OBSERVING CHANGES OF SETTLEMENT SIZE IN VITICULTURAL ZONES OF SERBIA USING VIIRS NIGHTTIME LIGHT DATA

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Abstract

Nighttime lights (NTL) data provides a comprehensive view of the spatial distribution of global human activities, especially in terms of population concentration, level of urbanization, estimation of economic growth, population mobility, determination of depopulation areas, etc. This article aims to map the spatio-temporal distribution of night lights of settlements in the wine-growing areas of Serbia using The Visible Infrared Imaging Radiometer Suite (VIIRS) NTL datasets from 2015 to 2019, explore the emerging spatial patterns, and compare these patterns with the database of census 2022. Results reveal that the wine-growing areas in Serbia illustrate population redistribution and settlement size change, as it includes larger cities as per the last wine-growing rezoning, reflecting the spatial redistribution of populations. Moreover, urbanization pattern and settlement size variations occur in cities or at their vicinities, with a prominent decrease in settlement size as people move away from cities, indicating a clear depopulation and delimitation of city areas.

Key words: *Geospatial analysis, Settlement size, Spatial analysis, VIIRS data, Viticulture zone.*

Introduction

Positive population policy and spatial distribution of the population have an important impact on the economic and social development of the country. Population censuses are an important source of data and their spatial

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distribution (Zeng et al., 2011). The traditional census of the population does not reflect the real, spatial distribution within one territorial unit. To obtain the numerical value of the number of inhabitants, satellite images, open-source night lighting data, and the use of geographic information systems (GIS) are used. The advantage of using modern geographical detectors in the investigation of spatial differences is in the application of quantitative and type data. On the other hand, there is still a strong influence on the study of the population, which is based on the census and data from statistical yearbooks with the application of various statistical methods.

In developing countries, the spatial dynamics of the population is monitored through the population census, although these countries do not have a trend of regular and accurate censuses (Bennett & Smith, 2017). In classic, traditional censuses, data on population density are obtained by the ratio of the number of inhabitants to the area of a given area, but this does not show the real dynamics of the population (Stevens et al., 2015). Census data and remote sensing techniques, especially night-time light data, are now combined to estimate population density (Doxsey-Whitfield et al., 2015; Pozzi, Small, & Yetman, 2003). Nighttime light (NTL) remote sensing data, widely used in buildings and infraestructures, is frequently used to investigate human activities (Chen, et al., 2021; Croft, 1978; Elvidge et al., 1997; Falchi et al., 2011; Li et al., 2018), namely urbanization processes (Liu et al., 2024; Sutton et al., 2001; Elvidge et al., 2014; Yu et al., 2018)

One of the biggest problems with the traditional population census is represented by sparsely populated areas. One example is Western China, where the census is held every 10 years and where it is difficult to obtain data on the population in a real space-time period. Collection, combination and integration of data with other data is of great importance for such sparsely populated areas and the spatial-temporal distribution of the population in real time (Chen & Nordhaus, 2015). These are data obtained using remote sensing techniques and geospatial research technologies, such as: remote sensing (RS) due to its fast and wide coverage (Xu et al. 2021).

Some researchers to obtain data on the population of different regions used data methods or by applying the kernel density method, and obtained a map of continuous changes in regional population density, area weighting (Bakillah et al., 2014; Wang et al., 2023), geographically weighted regression (Wang et al., 2018; Yuan et al., 2020; Wang et al., 2023) and zone density mapping (Qiu & Cromley 2013; Lin & Cromley, 2015; Wang et al., 2023).

There are 2 types of monitoring data (Elvidge at al. 1997; Levin & Duke, 2012):

1. The first type of data is used for large-scale monitoring (100 m-1 km) with a coarse spatial resolution at the regional level, where night light images are used to map various socio-economic activities)

2. Another type of data is used for monitoring smaller scales (<100 m) at the local level. These images are used in combination with Local Based Service (LBS) data and in the analysis of the spatial distribution of the population.

On the basis of such analyses, settlement mapping is done and they represent a realistic description of the spatial distribution of the population.

