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SPATIAL ANALYSIS OF MORTALITY IN BOSNIA AND HERZEGOVINA: A PRELIMINARY ANALYSIS

Original scientific paper

A. Kadusic[1], S. Smajic[2], S. Kunosic[3], N. Smajic[4]

[1,2,3,4] *Faculty of Natural Sciences and Mathematics, University of Tuzla, Bosnia and Herzegovina*

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ABSTRACT

In this study, using the methods of spatial autocorrelation in geographic information systems (GIS), an analysis of the spatial distribution of mortality rates in Bosnia and Herzegovina was performed in order to identify high-risk areas with increased mortality and depopulation. Spatial analysis is based on the calculation of global (Global Moran's I and Getis-Ord General G) and local (Anselin Local Moran's I and Getis-Ord Gi) statistical indices of spatial autocorrelation. The values of global statistical indices confirmed a clustering of high mortality values, while local statistical indices confirmed high mortality rates in the municipalities of northwestern and eastern Bosnia and Herzegovina. Conducted research provides an insight into spatial patterns of demographic processes, while results obtained by this research are significant for demographic development and future spatial demographic research in Bosnia and Herzegovina.*

***Keywords**: GIS, spatial analysis, spatial autocorrelation, mortality, Bosnia and Herzegovina*

INTRODUCTION

Due to the effects of mortality on demographic change, social, economic, and other processes in the world, in both developed and developing countries, there are numerous studies researching this demographic phenomenon (Lovic Obradovic et al., 2020; Xiang & Song, 2016; Ouellette et al., 2012). Furthermore, numerous studies monitor spatial disparities in the levels and causes of mortality since there are significant regional differences in the level of mortality in the world (Gavurova & Toth, 2019; Atanasova et al., 2016; Kibele et al., 2015; Kalogirou et al., 2012; Wang et al., 2012). In demographic analysis, and thus in the analysis of mortality trends and spatial differences in the level and causes of mortality of a particular area, spatial analysis in the geographic information system (GIS) environment is of particular importance (Lovic Obradovic et al., 2020; Mijic & Ateljevic, 2018; Arslan et al., 2013; Rodrigues et al., 2013; Weeks, 2004; Anselin & Getis, 1992). There are numerous studies in the world of spatial analysis of mortality. Atanasova et al. (2016) identified spatial disparities in Bulgarian mortality in the period 2000-2012. Kalogirou et al. (2012) investigated spatial differences in Greek mortality according to causes of mortality in the period 2006-2008. Wang et al. (2012) researched the geographical disparities of infantile mortality rates in rural China. Arslan et al. (2013) conducted a spatial analysis of perinatal mortality in Turkey. Rodrigues et al. (2013) used spatial analysis to identify areas of high infantile mortality rates in Brazil. Buajitti et al. (2019) conducted a spatial analysis of early mortality variations

Correspodence to: Prof.Asoc**.** Alma Kadusic, Faculty of Natural Sciences and Mathematics, University of Tuzla, Bosnia and Herzegovina
Email: alma.kadusic@untz.ba

in Ontario (Canada). Oliveira Santos et al. (2017) performed a spatial-temporal analysis of mortality caused by suicide within the old population in Brazil. Ocaña-Riola & Mayoral-Cortés (2010) identified spatio-temporal mortality trends in the municipalities of southern Spain. Divino et al. (2009) determined the geographical patterns of mortality in Italy, etc. Therefore, in recent years, spatial analysis has contributed to significant geographical insights through numerous geographical studies (Buajitti et al., 2019; Xiang & Song, 2016; Almeida et al., 2014; Divino et al., 2009). There are few studies on the spatial distribution and disparities of mortality in Bosnia and Herzegovina. However, some studies have been conducted on the crude mortality rates and demographic trends of this country and its individual regions. Mijic & Ateljevic (2018) conducted a study on the use of modern GIS software in demographic research of the Bosnian entity of Republic of Srpska; Gekic et al. (2020) investigated depopulation trends in Bosnia and Herzegovina at the end of the XX and the beginning of the XXI century; Kadusic (2013) researched the trends of mortality rates in the municipality of Tešanj in Bosnia and Herzegovina; Fatusic et al. (2012) conducted a research about perinatal mortality in Tuzla Canton; Fatusic et al. (2005) analysed the impact of the 1992-1995 war on perinatal and maternal mortality in Bosnia and Herzegovina, etc. Therefore, it should be noted that in the previous research on this demographic phenomenon in Bosnia and Herzegovina, spatial analysis has not been significantly applied. Spatial analysis of mortality can be performed using the method of spatial autocorrelation, which includes statistical and graphical techniques that enable geovisualization of the spatial distribution of data and determination of atypical locations and outliers, spatial patterns, etc. (Hasani et al., 2019; Anselin, 1995; Ord & Getis, 1995; Anselin & Getis, 1992). In the background of this research is the assumption that certain areas of Bosnia and Herzegovina are especially endangered by high death rates and depopulation. Therefore, the aim of this study is to conduct a spatial analysis of mortality rates in Bosnia and Herzegovina using spatial autocorrelation methods in geographic information systems in order to identify spatial patterns and clusters of high mortality rates and areas vulnerable to depopulation processes.

