

Accuracy comparison of various land cover and land use sources: case study of Poznań and poznański county

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Introduction

The primary application of digital satellite image classification methods is to acquire information about land cover and land use. Land use refers to areas utilized and transformed by humans, while land cover denotes the natural state of the Earth's surface. The outcome of satellite image classification is land cover and land use maps, enabling, among other things, monitoring changes occurring on the Earth's surface. Research conducted on the example of Poznań city and poznański county aimed to assess the accuracy of six different sources of satellite-derived data, including land cover and land use. These sources were compared with the most accurate reference source in Poland - the Topographic Objects Database at a scale of 1:10,000 (BDOT10k).

Data

We utilized seven datasets pertaining to land use and land cover in both vector and raster formats for analysis: BDOT10k, Urban Atlas, Sentinel-2 Global Land Cover (S2GLC), Esri Land Cover, ESA WorldCover, CORINE Land Cover (CLC), and a processed set derived from LUCAS. These datasets are publicly available and free, mainly sourced from 2018. Other products were excluded due to either not covering the study area (USGS National Land Cover Database), inappropriate data acquisition year (GlobeLand 30, 2010), low spatial resolution (ESA CCL), or unsuitable data type (original LUCAS).

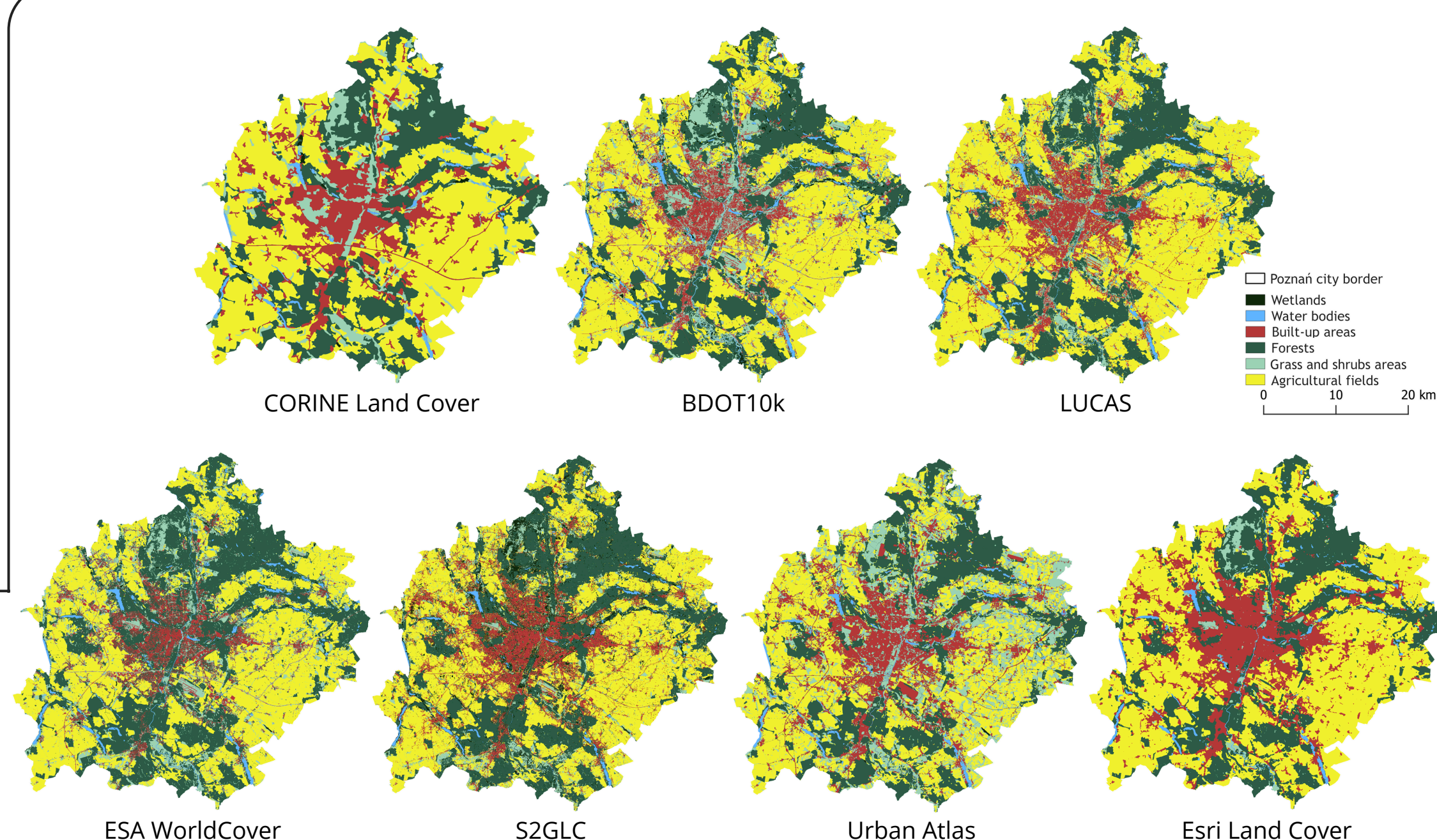
Methods

All datasets were reclassified into 6 main classes based on the manufacturer's documentation: wetlands, water bodies, built-up areas, forests, grass and shrub areas, and agricultural fields. The accuracy analysis of the data sources and classes was conducted using confusion matrix (error matrix), from which precision, recall, F1-score, accuracy, and Kappa statistics were calculated. The values of all indicators were obtained based on the proportion of classified raster cells of both compared sources.

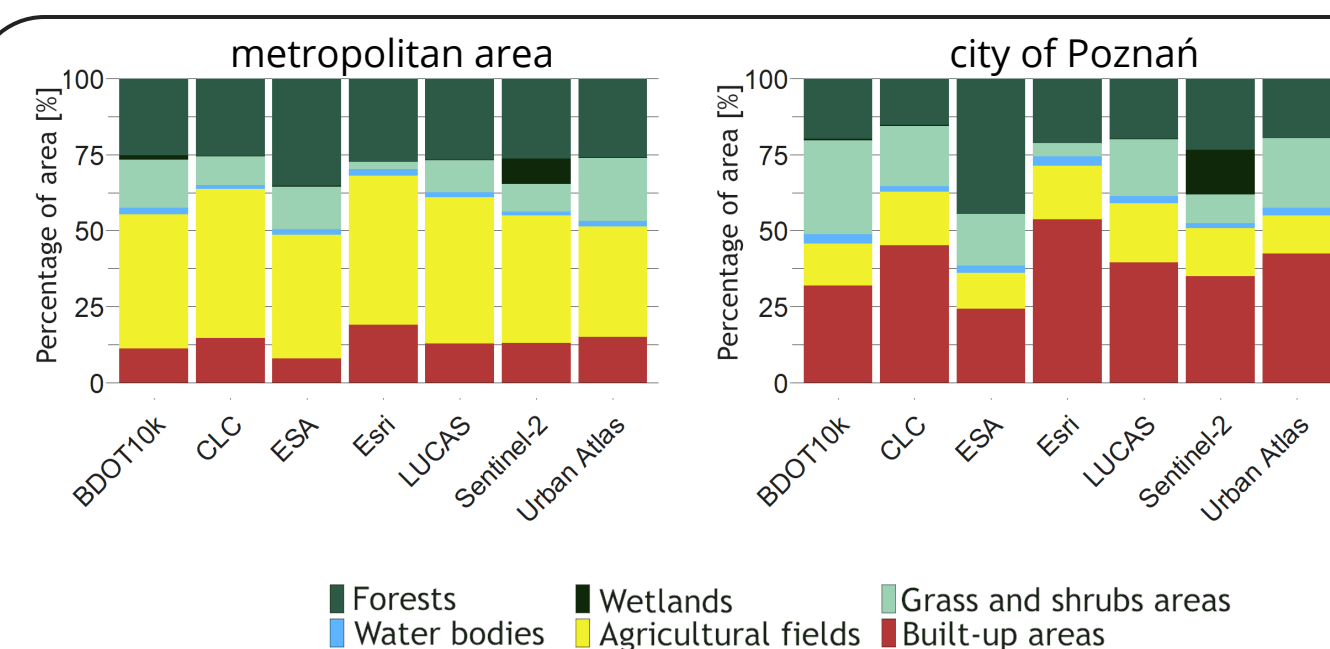
Precision refers to the percentage of areas in which a class of the data source matches the same class of the reference source (BDOT10k) - whereas recall determines the percentage in which a class of the reference source matches the same class of another data source. The F1-score is the harmonic mean of precision and recall - the higher the value, the better the classification matches the reference source. To compare classification accuracy, the proportion of correctly classified cells to all occurring cells was used, along with the Kappa statistic - a measure to determine the degree of agreement between classifications, taking into account random errors.

