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Correlation between precipitation and orography - key element of the Spatial Decision Support System for Prevention and Management of Floods in the Firiza Basin (Northwest Romanian Carpathians)

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Abstract

Research on the influence of relief on precipitation has been identified in many studies conducted locally, regionally or globally. However, the research on the area analyzed in the present paper is comparatively lacking. The surrounding mountain area we refer to is represented by the Someș and the Tisa watersheds. The present study focuses on analyzing the influence of the relief, i.e. of the altitude, slope orientation relative to the position of the Sun and the movement of air mass as a factor on precipitation and rainfall gradient. For that, datasets of daily precipitation recorded at 62 rainfall stations were used, as follows: 36 rainfall stations in Maramureş County, 19 rainfall stations in Satu Mare County, and 7 rainfall stations in Bistrița-Năsăud County. Precipitation data from rainfall stations located in the neighborhood of the study area were used in order to determine the influence of relief on frontal precipitation. The second purpose of the research was to determine if there is a correlation between precipitation and altitude. To this end, ArcGIS and Microsoft Office software were used. The results seem to confirm the major influence of the relief over the dynamic convection imposed to the air masses on ascending slopes, various average vertical precipitation gradients and differentiated distribution of rainfall. The present analysis and its results will highly contribute as an input element in a Spatial Decision Support System for Prevention and Management of Floods in Firiza Basin (North-Western Carpathians).

Keywords: *relief, rainfall, depression, climate, altitude, SDS System*

Rezumat. Corelația dintre precipitații și orografie - element cheie al Sistemului Spațial de Suport Decizional pentru Prevenirea și Managementul Inundațiilor în Bazinul Firiza (Carpații de Nord-Vest ai României)

Cercetările privind influența reliefului asupra precipitațiilor sunt prezente în multe studii realizate la nivel local, regional sau global. Prin comparație, cercetările privind zona abordată în prezenta lucrare lipsesc. Arealul montan în studiu este reprezentat de bazinele hidrografice Someș și Tisa. Studiul este axat pe analiza influenței reliefului în funcție de altitudine, orientarea pantei în raport cu poziția Soarelui și mișcarea maselor de aer ca factor de influență al precipitațiilor. În analiză au fost utilizate seturi de date referitoare la precipitațiile zilnice înregistrate la 62 de posturi pluviometrice, astfel: 36 posturi din județul Maramureș, 19 posturi din județul Satu Mare și 7 posturi din județul Bistrița-Năsăud. Pentru a determina influența reliefului asupra precipitațiilor frontale au fost utilizate datele de la posturile situate în vecinătatea zonei de studiu. Al doilea obiectiv a fost de a determina dacă există o corelație între precipitații și altitudine. Pentru aceasta s-au folosit software ca ArcGIS și Microsoft Office. Rezultatele par să confirme influența majoră a reliefului asupra convecției dinamice impuse maselor de aer în mișcare ascendentă pe versanți, respectiv diverșii gradienți medii verticali ai precipitațiilor și distribuția diferențiată a precipitațiilor. Întreaga analiză va contribui semnificativ la Sistemul Spațial de Suport Decizional pentru Prevenirea și Managementul Inundațiilor în Bazinul Firiza (Carpații de NV).

Cuvinte-cheie: *relief, precipitații, depresiune, climă, altitudine, Sistem SDS*

Introduction

Flood risk management in watersheds, with tools such as spatial decision support systems, among others, requires spatial and temporal analysis of rainfall to properly represent hydrological processes.

For the mountain areas, topography and elevation affect rainfall and have to be considered for prediction and mapping (Sanchez-Moreno et al., 2014). The influence of elevation on the precipitation, particularly on rainfall, has been studied for decades, for different regions and with various results (Alter, 1919; Bleasdale and Chan, 1972; Lee, 1911; Sindosi et al., 2015). Most of the studies revealed that rainfall amount increases with elevation in a usually linear relationship as it is connected to orographic updraft (Bleasdale and Chan, 1972; Henry, 1919; Hibbert, 1977; Llasat and Puigcerver, 1992; Weisse and Bois, 2001).

The linear relation is easy and represents an acceptable approximation between rainfall and elevation (Phillipset al., 1992), but for the North-Western Carpathians of Romania the relation is better described by nonlinear functions or it is not clear. However, additional factors influence the rainfall patterns, such as moisture sources or large circulation patterns over a region, which weakens the relationship between rainfall and elevation (Konrad, 1996). For certain areas, such as the Swiss Alps, it has been found that precipitation can decrease with elevation (Blumer, 1994), or elevation is of less

importance when compared to other variables such as exposure or relative distance between rainfall stations, as in Oahu Island (Cheng and Lau, 1970).

In mountain regions, where the nature of rainfall is influenced by orographic lifting, rainfall patterns are complex and not well understood (Prudhomme and Reed 1998). The influence of topography may express itself by changes in precipitation intensity, in the number of precipitation days or in a combination of both factors (Duckstein et al., 1973). For a better understanding and characterization, additional parameters should be considered in the predictions. For Western Colorado, Spreen (1947) found that elevation alone explains 30% of the seasonal variance of rainfall, while the combination of altitude, slope, exposure and orientation explained 88% (Sanchez-Moreno et al., 2014). Basist et al. (1994) found slope gradient, orientation, elevation and exposure as the best mean annual precipitation predictors for ten mountain regions all over the world (Sanchez-Moreno et al., 2014).