RESEARCH MATERIALS AND METHODS

The analysis of health and geographical spatial data enables a better understanding of the mortality of a certain population and the mapping of areas of social and health inequalities (Rodrigues et al., 2013), while the spatial pattern analysis of demographic phenomena, including mortality, improves understanding of demographic processes and emphasizes the significance of spatial statistical techniques in the spatial analysis of demographic phenomena (Kurek et al., 2021). Taking into account the high mortality rates of the population of Bosnia and Herzegovina, it is necessary to determine the high-risk areas of increased mortality rates in the country. Statistical data gathering at the level of smaller territorial units of Bosnia and Herzegovina, such as municipalities and settlements, is difficult and complicated for several reasons, the most significant of which is the inconsistency of the statistical data monitoring caused by the administrative division of this country, and due to the fact that in the post-war period (1992-1995) only one population census was conducted in 2013. Therefore, a preliminary geospatial analysis of mortality in Bosnia and Herzegovina was conducted for the period 2013-2020, using statistical estimates of crude mortality rates from the Agency for Statistics of Bosnia and Herzegovina (BHAS), the Federal Bureau of Statistics (FZS) and the Bureau of Statistics of the Republic of Srpska (RZSRS). Digital data related to the territory of municipalities in Bosnia and Herzegovina was retrieved from the Federal Geodetic Administration (FGA) in vector format (*shp) in the form of polygons. In order to perform spatial analysis of demographic parameters in Bosnia and Herzegovina at the municipal level, crude death rates and other demographic indicators, such as birth rates, natural population change rates, age coefficient, and vital index were determined for 142 municipalities in Bosnia and Herzegovina over a period of 8 years (2013-2020). In this study, the spatial autocorrelation method was used to identify spatial clusters with high or low mortality values in Bosnia and Herzegovina. Spatial autocorrelation is an indicator for determining the correlation between different variables and can be defined as the degree to which variables in certain locations are similar or different to those in the vicinity (Hasani et al., 2019; Anselin, 1995; Ord & Getis, 1995). There are global statistical tools that determine whether or not there is clustering of spatial data, and local statistical tools that give us an answer to the question of where spatial clustering in the researched area occurs, and whether low or high values are clustered (Hasani et al., 2019). In this study, spatial autocorrelation indices were used to determine whether or not mortality clusters occur in Bosnia and Herzegovina, i.e., high-risk areas that are exposed to high mortality rates. Global statistical indices, such as Global

Moran's I and Getis-Ord General G, can be used to analyse spatial autocorrelation through an entire dataset or statistical sequence, whereas local statistical indices of spatial autocorrelation, such as Anselin Local Moran's I and Local Getis-Ord Gi*, can be used to identify hot and cold spots areas (Vilinová, 2020; Hasani et al., 2019; Xiang & Song, 2016; Ord & Getis, 1995). Therefore, in this study, i.e., in the analysis of spatial patterns and spatial autocorrelation of mortality in Bosnia and Herzegovina, global statistical indices Global Moran`s I and Getis-Ord General G, and local statistical indices of spatial autocorrelation Anselin local Moran's I and Getis-Ord Gi* were used. The value of the global Moran's I Index ranges between -1 and +1. Analysis starts from the null hypothesis, which states that there is no spatial autocorrelation between variables. The statistical significance of the global Moran's I Index was determined on the basis of *p*-value and *z*-score. If the value of this index is significant and positive, the value of the index will range between 0 and +1, which indicates a positive spatial autocorrelation and spatial clustering of values or data. If the global Moran's I indicator is statistically significant and negative, its value will range between 0 and -1 and will indicate a negative spatial relationship between the values and the dispersion of the data. The Global Getis-Ord General G Index examines the clustering of low-risk or high-risk values. If the clustering is confirmed by rejecting the null hypothesis, a positive *z*-score for Getis-Ord General G indicates a clustering of high values, while a negative *z*-score indicates a clustering of low values. The Anselin Local Moran's I indicator can also be used to determine the clustering of low and/or high values. The statistically significant and positive value of this index shows us where in the area of research high and low values are clustering, while the negative index value indicates atypical points or outliers (low-high, high-low values). The Local Getis-Ord Gi* Index of spatial autocorrelation was also used in the study. The high *z*-score and low *p*-value of this index indicate the clustering of high values (hot spots), and the low negative *z*-score and low *p*-value indicate a significant clustering of low values (cold spots). The higher (or lower) the value of the *z*-score is, the more intensive the clustering of data is.

