HOW TO CATCH DEPOPULATION IN SERBIA? ALTERNATIVE APPROACH FOR DETECTION AND MONITORING

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ABSTRACT

Depopulation has been a process present in Serbia for decades, with constant progress and spatial expansion. Although depopulation is more common for rural areas, nowadays the population declining is affecting urban areas, as well. This paper is focused on the new possibilities and innovative approaches for detection and monitoring of population dynamics and economic activities, their spatial and temporal patterns and changes in Serbia. Therefore, a set of 12 indicators is created, classified into four groups: demographic indicators, (urban)morphological, (geo)spatial, and composite indicators, based on various datasets. In addition to traditional datasets, which are used to express population quantitative changes, the data relies on alternative sources that were incorporated too, such as satellite images of nighttime lights, digital terrain model, GHS Population Grid datasets, etc. This research is conducted at the municipal level and regarding the deeper insight into studied phenomenon, it has been extended to the settlement level for the territory of Serbia. Data preparation and calculation of indicators were performed in the GIS environment. The chosen approach highlighted the opportunities and advantages of different datasets crossover, which allowed greater precision and applicability of the obtained results and accurate detection of potentially demographically "empty", depopulated areas in Serbia.

Keywords: depopulation, traditional datasets, alternative datasets, remote detection, Serbia

INTRODUCTION

The project "Remote detection of (de)population processes" was realized as one of the winning solutions to the challenge "Data to better understand the depopulation process" announced by the United Nations Development Program (UNDP) and the UN Population Fund (UNFPA) in Serbia. The primary idea of the project was the identification and monitoring of depopulation at various territorial levels in the Republic of Serbia, using a mixed approach with data sets based on traditional statistical sources and remote sensing. Social phenomena, processes and events, such as the depopulation process, are complex, changeable, diverse, dynamic and multidimensional [1], so approaches and methods for their identification and monitoring, are exceptionally important. Some methods could be recognized as traditional, based on statistical data, on the other hand, there are other modern and innovative approaches [2,3,4]. First group is sometimes characterized as insufficiently precise, while the second characterized as more precise.

As an alternative tool for tracking social processes and phenomena, remote sensing has been introduced [5]. Remote sensing provides the possibility of using satellite-based indicators with high spatial resolution (e.g., from a few to several hundred meters) and time resolution (daily, monthly, annual level). According to OECD Glossary of Statistical Terms, includes a set of methods that enable the collection of information without direct, physical contact with the examined phenomenon or object by recording the emitted or reflected energy (satellite observations, aerial imaging, etc.), and then processing and analyzing the information obtained. Geospatial data generated by remote sensing methods have a wide range of applications in various research fields.
Demographic processes in Serbia have traditionally been expressed through quantitative changes registered in the inter-census period. On the other hand, the introduction of alternative data sources minimizes the generalization, enables observation at the local level (statistical and administrative spatial units). The application of remote sensing data in the study of (de)population processes enables us to overcome the limitations and supplement traditional data sources (e.g., Census). The advantages, as spatially and temporally “sensitive” data, are the possibilities of continuous monitoring of population changes [6,7].

INDICATORS BUILDING

For this purpose, a set of 12 indicators has been created that directly or indirectly detect and monitor the depopulation process in Serbia. For the identification, visualization, and interpretation of (de)population changes, it was used one or combination of several different data types which are overlapped. Satellite images and other remote sensing data, enable to monitor population dynamics with a spatial resolution of several hundred meters (e.g., fields of 250 x 250 m) at the settlement and municipality level. In order to generate the selected indicators, different source of data have been used:

- European Digital Elevation Model EU-DEM version 1.1 [European Environment Agency, 2016];
- 2011 Census of Population, Households and Dwellings in the Republic of Serbia (BOOK 2): AGE AND SEX” [Statistical Office of the Republic of Serbia, 2012];
- GeoSrbija [Open data of the National Data Infrastructure, Republic Geodetic Authority, n.d.]);
- The GHS-POP R2019A dataset—GHS population grid multitemporal [European Commission, Joint Research Center, 2019]
- GHS-BUILT R2018A—GHS built-up grid, derived from Landsat, multitemporal (1975-1990-2000-2014) [European Commission, Joint Research Center, 2018].
- satellite images of nighttime lights - Version 1 VIIRS DNB [Earth Observation Group (EOG); Colorado Mining School, 2012–2019] to determine the radiance (nW cm–2 sr–1)
- Corine Land Cover (CLC) 1990, Version 2020_20u1 [European Environmental Agency, Copernicus Land Monitoring Service, 2020]
- Corine Land Cover (CLC) 2018, Version 2020_20u1 [European Environmental Agency, Copernicus Land Monitoring Service, 2020].

