriptive attributes is assumed. Figure 1 presents the implementation scheme of raster data into a vector database. The right part of the scheme represents the first approach, while the second approach is shown on the left.

The process of converting raster into vector data is not a difficult task, it only requires changing dataset into a vector format using simple tools. But the GUF raster data are a continuous image showing only presence (or absence) of the settlement network. However, these data do not allow the identification of the boundaries between each individual locality (e.g. city, village, hamlet) and do not include additional information on these ob-

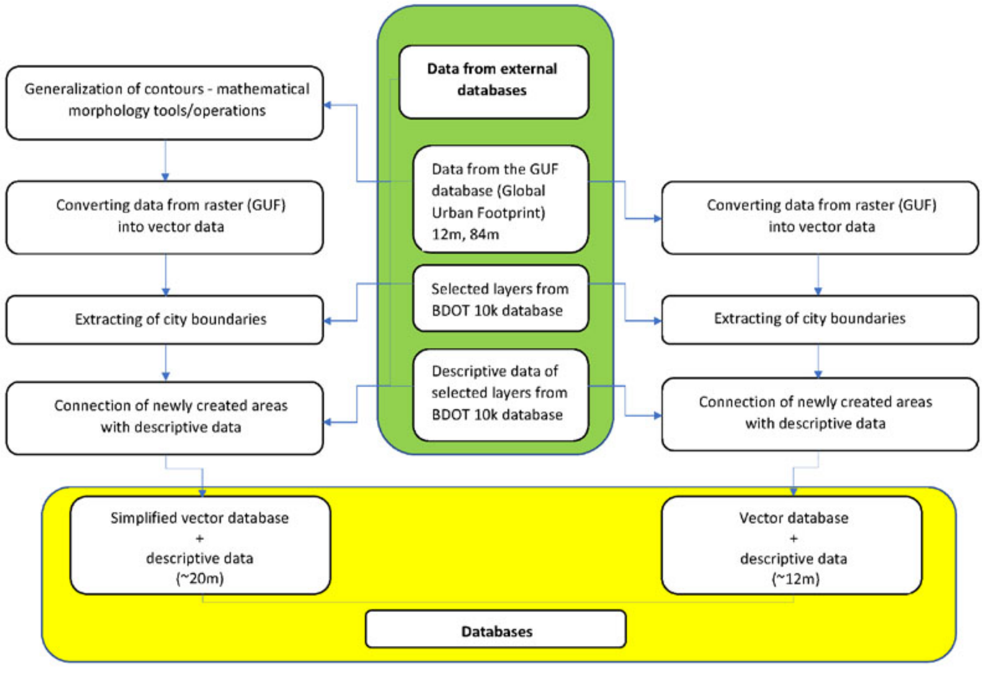


Fig. 1. The implementation scheme of raster data into a vector database (source: own work)

jects. The use of PRG data for identification of these boundaries is problematic as this database includes information on borders of cities and basic units of settlement only. This kind of unit can include many villages and there is no data about their boundaries.

Due to the shortage of PRG, the data from the Database of Topographic Objects (BDOT10k) were employed to identify the boundaries of individual settlements on the GUF data (class of objects: ADMS_A of BDOT10k). These two bases, GUF and BDOT10k, have been intersected. As the result of intersection tool, attributes of both intersected layers were copied to the final layer. Due to this process, the boundaries of individual localities have been separated on the GUF data and the attributes from the BDOT10k base have been copied to the settlement objects.

There is still no universal set of rules that clearly define how generalization should be carried out (Gashi and Nikolli, 2017). In the project, mathematical morphology was used to generalize GUF data. Mathematical morphology is a powerful tool for image analysis (Serra, 1982; Soille, 1999), developed 55 years ago. Morphological operators refer directly to the shape and when used correctly they can simplify the images while maintaining their basic shapes (Wu and Gao, 2011). Morphological operators have been used several times for the generalization of buildings, and for raster data morphological operators can be used for urban generalization (Cámara et al., 2004; Su et al., 1997). According to Lupa M. and Wu H. (Lupa et al., 2013; Wu and Gao, 2011), mathematical morphology methods can be treated successfully as a novel approach in the optimization of spatial databases and constitute an interesting subject for further research.

Mathematical morphology is already used in GIS to "clean up" raster images acquired from scanning. Such operations are performed before the scanned image is changed from a raster to a vector format. In our research morphology operations of dilatation and erosion were employed to "clean up" the data of small, unnecessary elements, to include of individual pixels in larger areas or to remove holes in the form of opening and closing tools.