RESULTS

A *p*-value of 0.005 for Global Moran's I and a *p*-value of 0.002 for Getis-Ord General G imply that the null hypothesis is rejected and that the spatial distribution of high and/or low values in the observed statistical dataset of mortality rates in Bosnia and Herzegovina is more clustered than would be expected in random spatial processes. Further, given a *z*-score of 2.801 for Global Moran's I and a *z*-score of 2.982 for Getis-Ord General G, there is less than a 1.0% probability that this spatial distribution of mortality rates could be the result of chance. As a result, Global Moran's I of 0.134 (positive *z*-score of 2.801 and *p*-value of 0.005) and Getis-Ord General G value of 0.007 (positive *z*-score of 2.982 and statistically significant *p*-value of 0.002) confirm the clustering of mortality rates in Bosnia and Herzegovina (Figs. 1 and 2).

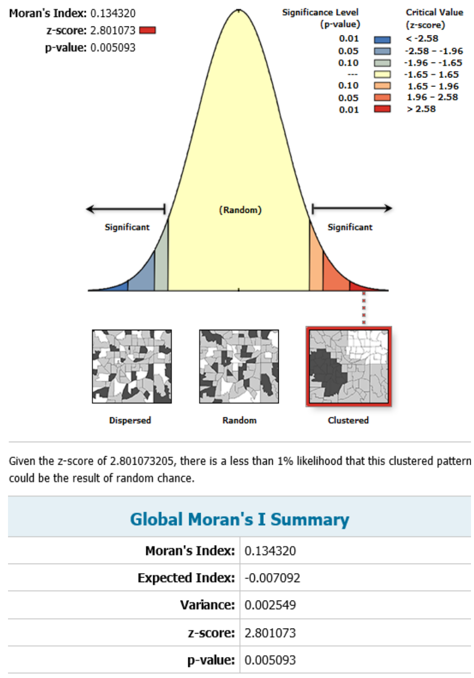
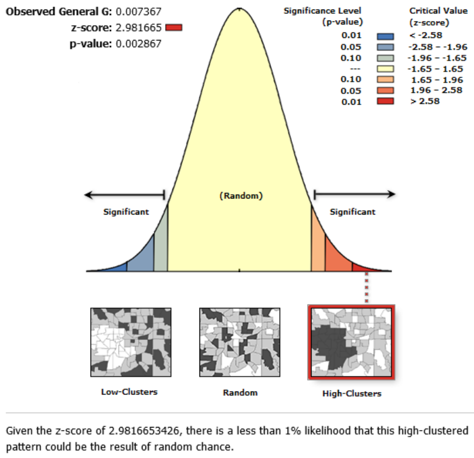


Figure 1: Global Moran's I final statistics and diagram for mortality rates in B&H, 2013-2020

The local statistical indices Anselin Local Moran's I and Getis Ord Gi* enabled the identification or existence of spatial clusters with high or low mortality values in Bosnia and Herzegovina. The statistical significance of local indices is based on the ratio of the *z*-score and *p*-value at the 0.05 significance level. Moran's diagram for the mortality of the population of Bosnia and Herzegovina in the period 2013-2020 shows the value of the Anselin Local Moran's I at a value of 0.134, which indicates moderate positive spatial autocorrelation. This value of the index indicates the clustering of high and low values of mortality rates. Moreover, positive autocorrelation suggests that values in one geographic area are similar to the values in neighbouring areas, while negative autocorrelation indicates atypical points or outliers, i.e., certain areas with high mortality rates are surrounded by areas with low mortality rates, and vice versa (Figs. 1, 2 and 3). The municipalities of Bosnia and Herzegovina identified in the high-high quadrant are Novi Grad, Prijedor, Krupa na Uni, Ostra Luka, Bosanski Petrovac, Ribnik, Drvar, Glamoc, Kupres, Pale (RS), Foca (FB&H) and Gacko, while in the low-low quadrant are Velika Kladusa, Zenica, Busovaca and Bratunac. The municipalities of Bosnia and Herzegovina registered in the low-high quadrant are Sanski Most, Kljuc, Banja Luka, Donji Vakuf, Livno, Trnovo (FB&H) and Trnovo (RS), while only the municipality of Sekovici is in the high-low quadrant (Fig. 3).



General G Summary	
Observed General G:	0.007367
Expected General G:	0.007092
Variance:	0.000000
z-score:	2.981665
p-value:	0.002867

Figure 2: Getis-Ord General G final statistics and diagram for mortality rates in B&H, 2013-2020