The spatial distribution of classes after reclassification revealed distinctive characteristics of individual datasets, visually indicating differences in original resolution or level of generalization, as well as dominant classes and tendencies towards overestimation or underestimation of specific classes. The most significant visual differences compared to BDOT10k are primarily observed in the CLC dataset, characterized by a spatial resolution of 100 meters. Among the remaining datasets, the most noticeable differences are found in S2GLC and Urban Atlas, which respectively overestimate the occurrence of wetlands and grass/shrub areas.

Results - data after reclassification

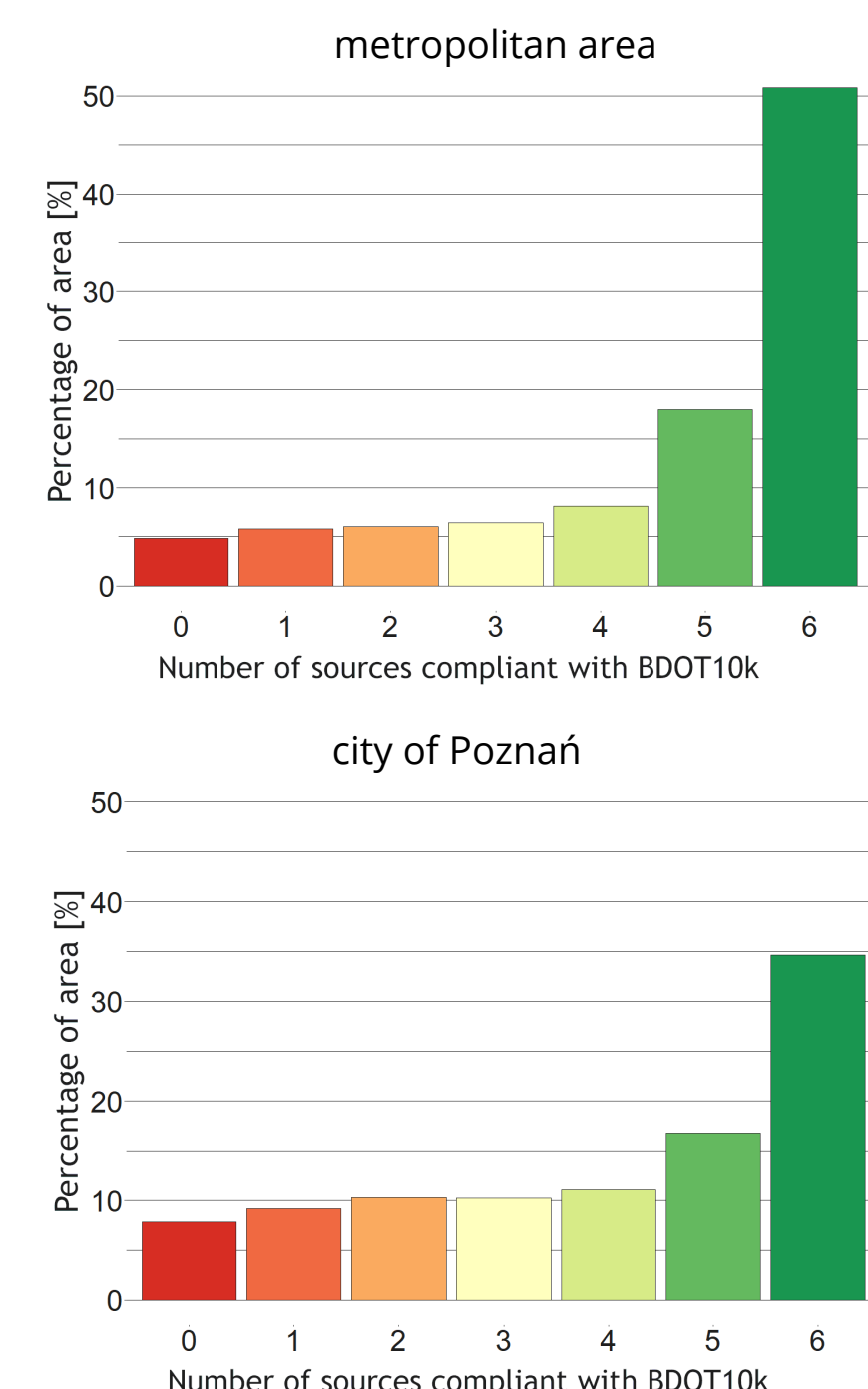


Percentage of classes after reclassification



The percentage of classes for each data source allows us to determine their overestimation or underestimation relative to the BDOT10k data source. The class exhibiting the greatest underestimation is grass and shrub areas classified within the Esri Land Cover source. One of the classes that achieved very similar values to BDOT10k is forests; however, in the case of the ESA WorldCover source, they were largely overestimated - by almost 10% for the metropolitan area and by 24.4% for the city of Poznań. The wetland areas within the S2GLC resource exhibit the greatest overestimation, with their percentage share being 7% and 14%, respectively. The percentage share of agricultural fields and water bodies for all compared sources in the metropolitan area and the city of Poznań is very close to that of BDOT10k.