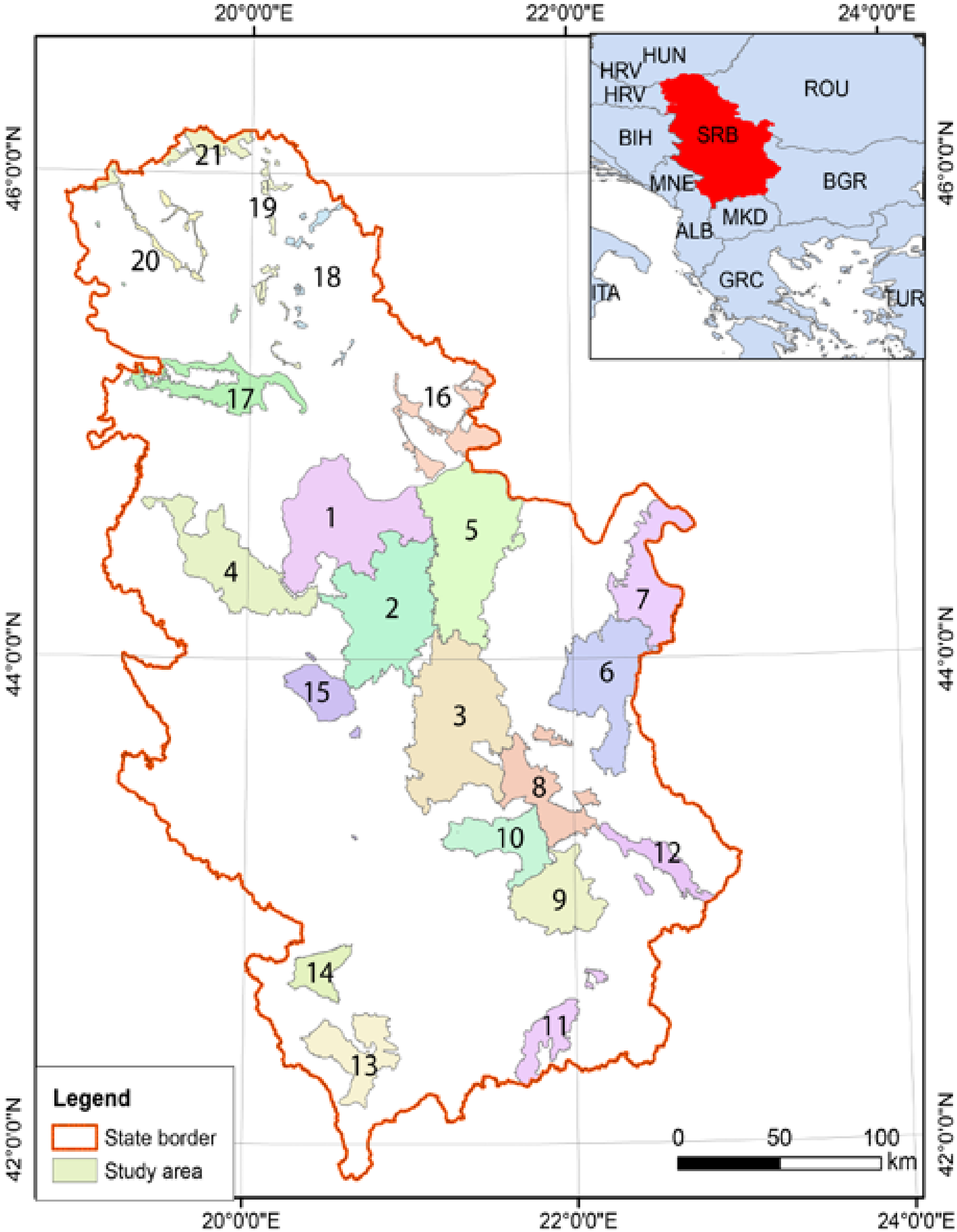
The main goal of the article is to look at the space and distribution of the population through other sources of data collection and quantitative indicators in demography, in addition to the traditional population census of Serbia. In the wine-growing zone of Serbia, there are peripheral areas that are empty or partially empty (such as the southern and southeastern parts), and others are densely populated (urban areas) and with the application of alternative methodologies (e.g. satellite images of the night world) it is possible to more precisely determine the size of the inhabited area.

Study area

The wine-growing region of Serbia is a good example of different populations, size of settlements and spatial distribution of population. The wine-growing borders include densely populated cities (Belgrade, Kragujevac, Niš, etc.), and on the other hand, partially populated and displaced areas of Serbia (especially the southern and southeastern parts).

Grape vines in Serbia are grown on hilly terrain between 80 and 500 m above sea level. Serbia is located in the zone between 41°50’ and 46°10’ SG, which enables the conditions for growing different varieties of vines, and as a result, the production of quality grapes and wine. The viticultural area of Serbia covers a total area of 23,675 km² (99.86% includes the belt up to 800 m above sea level, and from 800 m it covers the area of 31.42 km², i.e. 0.13%). The largest wine-growing unit in the wine-growing area of Serbia is represented by wine-growing Serbia. Within wine-growing Serbia there are viticultural areas: region, region, vineyard (Rulebook on the rezoning of viticultural geographical production areas, 2015; Jovanović, 2020) (Figure 1).