Mathematical morphology operations consist in the image analysis with a structuring element (usually a square $3 \times 3$ pixels, with a central point as the analysis point). Depending on the convergence of the environment of the central point, the pixels examined and the kind of operation being performed, a new value is assigned to them. Due to the fact that mathematical morphology operations are performed on the binary images, where the pixels assume the values 0 or 255, in the case of erosion assigned value is 0 and in the case of dilation the value is 255.

The dilation (Figure 2) of a set binary image $I$ by the structuring element $E$ is defined by:

$$I \oplus E = \{(x,y)+(i,j)\colon (i,j) \in Q_I,\ (x,y) \in Q_E\} \tag{1}$$

or

$$I \oplus E = U_{(x,y)\in Q_I} E_{(x,y)} \tag{2}$$

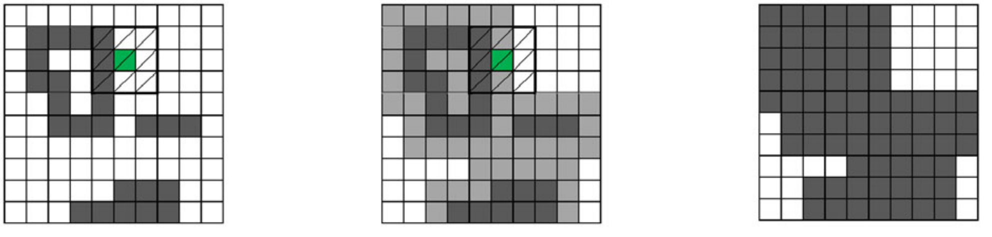

Fig. 2. Example of dilation applied on a binary image (source: own work)

The dual operation of dilatation is called erosion (Figure 3), and the erosion of a set $I$ by a structuring element $E$ is defined by:

$$I \ominus E = \{(x,y)\colon ((x,y)+(i,j)) \in Q_I,\ \text{for all } (i,j) \in Q_E\} \tag{3}$$

or

$$I \ominus E = \{(i,j)\colon E_{(i,j)} \subset Q_I\} \tag{4}$$

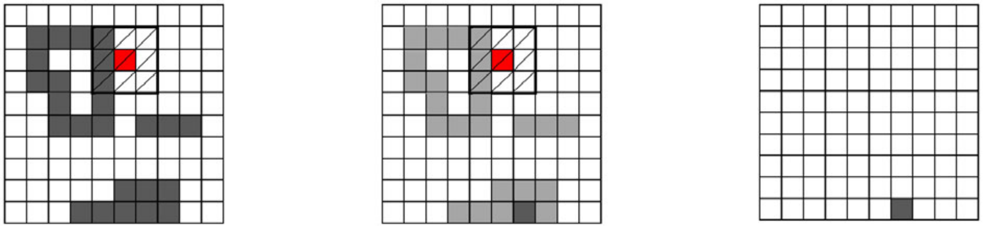

Fig. 3. Example of erosion applied on a binary image (source: own work)

The composition of the erosion and dilatation operations has interesting properties. The morphological opening (Figure 4) and closing (Figure 5) are defined by:

Opening: $$I \circ E = (I \ominus E) \oplus E \tag{5}$$

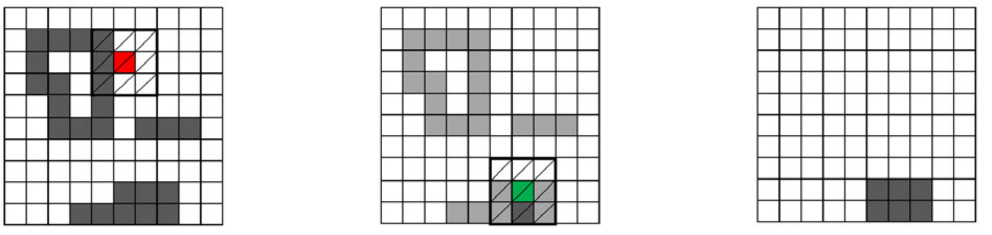

Fig. 4. Example of opening operation applied on a binary image (source: own work)