Compatibility with BDOT10k

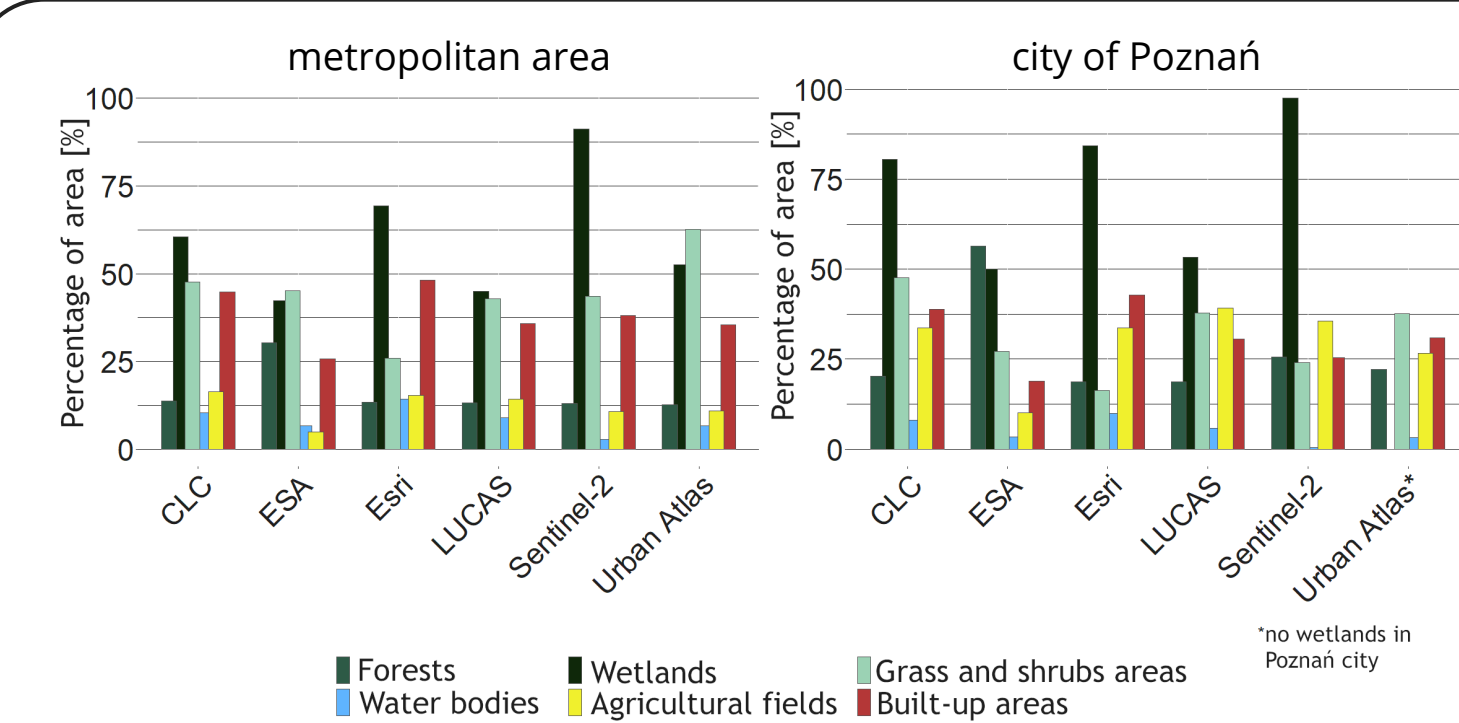


Accuracy comparison of data sources

To assess the quality and accuracy of each land cover and land use source, an analysis was conducted using confusion matrix. The most accurate resource for the entire metropolitan area turned out to be LUCAS, with an accuracy of 0.80 and a Kappa of 0.71. The weakest performer, on the other hand, was Urban Atlas, with respective accuracy and Kappa values of 0.74 and 0.64. Regarding the city of Poznań, the most accurate classification compared to BDOT10k was achieved by the Urban Atlas resource (accuracy: 0.71, Kappa: 0.6), which focuses on land cover and land use mainly in urban areas. The least accurate resource in the Poznań county was S2GLC, with an accuracy of only 0.63 and a Kappa coefficient of 0.53.

SOURCE DATASET	METROPOLITAN AREA - ACCURACY	METROPOLITAN AREA - KAPPA	POZNAŃ CITY - ACCURACY	POZNAŃ CITY - KAPPA
LUCAS	0,802	0,713	0,693	0,590
ESA WorldCover	0,786	0,695	0,644	0,535
Esri Land Cover	0,787	0,691	0,660	0,545
S2GLC	0,754	0,658	0,628	0,530
CORINE Land Cover	0,771	0,668	0,636	0,508
Urban Atlas	0,742	0,644	0,706	0,601

Accuracy comparison of classes



The class with the highest classification error, both in the metropolitan area and in the city of Poznań, is wetlands, with average errors of 0.65 and 0.73, respectively. This confirms that wetlands are the most challenging class to classify based on satellite imagery, due to spectral similarities with other land cover and land use classes and the presence of various types of wetland terrain. Other classes with fairly significant classification errors include grass and shrub areas, of which 44.6% of the metropolitan area and 31.7% of the city of Poznań were classified incorrectly, as well as built-up areas - 38% and 31.2%, respectively. The class with the highest classification accuracy relative to BDOT10k turned out to be water bodies, with average errors of 0.05 for the city of Poznań and 0.08 for the metropolitan area. Due to the significant coverage of forests (over 25% of the county) and agricultural fields (44%) in the Poznań county, these classes also stand out with low classification errors for the metropolitan area, only 0.16 and 0.12, respectively.

Summary

