Spatiotemporal Dynamics and Prediction of Land Cover Changes in the Warsaw Metropolitan Area

Beata Calka, Zuzanna Remiszewska, Olga Matuk (Poland) and Alexandra Gemitzi (Greece)

Key words: Land management; Spatial planning; land use prediction; sustainable development goals; LUE; PGR

SUMMARY

Land cover analysis is a key element of research on environmental transformations and spatial development, enabling the assessment of urbanization trends and the effects of human activity. Equally important is the prediction of spatial changes, which allows forecasting future transformations and supports decision-making in sustainable planning. The presented research concerns intensive spatial transformations occurring in the Warsaw Metropolitan Area, the capital of Poland, which is one of the most dynamically developing regions in the country. The main objective was a comprehensive analysis of land cover changes between 2000 and 2018 and the development of a spatial prediction for the year 2030, using geospatial data and predictive modeling in the context of sustainable development principles. CORINE Land Cover data (2000–2018) served as the primary source of information for analyzing changes and modeling future transformations. Spatial factors included the distance from roads, built-up areas and protected zones, as well as topographic elements such as elevation (DTM) and slope. Modeling was performed using a hybrid model combining Markov chains, cellular automata, and artificial neural networks. By 2030, the area of built-up land is expected to increase to over 120,000 ha, representing an expansion of approximately 10,000 ha compared to 2018. Spatial analysis indicates that the most significant changes will occur in districts adjacent to the Warsaw city district, which are already characterized by intensive single-family housing development, relatively lower land prices, and convenient access to the capital via an extensive road and rail network. At the same time, the area of agricultural land is expected to decline below 300,000 ha, while forests and semi-natural areas are projected to increase by about 2,500 ha compared to 2018. Indicators used to assess changes in the context of sustainable development revealed a considerable imbalance between the pace of urban expansion and population growth. The PGR index showed that the most intensive development occurred in the Piaseczno, Grodzisk, Legionowo, Wołomin, and Warsaw West districts. Between 2018 and 2024, PGR values exceeded 0.17 in these areas, confirming

strong investment pressure. Although this dynamic is expected to slow slightly in subsequent years, the expansion of built-up areas will remain high, especially in the Piaseczno and Warsaw West districts. This intensive development primarily takes place at the expense of agricultural land, leading to ecosystem fragmentation, loss of biodiversity, deterioration of the local microclimate, intensification of the urban heat island effect, and an increased risk of flooding. The results provide valuable insights into the directions of spatial transformations in the Warsaw Metropolitan Area and may serve as a practical tool to support responsible spatial planning and metropolitan development management in line with the principles of sustainable development.