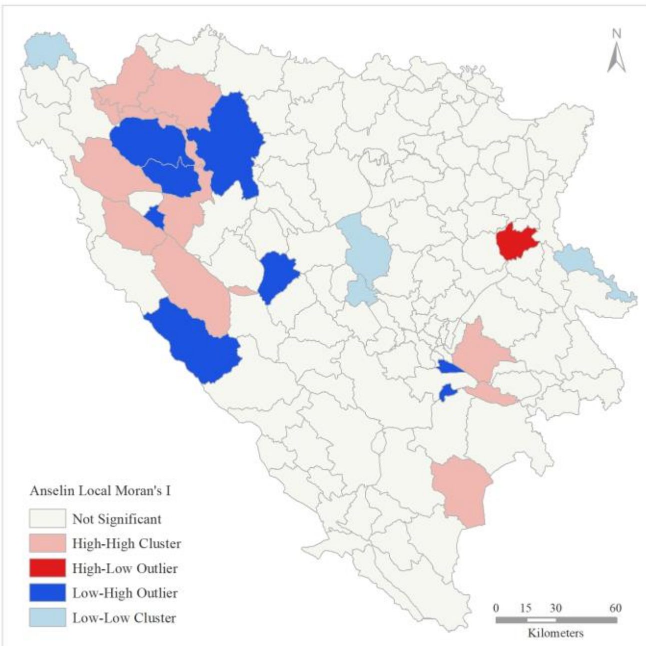


Figure 3: Analysis of local spatial autocorrelation of mortality rates in Bosnia and Herzegovina, 2013-2020

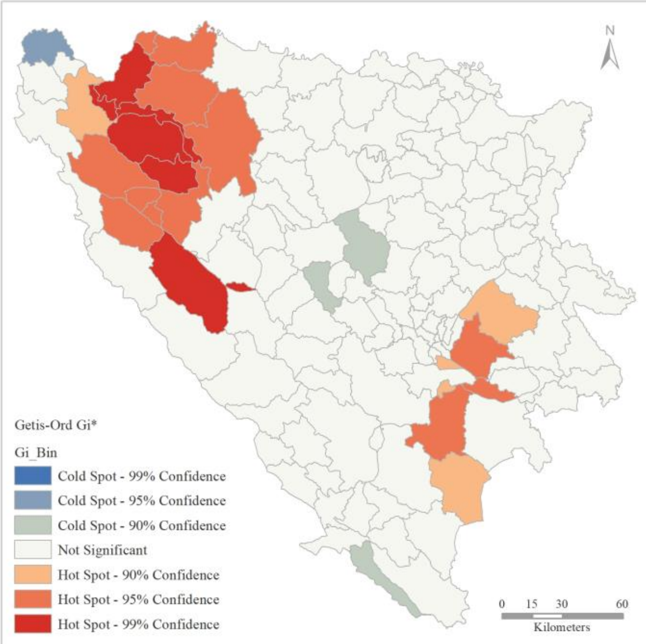


Figure 4: Getis-Ord G analysis of mortality rates in Bosnia and Herzegovina, 2013-2020*

The Getis-Ord Gi* Index was used to identify high-risk and low-risk areas of mortality and depopulation in Bosnia and Herzegovina. The Gi* was calculated for each data point in the statistical mortality dataset. Hot spots with 99% confidence intervals (municipalities of Novi Grad, Krupa na Uni, Ostra Luka, Sanski Most, Kljuc, Glamoc and Kupres) and 95% confidence intervals (municipalities of Kostajnica, Kozarska Dubica, Prijedor, Banja Luka, Ribnik, Petrovac, Istocni Drvar, Drvar and Bosanski Petrovac) were identified in the north-western parts of Bosnia and Herzegovina. A hot spot cluster with a 95% confidence interval was also identified in the eastern parts of Bosnia and Herzegovina (Pale and Kalinovik municipalities in the Republic of Srpska, and Foca in the Federation of Bosnia and Herzegovina) (Fig. 4). Spatial clustering of high mortality rates in some areas of Bosnia and Herzegovina is a consequence of numerous factors, the most significant of which are social, economic, and political factors. These factors caused negative natural population change, an increase in the share of the elderly population, intensive emigration of the young population (mostly between 20 and 40 years of age), and therefore a decline in the potential biodynamics and vitality of the population, etc. These adverse demographic trends are especially aggravated in rural municipalities and municipalities that are also situated along the entity demarcation line between entities Federation of Bosnia and Herzegovina and the Republic of Srpska. Furthermore, the mortality trends in this country are also a consequence of certain biological factors, as well as the living standards of the population and the state of the health care and social protection systems. Unfavourable economic, social, political, and other conditions contributed to the decrease of natural population change rates in Bosnia and Herzegovina at the end of the XX and the beginning of the XXI century. Birth rates in Bosnia and Herzegovina have been below 12.0‰ since 1996, and at the same time, there has been a noticeable increase in mortality rates in the period of 1996-2020 from 6.9 to 12.8‰. Despite socioeconomically lagging behind highly developed countries with a low level of reproduction, these statistics show that Bosnia and Herzegovina has entered the post-transition stage of demographic development (Frejka & Sobotka 2008). Since 2010, this country has been recording negative rates of natural population change, which in 2020 reached a value of -5.0‰ (Tab. 1).