Closing: $$I \cdot E = (I \oplus E) \ominus E \tag{6}$$

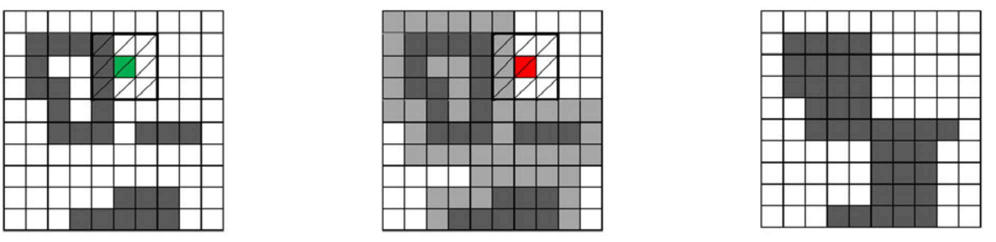

Fig. 5. Example of closing operation applied on a binary image (source: own work)

## 3. Results

During the first test of the proposed method, the GUF data were converted into vector data and divided into smaller fragments, according to the extents of occurrence of individual settlements units from BDOT10k, precisely administrative division (boundaries of cities, villages, hamlets). The results of the work are presented in Figure 6. It shows the boundaries from BDOT10k, division of the settlement geometry into particular localities as well as the attributes assigned to each of them. The detail of the target data is analogous to that of the GUF source data.

The production of a less detailed database required the use of mathematical morphology. Figure 7 shows how the geometry of GUF data changes as a result of the closing and opening process. In Figure 7a there are original GUF data (converted into a vector form), in Figure 7b the same data previously subjected to closing process, while Figure 7c presents data that were result of the closing process and then the opening process. This way, the data are first aggregated and, where possible, small surfaces are connected to larger ones. The smallest areas that have not been joined anywhere are removed in the last process – opening. By applying the closing operation first, and then opening operation, the best result was achieved. It incorporates small area elimination, detail

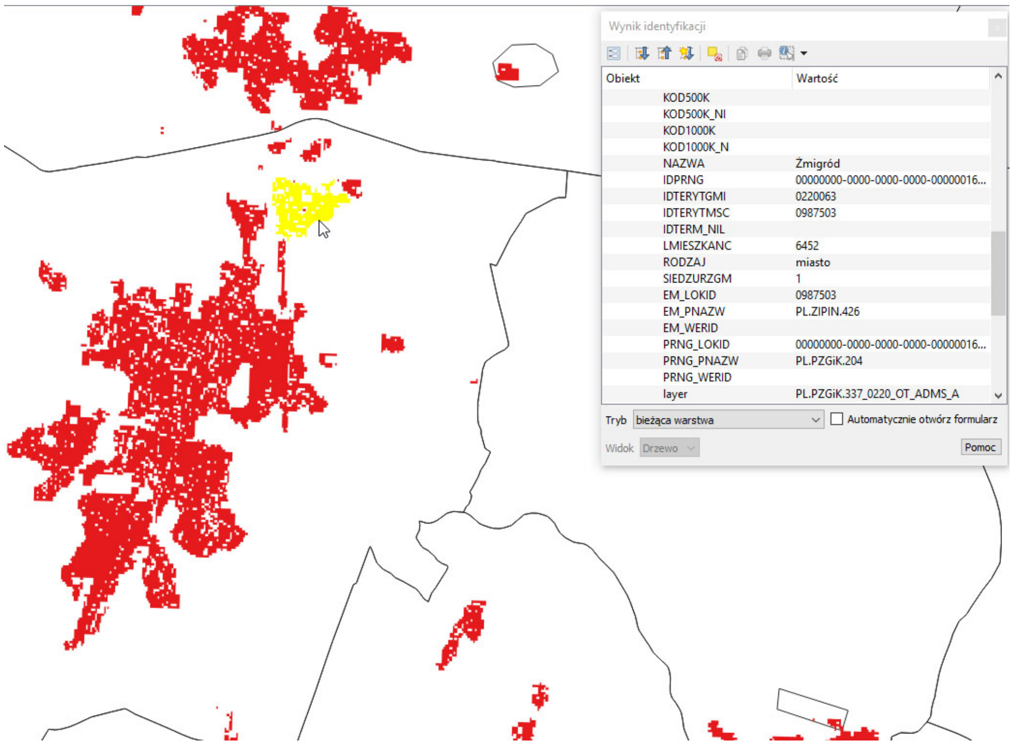


Fig. 6. The result of implementing GUF data into the vector database with details in the source data resolution and intersection with BDOT10k database (source: own work)

elimination and area aggregation and gives output of high quality – which confirms the research results of Damen et al. of 2008 (Damen, van Kreveld and Spaan, 2008).