Indicators are classified into four groups:

- **Demographic indicators** are based on the long-term population data as the exact numerical values. The novelty comes from the gridded data sets showing the population count on more prices spatial resolution. Two indicators are in this group:

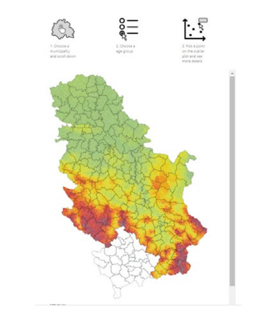
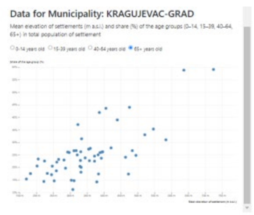
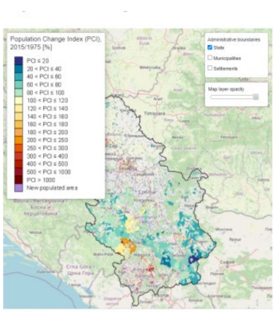
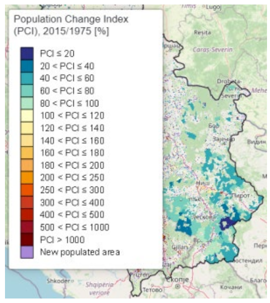
Population Age Structure by Altitude Zones, 2011 and Population Change Index, 2015/1975.
- **(Urbo)morphological indicators** are focused on the spatial distribution, and contains population data. This group enables identification of temporarily and permanently abandoned objects directly indicating the depopulation process. Three indicators are in this group: Population Density in Serbia, 2015, Lot Coverage Change Index, 2014/1975, and Real Abandoned' and Temporarily Used Built-Up Areas, 2015.
- **(Geo)spatial indicators** express spatial changes and their connection with population processes. The innovation is the nighttime lights used to detect the process of depopulation and the seasonal character of settlements [8]. Spatial component is perceived through the development of road networks as basis for studying spatial "isolation". Four indicators are in this group: Hypsometric Structure (Altitudinal Zonality) of Municipalities and Settlements, 'Spatial Lighting', Seasonal Character of Settlements, and Road Network Density.
- **Composite indicators** are combination of different types of data (spatial, morphological, population changes). For instance, population density (grid-based) was overlapped with hypsometric zones, population changes with accessibility to municipal centers and land cover with the emphasis on land conversion to natural ecosystems. Such indicators are non-typical in the research of population changes and represent a contribution to scientific methodology in Serbia. Three indicators belong to this group: Altitudinal Conditionality of the Population Density' Changes, Accessibility as a Determinant of Depopulation, and Land Cover as a 'Tool for Monitoring' Population Change.

RESULTS

Some of the proposed indicators are well known in science, however, others are non-typical and used in this research for identification of the depopulation causes and spatial transformation under the population changes (nighttime lights, seasonal settling, distribution of the population by hypsometric zones, accessibility, and land cover changes, etc.).

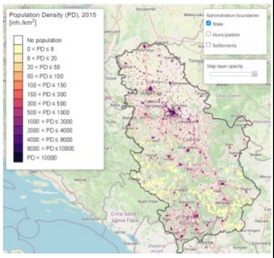
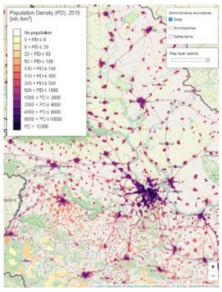
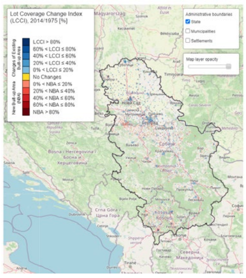
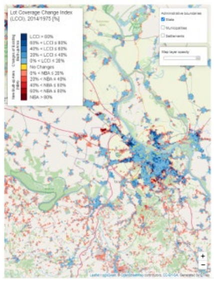
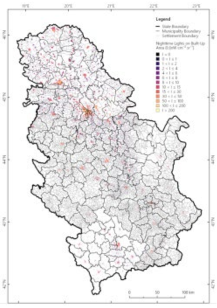
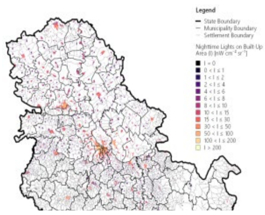
Demographic indicators have enabled monitoring of temporal and structural components of depopulation (Table 1). They have highlighted that 1) with the increase in altitude, the share of the elderly reciprocal increases; 2) population changes in Serbia 1975-2015, emphasized a decrease in the inhabitants number, especially dominant in the peripheral zones of South Serbia, while the population increase is characteristic mostly for urban areas;