Table 1. Natural population change rates in B&H, 1996-2020

Year	Natality rates (‰)	Mortality rates (‰)	NPG rates (‰)
1996	12.8	6.9	5.9
2000	10.5	8.1	2.4
2005	9.0	9.0	0.1
2010	8.7	9.1	-0.4
2013	8.7	10.1	-1.4
2014	8.6	10.2	-1.6
2015	8.5	10.8	-2.3
2016	8.6	10.4	-1.8
2017	8.6	10.8	-2.2
2018	8.4	10.8	-2.4
2019	8.1	11.1	-3.0
2020	7.8	12.8	-5.0

* NPG - Natural Population Change Rate
Source: Agency for statistics of Bosnia and Herzegovina, 2021

Analysis of demographic parameters in Bosnia and Herzegovina for the period from 2013 to 2020 confirmed that there is a strong relationship between mortality and components of natural population change, vital index and age coefficient (moderate negative correlation of -0.514 between mortality and vital index, and a high positive correlation of 0.701 between mortality and age coefficient). Municipalities in Bosnia and Herzegovina with negative natural population change rates, low vitality indexes, and high values of the age coefficient record higher mortality rates (Fig. 5). The highest mortality rates in the period 2013-2020 were recorded in the municipalities of Petrovac (26.7‰), Kupres (FB&H) (25.9‰), Krupa na Uni (24.5‰), Istocni Stari Grad (24.1‰), Kalinovik (23.0‰), etc. At the same time, the largest share of the elderly in the total population was recorded in the municipalities of Kupres (RS) (47.3%), Bosansko Grahovo (36.8%), Drvar (30.5%), Trnovo (29.8%), Kalinovik (28.4%), and the lowest vital index in Pelagicevo municipality (0.042), Donji Zabar (0.067), Ravno (0.100), Bosansko Grahovo (0.172), Istocni Mostar (0.170), Krupa na Uni (0.186), etc. (Fig. 5).

Biological and socioeconomic variables also influence the mortality patterns in Bosnia and Herzegovina. While the birth rate and fertility were mostly influenced by numerous social, economic, and psychological factors, the mortality rate was also significantly influenced by the biological conditions and conditions in the health care of the population of Bosnia and Herzegovina. Among the biological factors, the age structure of the population, the health condition of the population, etc. should be especially emphasized. However, socioeconomic factors also had an impact on mortality. The level of living standards and the state of Bosnia and Herzegovina's health care system are the most important economic and social factors influencing mortality (Kadusic & Suljic, 2018; Kadusic, 2013).

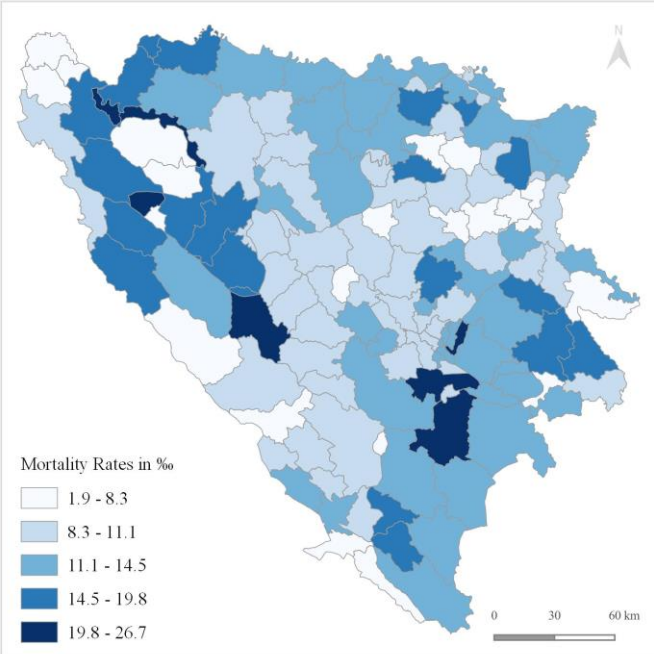


Figure 5: The distribution of mortality rates by municipalities in Bosnia and Herzegovina, 2013-2020

The level of mortality is strongly impacted by the age of the population, and it is logical that mortality affects older population groups more. Based on the share of the population older than 65 in the total population, it is possible to determine the level of age of a certain population. In 2013, the age coefficient was 14.3%, and in 2020 it was 17.9%, which implies that the population of Bosnia and Herzegovina has reached an advanced demographic age and a decline in the potential biodynamics of the population. The decline in the vitality of the population of Bosnia and Herzegovina is also indicated by the vitality index, whose value in 2013 was 0.869 and in 2020 0.618. The demographic ageing and decline of the potential biodynamics of the population of Bosnia and Herzegovina have been influenced by the reduction of birth rates and emigration of the population. Emigration, mainly of the younger population aged 20-40, is reflected in the reproduction of the population and thus in the age composition and mortality of the population of Bosnia and Herzegovina (Gekic et al., 2020; Kadusic & Suljic, 2018). Mortality is also a significant indicator of socio-economic processes and the conditions of the sanitary and health care of the population. To a certain extent, the level of mortality in the population of Bosnia and Herzegovina is also influenced by bio logical and medical factors, which include various inherited traits that make individuals or groups of the population prone to certain diseases. In 2020, the leading causes of mortality in Bosnia and Herzegovina were diseases of the circulatory system (45.1%) and neoplasms (17.7%) (BHAS, 2021).