a) b) c)

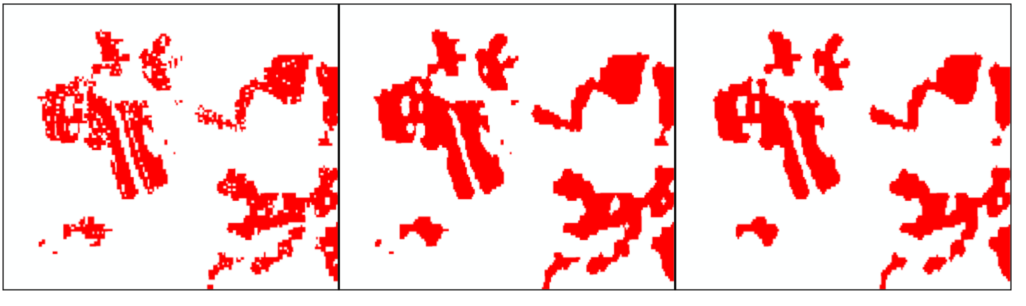

Fig. 7. Example of GUF data a) original data, b) data after the closing process, c) data after closing and opening processes (source: own work)

All operations were tested at first for the local level administration unit (Piotrkowski county), then for regional level unit (Łódzkie voivodship), and finally for the whole country (Poland).

After the closing and opening processes, the number of contours of the built-up areas of the Piotrkowski county decreased by 58.3% and the number of "zero" areas that are outside built-up areas and internal surfaces – so called holes decreased by 97.9%. For the Łódzkie voivodship it was 60.5% and 97.1%, respectively. Similar result was obtained for the entire territory of Poland, 63.3% and 97.8%, respectively (Table 2). The slight differences could be a sign of data consistency for the whole country.

Table 2. The number of contours of the GUF vector layer before and after the closing and opening processes (source: own work)

Piotrkowski county

| Layer / The number of contours | Value 0 (non built-up area) | Value 255 (built-up area) | amount |
|---|---|---|---|
| Before the closing and opening processes | 13,801 | 4,003 | 17,804 |
| After the closing and opening processes | 291 | 1,669 | 1,960 |
| Per cent of change | 97.9% | 58.3% | 89.0% |

Łódzkie voivodship

| Layer / The number of contours | Value 0 (non built-up area) | Value 255 (built-up area) | amount |
|---|---|---|---|
| Before the closing and opening processes | 166,325 | 55,346 | 221,671 |
| After the closing and opening processes | 4,860 | 21,869 | 26,729 |
| Per cent of change | 97.1% | 60.5% | 87.9% |

Poland

| Layer / The number of contours | Value 0 (non built-up area) | Value 255 (built-up area) | amount |
|---|---|---|---|
| Before the closing and opening processes | 2,972,011 | 791,302 | 3,763,313 |
| After the closing and opening processes | 64,289 | 290,435 | 354,724 |
| Per cent of change | 97.8% | 63.3% | 90.6% |

It was also noticed (Karsznia and Leszczuk, 2017) that in case of application of mathematical morphology to the generalization of vector spatial data the duration of the process itself may be an obstacle. However, for input raster data this problem does not occur. The process of closing and opening Global Urban Footprint data at a resolution of 12 m for the whole area of Poland, took 10 minutes per process.

Apart from the short time of the closing or opening process itself, the second important factor is the occupied disk space. In all cases, from the county to the entire territory of Poland, after the opening and closing processes, each of the files decreased its volume by about 50% (Table 3).

Table 3. Information on disk space before and after the closing and opening processes and conversion to the vector format (value 255 – built-up area) (source: own work)

| | Piotrkowski county | Łódzkie voivodship | area of Poland |
|---|---|---|---|
| Before the closing and opening processes | 2,881 KB | 31,168 KB | 585,808 KB |
| After the closing and opening processes | 1,389 KB | 18,388 KB | 259,527 KB |
| Per cent of change | 51.8% | 41.0% | 55.7% |

The combination of data where source format was a raster with descriptive data was also an important achievement. This solution allows carrying out spatial and attribute analyses. Thanks to this, it is possible to present data for built-up areas, depending on the type of settlement or the population (Figure 8). Such information is available in the