The obtained results exhibit lower compatibility and accuracy with the BDOT10k datasets in the area of the city of Poznań, whereas these measures assume higher values across the entire metropolitan area. Urban Atlas emerged as the most accurate land cover and land use source within the city, while LUCAS proved to be the most accurate within the metropolitan area. For the city of Poznań, the LUCAS dataset ranked as the second most accurate, with only a one percentage point difference from Urban Atlas, which, in contrast, ranks last in the case of the metropolitan area. These findings demonstrate a relatively high level of accuracy in the Urban Atlas dataset for the Poznań area, which, due to its specificity, is tailored for urban areas.

In both study areas, wetlands are the least accurate class in 4 out of 6 datasets. The obtained results confirm the difficulty of accurately classifying them from satellite images, as evidenced by the area occupied by incorrectly classified classes for each dataset. Both in the metropolitan area and in the city of Poznań, water bodies emerged as the most accurate land cover and land use class - similar results were also observed for agricultural fields across the entire metropolitan area.

The obtained results provide an approximation of the actual accuracy of the datasets and stem from the subjective classification of categories based on dataset documentation. These findings can be utilized to select the most useful dataset at the local level and also contribute to expanding research towards comparing the accuracy of land cover and land use classes with landscape metrics.

The specification of the compared data sources and the study area influences significant differences in the classification compatibility of the same areas relative to the reference source. The presented map primarily illustrates the impact of spatial complexity on the accuracy of reclassification by all land cover and land use sources - the larger and more homogeneous the areas of a given class, the greater the compatibility among all resources. The highest compatibility is observed in extensive agricultural areas, including the Zielonka Forest and the Wielkopolski National Park. There is a noticeable relationship between the compatibility and accuracy of classes and the configuration and composition of the landscape. All sources in the metropolitan area exhibit better compatibility with BDOT10k in areas with lower diversity and greater compactness of classes.