Table 1. Summary of demographic indicators and outputs [9].

Indicator	Research interest	Output	Output
Population Age Structure by Altitude Zones, 2011	Where is the elderly population located? Is the elderly population prevalent in mountainous areas?		
Population Change Index, 2015/1975	Depopulation – a challenge or a reality? How intensive is the population decline in Serbia? Where is depopulation the most pronounced?		

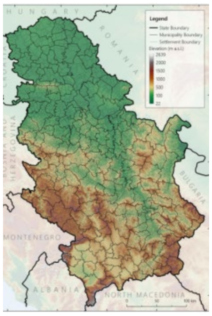
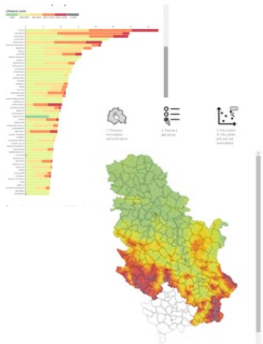
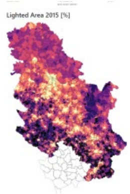
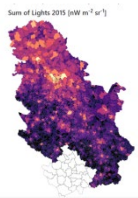
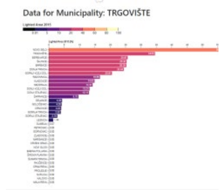
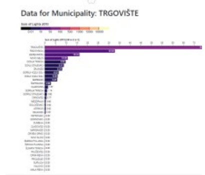
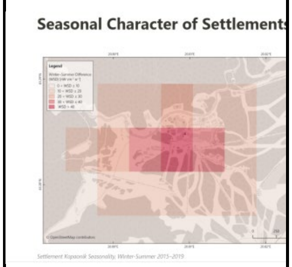
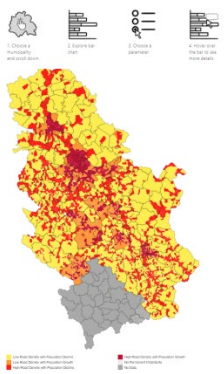
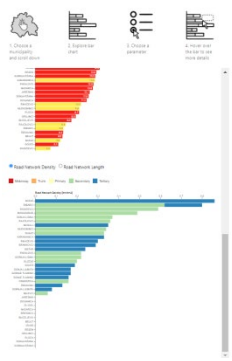
(Urbo)morphological indicators (Table 2) served for the depopulation zones delimitation. The results highlighted that: (1) low population density is typical for peripheral parts of Serbia, while highly urban areas and frequent traffic routes have been identified as zones of population concentration; (2) the lowest population concentration per built-up area is dominantly identified in East and Southwest Serbia. Low population concentration is characterized by low presence of built-up area, and the spatial transformation is "absent"; (3) the areas that are the most affected by abandoning of the facilities are: traditionally depopulated municipalities, municipalities in East Serbia and Pomoravlje area with intensive emigration, municipalities in border and mountainous areas and some municipalities in Kosovo and Metohija.

Table 2. Summary of (urbo)morphological indicators and outputs [9].

Indicator	Research interest	Output	Output
Population Density in Serbia, 2015	What are the poles of the population concentration? Which areas are gradually shrinking? Which areas are growing in height?		
Lot Coverage Change Index, 2014/1975	Where do you plan to live? Which areas are attractive for new?		
'Real Abandoned' and Temporarily Used Built-Up Areas, 2015	Where are the areas that really have no inhabitants? Which facilities are abandoned?		