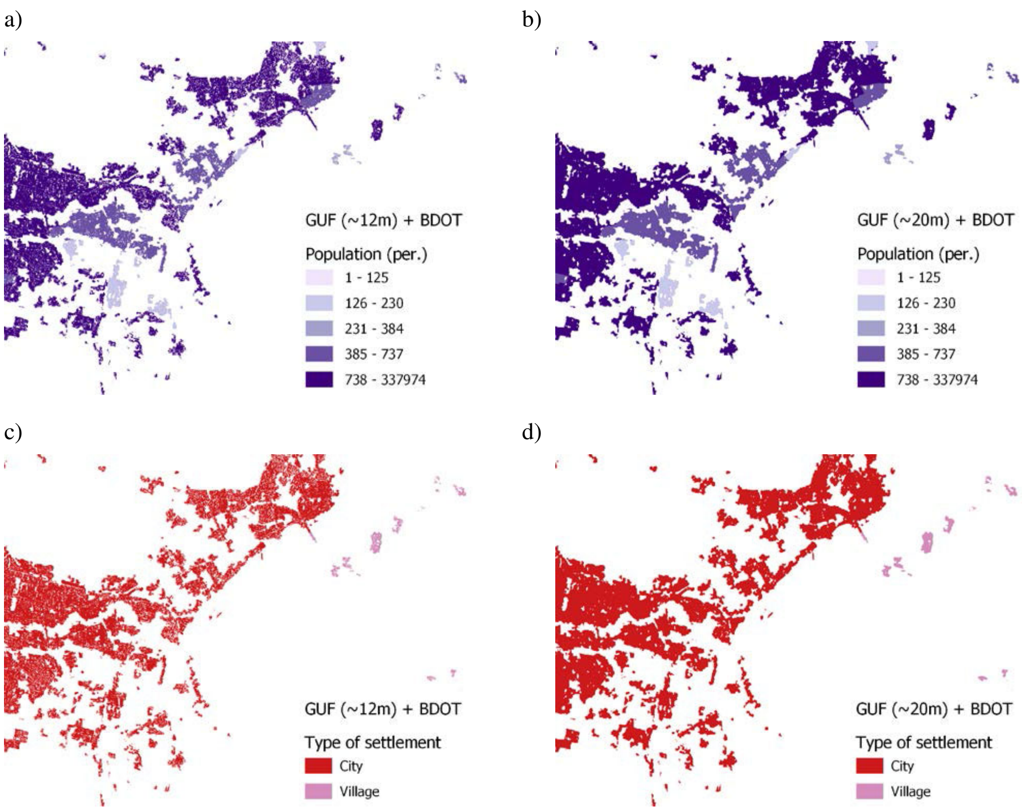


Fig. 8. An example of a GUF database subjected to processes of mathematical morphology and combined with BDOT10k and displayed depending on a), b) the number of inhabitants, c), d) the type of settlement (source: own work)

Database of Topographic Objects, with which the GUF database has been connected. Figure 8 shows the possibility of using descriptive data to present GUF data. Figures 8a and 8b shows the built-up areas distinguished depending on the number of inhabitants of a settlement (or part of it). Figures 8c and 8d show the same data with distinction of the type of settlement. From the homogeneous layer of the built-up areas the information on the extent of each settlement (or it's part), type of settlement and other descriptive information included in the database was obtained.

## 4. Discussion

The use of data from the National Geodetic and Cartographic Resource to develop the database made it possible to extract areas belonging to individual localities from the GUF. It was also possible to identify those parts of the GUF settlement network that do not belong to any of the settlements. This allowed the identification of undefined, uninhabited areas or, e.g., open-cast mines. In GUF they are identified as a settlement network whereas in BDOT10k they appear as other types of objects. If GUF data appear in such places, it is known that they are incorrectly identified or it is a problem of GUF data identification accuracy, which is still unknown for the territory of Poland, and might be a subject for further research.

Geographical space changes over the years. The natural elements change more slowly (or not at all), while the anthropogenic elements change faster. Together, they enable us to understand the topographical conditions of many phenomena. But the most important elements enabling us to orient ourselves on maps unambiguously are names (Mościcka and Kuźma, 2018).

Moreover, any official changes in locality names or administrative boundaries are published in Polish Journal of Law every year, and they on a regular basis are implemented to PRG which is the reference database for BDOT. As a result, data necessary to update GUF attributes are easily accessible.