DISCUSSION

Numerous studies on the level and causes of mortality have been conducted worldwide (Lovic Obradovic et al., 2020; Ouellette et al., 2012), with special emphasis on studies that indicate spatial disparities and variations in mortality in some parts of the world (Gavurova & Toth, 2019; Atanasova et al., 2016). The results of this study confirmed that spatial analysis in a GIS environment is a very effective tool in determining spatial distribution, spatial disparities, and clustering of mortality values, and the data obtained by this analysis contribute to a better understanding of mortality trends and factors influencing this demographic phenomenon (Buajitti et al., 2019; Hasani et al., 2019; Mijic & Ateljevic, 2018; Arslan et al., 2013; Anselin & Getis, 1992). This study presents the preliminary geospatial analysis of crude mortality rates in Bosnia and Herzegovina, conducted by the method of spatial autocorrelation, i.e., global (Global Moran's I and Getis-Ord General G) and local (Anselin Local Moran's I and Getis Ord Gi*) statistical indices of spatial autocorrelation. Spatial autocorrelation enables the determination of correlation between different variables and indicates spatial disparities, i.e., whether there is clustering of data in the researched area or not (Kurek et al., 2021; Lovic Obradovic et al., 2020; Hasani et al., 2019; Anselin, 1995; Ord & Getis, 1995). Therefore, a significant number of papers in the world treat the issue of spatial disparities in the level of mortality with the use of spatial autocorrelation methods (Buajitti et al., 2019; Hasani et al., 2019; Xiang & Song, 2016; Rodrigues et al., 2013). Global statistical indices confirmed the clustering of mortality rates, while local statistical indices indicated that mortality rates in some municipalities in northwestern and eastern Bosnia and Herzegovina were higher than the mean mortality rates at the level of Bosnia and Herzegovina, and therefore these areas are considered high-risk areas. The causes of spatial disparities in the level of mortality in Bosnia and Herzegovina are numerous, and the most important are social, economic, and political factors. These factors significantly influenced the demographic processes and trends of the population of Bosnia and Herzegovina at the beginning of the 21st century. The most significant demographic problems in this country are population ageing and intensive emigration of the young population of Bosnia and Herzegovina to Western European countries and other countries (Gekic et al., 2020; Kadusic & Suljic, 2018). In addition to the abovementioned factors, it is necessary to single out biological factors and the health of the population of Bosnia and Herzegovina, as well as the quality of the health care system in Bosnia and Herzegovina (Tokalić et al., 2021; Ivanković et al., 2010; Masic et al., 2006). The presence of hot-spot areas or clusters of high mortality rates indicates that certain parts of Bosnia and Herzegovina are particularly vulnerable to depopulation processes. Rural municipalities in Bosnia and Herzegovina, as well as municipalities located along the entity boundary line between entities of the Federation of Bosnia and Herzegovina and the Republic of Srpska, are particularly affected by these unfavourable demographic trends. Although there is an inconsistency in the methodology of collecting and publishing statistical data at the level of administrative entities in Bosnia and Herzegovina caused by the administrative and political organization of this country, the spatial analysis enabled the identification of spatial disparities in the level of mortality of the population of Bosnia and Herzegovina.

The results obtained by this study represent a significant contribution and prerequisite for future demographic research, as well as the basis for the planned demographic development of Bosnia and Herzegovina. The conducted research is significant in terms of determining the depopulation areas of Bosnia and Herzegovina, which are caused by high mortality rates, demographic ageing, and intensive emigration processes. The results of the research can serve for further identification and research of factors that cause spatial disparities in the level of mortality and can also serve as a basis for future research on not only mortality rates but also other demographic parameters in Bosnia and Herzegovina. Therefore, the focus of future research should be on the spatial analysis of standardized mortality rates and the identification and elucidation of the factors that caused the spatial variations in mortality and depopulation processes in Bosnia and Herzegovina.

CONCLUSION

The spatial autocorrelation method confirmed the spatial disparities in the values of mortality rates in Bosnia and Herzegovina. Global statistical indices of spatial autocorrelation indicated a moderate positive autocorrelation, while local statistical indices indicated a clustering of high mortality values in the municipalities of north western and some municipalities in eastern Bosnia and Herzegovina. The spatial clustering of high mortality rates in some areas of Bosnia and Herzegovina is a consequence of numerous social, economic, and political factors. These factors contributed to negative demographic trends throughout the country, particularly in rural municipalities (negative natural population change, high share of elderly population, decline in vital index, i.e., decline in potential biodynamics and vitality of the population, intensive emigration of people aged 20 to 40, and so on). Furthermore, the mortality trends in this country are a consequence of certain biological factors, as well as the living standards of the population and the state of the health care and social protection systems. The results obtained by this research are significant from the aspect of future demographic development and can also serve as a basis for future geospatial demographic research in Bosnia and Herzegovina.