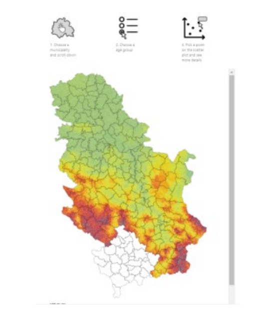
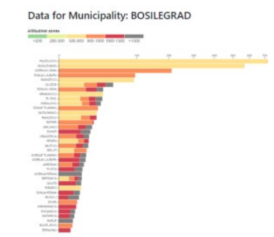
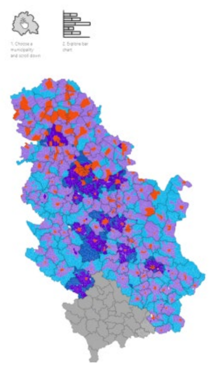
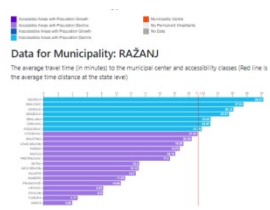
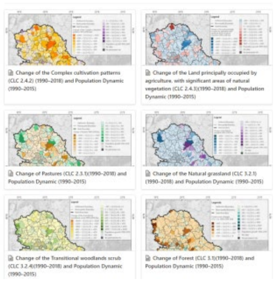
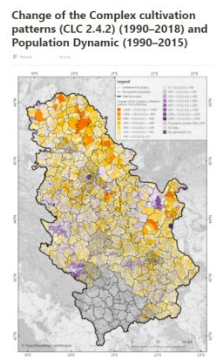
(Geo)spatial indicators (Table 3) pointed out: (1) the altitude of 800 m a.s.l. is the upper threshold for settlement distribution; (2) areas with intensive depopulation have the lowest light intensity; (3) seasonal migrations, temporary settling and occasional use of residential and economic facilities are particularly observed in tourist and weekend settlements in the winter–summer season [8]; (4) with increasing altitude the number of high-density settlements decreases.

Table 3. Summary of geospatial indicators and outputs [9].

Indicator	Research interest	Output	Output
Hypsometric Structure (Altitudinal Zonality) of Municipalities and Settlements	Which are the “highest” settlements in Serbia? What is the altitudinal limit for settling?		
‘Spatial Lighting’	Where the “dark has fallen” in Serbia? What are the areas where the overall activity is reduced?	 	 
Seasonal Character of Settlements	Which areas are permanently abandoned and which are still occasionally used?		
Road Network Density	What is the relationship between the road network and the population size of the settlement? Does poor infrastructure lead to population decline?		

Composite indicators (Table 4) pointed out: (1) approximately 40.5% of settlements in Serbia have unfavorable traffic infrastructure, which contributes to their isolation and depopulation; (2) poor accessibility occurs in one-third of all settlements in Serbia (32.1%), usually in mountainous and border areas; (3) reduced activity or absence of population is detect through conversions of cultivated land towards transitional categories of mixed, grassland and forest.

Table 4. Summary of composite indicators and outputs [9].

Indicator	Research interest	Output	Output
Altitudinal Conditionality of the Population Density' Changes	Does altitude determine settling trends? Does the population prefer living at lower or higher altitudes?		
Accessibility as a Determinant of Depopulation	Isolation = depopulation? Are accessible areas also attractive?		
Land Cover as a 'Tool for Monitoring' Population Change	Does depopulation affect land cover changes? Does depopulation imply untouched nature?		

CONCLUSION

For identification and monitoring of the depopulation process in Serbia, a set of 12 indicators has been specified, based on spatially and temporally sensitive data. Considering that depopulation is a complex phenomenon, various factors were incorporated during the defining of indicators. The list of indicators for monitoring

depopulation in Serbia was designed through the intersection of different data sets in order to enable the identification, visualization, and interpretation of the population changes in general.
General remarks regarding applied indicator set pointed out that for complete understanding of depopulation in Serbia, should consulted and use traditional (statistical data), as well as, modern datasets (remote sensing). Proposed alternative data are characterized with "finer" spatial and temporal resolution, which provide accurate identification and monitoring of population processes. Application of the satellite images of nighttime lights, as one of the innovative approaches, gave impressive results during detection of spatial dispersion of the population and activities, their trends as well as seasonal changes. Used data sets enable further analysis, mathematical-statistical modeling, and upgrade to new data sources. The high spatial resolution layers resulting from the project can serve as input data for all models, where one of the variables is the spatial distribution of the population, the dynamics of population change, as well as the transformation in built-up area and land use due to population changes. The developed platform is an open data concept. Integrating the new results represents a key task for the future.

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