The use of a global database obtained from satellite data and the Database of Topographic Objects not only enables spatial and attribute analyses, but also gives a broader view of the development of large cities and the disappearance of rural areas. The combination of these data also enables the assessment of correct identification of the GUF settlement network for the territory of Poland. Studies evaluating GUF data on a global scale (Esch et al., 2018, 2017; Klotz et al., 2016; Klotz et al., 2014) clearly indicate the unique cognitive value of these data in relation to the representation of rural and urban settlement systems. Therefore, it can be expected that these data will change the approach to the analysis of global urbanization and settlement models.

The study has confirmed that mathematical morphology is an excellent tool to generalize settlement network raster data (especially reducing level of detail, which corresponds to 1:10,000 – 1:20,000/1:25,000 scale maps). Generalization of these data to a scale of 1:500,000 will be the subject of further research. Certainly, however, mathematical morphology can be used to introduce small changes such as data cleansing, hole removal and smoothing. As the study results prove, mathematical morphology works much better on raster data. Therefore, if the input data are in a raster form, the opening and closing operations could be immediately applied. However, if the input data are in a vector form, it is more beneficial to convert them first into a raster form and then apply the opening and closing operations only. Actions on vector data are very time-consuming (Karsznia and Leszczuk, 2017), in contrast to actions performed directly on raster. Data prepared in this way can be implemented into a vector database.

The problem of generalization of raster data to smaller scales as well as the accuracy of the GUF database for the area of Poland will be the subject of further research. It should be stressed that recent articles on checking the accuracy of the GUF database concern individual cities or regions, depending on the place of residence of the authors (Esch et al., 2017; Minghini et al. 2017).

## 5. Conclusion

GUF data merit special attention for two reasons: firstly, these data are registered by two radar satellites so that the information is not affected by poor weather conditions or cloudiness, and secondly the resolution of the obtained data is 12 m. The GUF layer also benefits from the fact that the global input data could be collected within just two years. Hence, the GUF data base shows a unique spatio-temporal consistency that predestines it as a main layer or starting point for comparative global and/or multi-temporal studies (Esch et al., 2017). The second similar database is the Global Human Settlement Layer (GHSL), where data are obtained from Sentinel 1 and 2 satellites. At the same time, the outcome of the worldwide quality assessment confirms a high accuracy of the GUF map as it had already been indicated at the regional scales (not for the territory of Poland) by previous studies (Esch et al., 2017; Klotz et al., 2016; Muck, Klotz, and Taubenbock, 2017). With a Kappa coefficient of 0.6373, the GUF 0.4″ shows values about 0.16 higher with respect to both the state-of-the-art GHSL and GL30 layer derived from optical data (Esch et al., 2018).

It should be expected that the settlement network layer will open new possibilities in regard to the analysis of global urbanization and population assessment. The global set of data on settlement could prove invaluable for such organizations as the World Bank, government agencies or scientific and analytical centers. Both data obtained allow us to perform the quantitative and qualitative analyses and compare the settlement network at a regional, national and global scale. This could be a valuable contribution to the design of urban and regional development projects and help us understand how urbanization is linked to economic growth and how it affects, e.g., pollutant emissions. Along with other data sets from satellite Earth Observation or with population distribution data, the GUF settlement map provides a deeper understanding of the urbanization impact on global development processes.

This map of GUF data shows clusters of urban settlement, not only in the form of large agglomerations of Silesia, Warsaw, Łódź or Wrocław, but also small towns that can be identified unmistakably on this map. There are also visible types of rural settlement depending on the region. This may be the basis for studying the spatial distribution of settlements.

Thanks to the vector format of data, it is possible to store in the database information of individual localities. Various types of spatial and attribute analyses are possible as well as their presentation in the form of thematic maps, e.g. only city or rural extents.

The use of satellite data is becoming more and more popular. They are used for many studies related to population, economy, climate, sustainable development, all kinds of threats and many other issues. The possibility of implementing these data into existing vector databases, and thus the generalization of these data is valuable. The ever-growing market of publicly available satellite data which become more and more accurate every year, implies that we need to take a closer look, to develop a methodology for assessing the correctness of identification and to adapt them to various needs.

## Acknowledgements

The research was conducted in the framework of the statutory project "Map of the comprehensive settlement network in Poland" of the Institute of Geodesy and Cartography (IGiK), Warsaw, financially supported by the Polish Ministry of Science and Higher Education.

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