REFERENCES

Almeida M.C., Gomes C.M., & Nascimento L.F. (2014). Spatial analysis of neonatal mortality in the state of São Paulo, 2006-2010. *Revista Paulista Pediatria,* 32(4), 374-380. https://doi.org/10.1016/j.rpped.2014.01.001

Anselin, L. (1995). Local Indicators of Spatial Association - LISA. *Geographical Analysis,* 27(2), 93-115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x

Anselin, L., & Getis, A. (1992). Spatial statistical analysis and geographic information systems. *The Annals of Regional Science,* 26, 19-33. https://doi.org/10.1007/BF01581478

Arslan, O., Çepni, M.S., & Etiler, N. (2013). Spatial analysis of perinatal mortality rates with geographic information systems in Kocaeli, Turkey. *Public Health,* 127(4), 369-379. https://dx.doi.org/10.1016/j.puhe.2012.12.009

Atanasova, V., Mircheva, I., & Dokova, K. (2016). Regional disparities in all-cause mortality in Bulgaria for the period 2000-2012. *Scripta Scientifica Salutis Publicae,* 2(1), 7-11. Available at: https://journals.mu-varna.bg/index.php/sssp/article/view/1550/1713 (03.10.2022)

BHAS. (2021). Demography 2020. Thematic Bulletin, TB 02. Agency for statistics of Bosnia and Herzegovina. Available at: https://bhas.gov.ba/Calendar/Category/14?lang=en (17.03.2022)

Buajitti, E., Watson, T., Norwood, T., Kornas, K., Bornbaum, C.,Henry, D., & Rosella, L.C. (2019). Regional variation of premature mortality in Ontario, Canada: a spatial analysis. *Population Health Metrics,* 17(9), 1-8. https://doi.org/10.1186/s12963-019-0193-9

Divino, F., Egidi, V., & Salvatore, M.A. (2009). Geographical mortality patterns in Italy: A Bayesian analysis. *Demographic Research,* 20(18), 435-466. https://doi.org/10.4054/DemRes.2009.20.18

Fatusic, J., Hudic, I., & Fatusic, Z. (2012). Perinatal Mortality During Fifteen-year Period in Tuzla Canton, Bosnia and Herzegovina. *Medical Archives*, 66(4), 258-261. https://doi.org/10.5455/medarh.2012.66.258-261

Fatusic, Z., Kurjak, A., Grgic, G., & Tulumovic, A. (2005). The influence of the war on perinatal and maternal mortality in Bosnia and Herzegovina. *The Journal of Maternal-Fetal and Neonatal Medicine*, 18(4), 259-263. https://doi.org/10.1080/147670500198501

FGU (2018). GeoPortal (electronic resource). Sarajevo: Federal Administration for Geodetic and Property Affairs.

Frejka, T., & Sobotka, T. (2008). Fertility in Europe - Diverse, delayed and below replacement. *Demographic Research*, 19, 15-43. https://doi.org/10.4054/DemRes.2008.19.3

FZS (2021). Statistical Yearbook 2021. Sarajevo: Institute for statistics of FBiH. Available at: http://fzs.ba/index.php/publikacije/statisticki-godisnjaciljetopisi/ (12.03.2022)

Gavurova, B., & Toth, P. (2019). Preventable Mortality in Regions of Slovakia-Quantification of Regional Disparities and Investigation of the Impact of Environmental Factors. *International Journal of Environmental and Public Health,* 16(8), 1382. https://doi.org/10.3390/ijerph16081382

Gekic, H., Gekic-Bidzan, A., Miric, R., & Remenyi, P. (2020). Hidden geographies of population implosion in Bosnia and Herzegovina. *European Journal of Geography*, 11(2), 047-064. https://doi.org/10.48088/ejg.h.gek.11.2.47.64

Hasani, J., Erfanpoor, S., Rajabi, A., Barzegar, A., Khodadoost, M., Afkar, M., Saeed, S., & Nazari, S.S.H. (2019). Spatial analysis of mortality rate of pedestrian accidents in Iran during 2012–2013. *Traffic Injury Prevention,* 20(6), 636-640. https://doi.org/10.1080/15389588.2019.1628223

Ivankovic, A., Ravlija, J., Škobic, H., Vasilj, I., Ivankovic, Z., Pejanovic-Škobic, N., & Pavlekovic, G. (2010). Health Status of Population in Federation of Bosnia and Herzegovina in 15 Years of Transitional Period. *Coll Antropol.,* 34 (2010), 325-333. Available at https://hrcak.srce.hr/file/79205 (24.02.2022)

Kadusic, A. (2013). Mortalitet stanovništva općine Tešanj (Mortality of municipality Tešanj*). Zbornik radova Prirodno-matematičkog fakulteta Univerziteta u Tuzli,* Svezak Geografija, 8-9, 21-39.