Figure 1. *Study area - wine-growing regions in Serbia*



Source: Elaborated by authors

Wine-growing regions:

1	Belgrade	12	Nišava
2	Šumadija	13	South Metohija
3	Three Morava	14	North Metohija
4	Pocerina-Valjevo	15	Čačak-Kraljevo
5	Mlava	16	South Banat
6	Knjaževac	17	Srem
7	Negotin	18	Potisje
8	Niš	19	Banat
9	Leskovac	20	Teleč
10	Toplica	21	Subotica
11	Vranje		

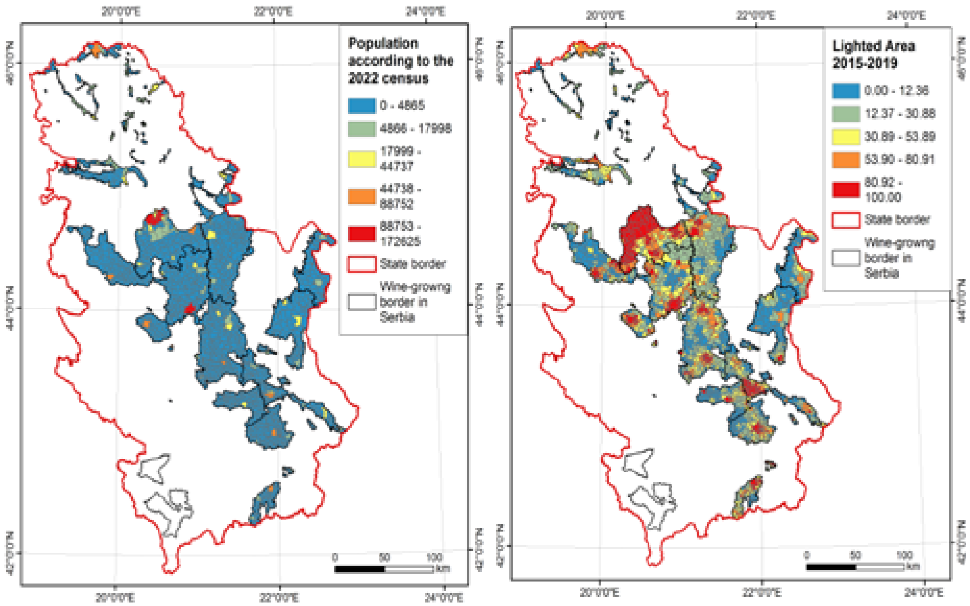
According to the 2011 census, in the analyzed area, for the period 1961-2011, there was a spatial distribution of the population from villages to urban areas. According to the 1961 census, 2,629,774 people lived in wine-growing areas where grapes were grown, and according to the 2011 census, 3,139,914 inhabitants. According to the last population census, from 2022, the number of inhabitants is 2963715 (Comparative overview of the number of inhabitants, 2014; Jovanović, 2020). On the basis of remote detectors and the GIS and the last population census, research, quantified assessment and comparative analysis of the population density of a certain part of the wine-growing area of Serbia was carried out.

The main limitation and shortcomings of the study is that the use of VIIRS night light data is related to a certain period of time, as well as the ability of satellite sensors to capture individual light sources in areas that are not heavily populated.

Results

Data from VIIRS NTL datasets from 2015 to 2019 obtained for areas with different intensity of NTL. In the case of settlements of a rural character, which are small and scattered, they are not considered as much as comparing the size of urban settlements where the population density is high and the NTL values are high.

Figure 2. Comparative overview of the size of the population census (2022) and illuminated wine-growing area (2015-2019) of Serbia



Source: Elaborated by authors

Source data: https://data.gov.rs

Based on the obtained results, it can be inferred that the spatial distribution of the population and the size of the settlement is greater on the data obtained from the VIIRS NTL datasets from 2015 to 2019, than from the census of the number of inhabitants in 2022. This difference is especially noticeable in wine-growing areas where larger cities of Serbia (with a range of 50,000 to over 1,500,000 inhabitants): Belgrade, Kragujevac, Valjevo, Niš, Leskovac, Knjaževac, Negotin, Vranje. In the 2022 population census, a similar identity (red color in Figure 2) can be seen and compared with VIIRS NTL datasets from 2015 to 2019 only in the cities: Belgrade, Kragujevac (red color in Figure 2) and significantly less in the cities of Vranje, Leskovac , Niš (which are marked in orange or yellow).

Conclusions

In addition to the classic way of censusing the population, the use of modern remote sensing techniques in night light is of great importance. With the help of this technique, it is possible to detect and provide reliable information for population density modeling, because NTL is related to human activities. Some further monitoring of the movement and distribution of the population can be observed through the point of interest (POI). POI and LBS data have easy access, high positioning accuracy compared to the traditional way of data collection. POI and LBS data can also serve as a modeling factor for percentage population density.

A special advantage can be provided by the combination of POI and LBS data with VIIRS data.

Also, the future of large-scale dense population mapping should be viewed through machine learning, which would enable the simulation and modeling of population and territory, changes in these variables, through an adequate tool.

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