Kadusic, A., & Suljic, A. (2018). Migration and Demographic Changes: The Case of Bosnia and Herzegovina. *European Journal of geography*, 9(4), 75-86. Available at: https://ojs.eurogeojournal.eu/index.php/egj/article/view/52 (27.06.2022)

Kalogirou, S., Tsimbos, C., Verropoulou, G., & Kotsifakis, G. (2012). Regional mortality differentials in Greece by selected causes of death. *Journal of Maps*, 8(4), 354-360. https://doi.org/10.1080/17445647.2012.743439

Kibele, E., Klüsener, S., & Scholz, R. (2015). Regional Mortality Disparities in Germany: Long-Term Dynamics and Possible Determinants. *KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie,* 67, 241–270. https://doi.org/10.1007/s11577-015-0329-2

Kurek, S., Wójtowitz, M., Galka, J. (2021). Using Spatial Autocorrelation for identification of demographic patterns of Functional Urban Areas in Poland. *Bulletin of Geography. Socio-economic series*, 52 (2021): 124-144. https://doi.org/10.2478/bog-2021-0018

Lovic Obradovic, S., Krivosejev, V., & Yamashkin, A. A. (2020). Utilization of hot spot analysis in the detection of spatial determinants and clusters of the Spanish flu mortality. *Journal of the Geographical Institute "Jovan Cvijić" SASA,* 70(3), 289-297. https://doi.org/10.2298/ IJGI2003289L

Masic, I., Novo, A., Pilav, A., Jokic, I., & Toromanovic, S. (2006). *Health Care System in Federation of Bosnia and Herzegovina.* Materia Socio Medica, 18(4), 2012-2018.

Mijic, N., & Ateljevic, J. (2018). Demographic Analysis Using Modern GIS Software Tools - Case Study of the Republic of Srpska (Bosnia and Herzegovina). In Hadžikadić, M., Avdaković, S. (eds) Advanced Technologies, Systems, and Applications II. IAT 2017. Lecture Notes in Networks and Systems, Vol 28, 571-591. Springer, Cham. https://doi.org/10.1007/978-3-319-71321-2_51

Ocaña-Riola, R., & Mayoral-Cortés, J.M. (2010). Spatio-temporal trends of mortality in small areas of Southern Spain. *BMC Public Health*, 10, 26 (2010). https://doi.org/10.1186/1471-2458-10-26

Oliveira Santos, E.G., Costa Oliveira, Y.O.M., Azevedo, U.N., Silva Nunes, A.D., Amador, A.E., & Barbosa, I.R. (2017). Spatial temporal analysis of mortality by suicide among the elderly in Brazil. *Revista Brasileira de Geriatria e Gerontologia,* 20(6), 845-855. https://doi.org/10.1590/1981-22562017020.170115

Ord, J.K., & Getis, A. (1995). Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. *Geographical Analysis*, 27(4), 286-306. https://doi.org/10.1111/j.1538-4632.1995.tb00912.x

Ouellette, N., Bourbeau, R., & Camarda, C.G. (2012). Regional disparities in Canadian adult and old-age mortality: A Comparative study based on smoothed mortality ratio surfaces and age at death distributions. *Canadian Studies in Population*, 39(3-4), 79-106. https://doi.org/10.25336/P61P53

Rodrigues, M., Bonfim, C., Portugal, J. L., Gurgel, I. G. D., & Medeiros, Z. (2013). Using spatial analysis to identify areas vulnerable to infant mortality. *Revista Panamericana de Salud Publica*, 34(1), 36-40. Available at: https://scielosp.org/article/rpsp/2013.v34n1/36-40/ (06.10.2022)

RZSRS (2022). Population estimates 1996-2021. Banja Luka: Republic of Srpska Institute of Statistics. Available at: https://www.rzs.rs.ba/front/ category/2/ (17.03.2022)

Tokalic, R., Vidak, M., Mahmic Kaknjo, M., & Marusic, A. (2021). Antifragility of healthcare systems in Croatia and Bosnia and Herzegovina: Learning from man-made and natural crises. The Lancet *Regional Health-Europe*, 9(2021). https://doi.org/10.1016/j.lanepe.2021.100216

Vilinová, K. (2020). Spatial Autocorrelation of Breast and Prostate Cancer in Slovakia. *International Journal of Environmental Research and Public Health*, 17(12), 4440. https://doi.org/10.3390/ijerph17124440

Wang, Y., Zhu, J., He, C., Li, X., Miao, L., & Liang, J. (2012). Geographical disparities of infant mortality in rural China. *Archives of Disease Childhood. Fetal and Neonatal Edition*, 97, F285–F290. https://doi.org/10.1136/archdischild-2011-300412

Weeks, J. (2004). The role of spatial analysis in demographic research. In: Goodchild, M.F. and Janelle, D.G. (eds.). Spatially integrated social science. Oxford University Press.

Xiang, K., & Song, D. (2016). Spatial Analysis of China Province-level Perinatal Mortality. *Iran J. Public Health*, 45 (5), 614-622. Available at: https://ijph.tums.ac.ir/index.php/ijph/article/view/6797(31.08.2022)