An important variable that influences the spatial distribution of rain in mountain regions is the prevailing wind direction (Sanchez-Moreno et al., 2014). Strong winds may redistribute the precipitation, facilitating larger amounts in the valleys and smaller ones on windward slopes (Sanchez-Moreno et al., 2014). The erratic and turbulent nature of wind makes its characterization difficult (Sanchez-Moreno et al., 2014). The influence of wind can be indirectly described by the orientation and width of the valleys, parameters that can be considered in the analysis in form of additional topographic variables, such as aspect (Daly et al., 1994; Sevruk et al., 1998).

Mountain slopes facilitate the uplift of moisture that results in high rainfall intensities on the windward side of the mountains (Singhet al., 1995), where the rainfall stations tend to be placed. For practical reasons, in mountain areas rain gauges are usually located in valleys, thus biasing the information towards low areas (Prudhomme and Reed, 1998). The position of the rain gauges can be used to describe wind direction and allows a better understanding of the motion path of clouds. For Western Oregon and Washington, Schermerhorn (1967) found that an index for the latitude of the station, combined with terrain elevation and barrier elevation explains most of the variations of annual precipitation during the winter season. Buytaert et al. (2006) explained the monthly variability of rainfall in the Ecuadorian Andes in terms of slope, aspect, elevation and position of the stations.

The present research takes place in the Someș-Tisa Watersheds, NW Romania (the Firiza watershed), as part of the Spatial Decision Support System (SDSS) project (Fig. 1).

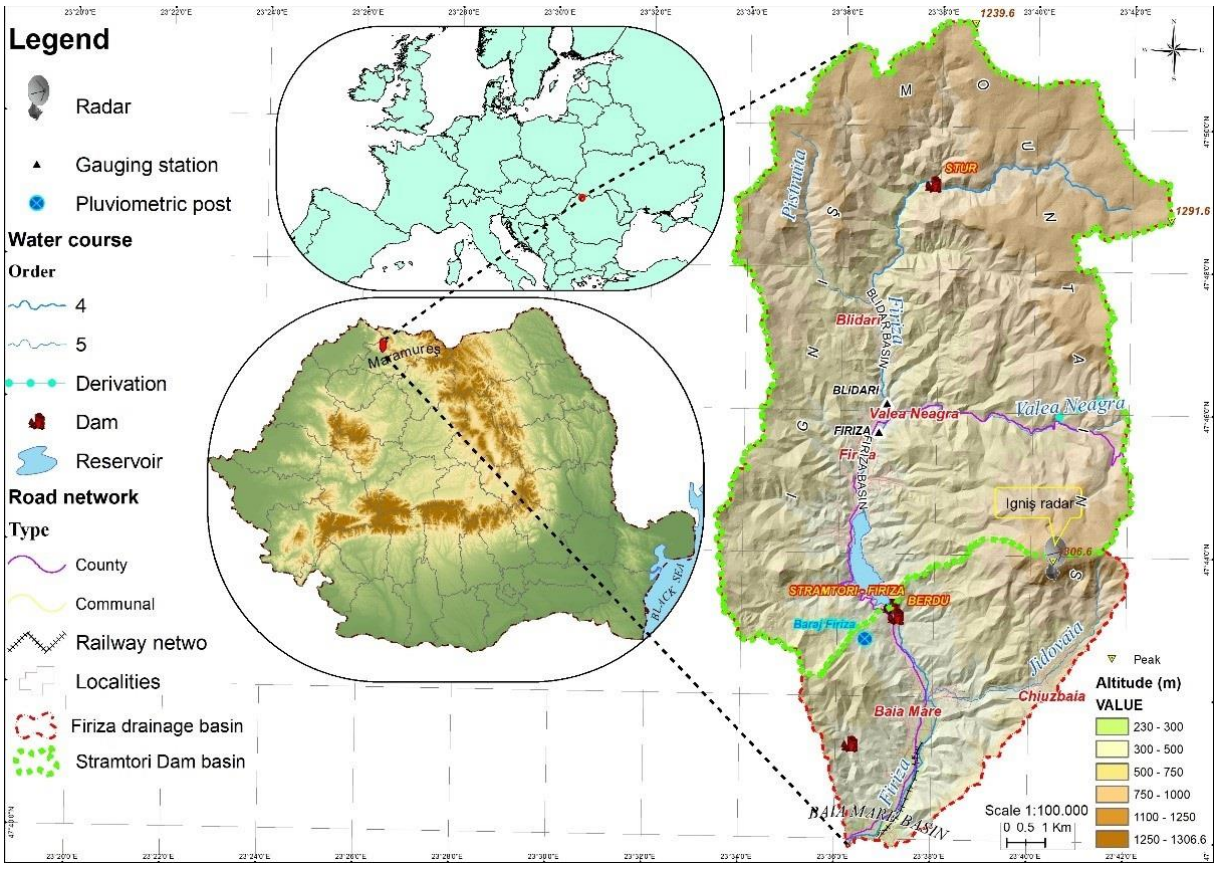

Fig. 1: Location of the Firiza river basin (altitude source: Topo Map RO & PPPDI-DTM, 2014)

The relief and elevation variations in the Firiza watershed and surrounding mountain areas suggest a strong influence of topography on rainfall variability (Sabău et al., 2020); however, this effect has hardly been studied (Bazac, 1983) and without taking into account additional topographic parameters or the position of the rain gauges. Long-term records of rainfall are available for the Firiza watershed and the surrounding mountain area. In this study, the rainfall has been analyzed from low to high temporal periods, to show how the aggregation of rainfall may have an effect in its correlation with topographic parameters.

Within the area, there are few weather stations with disposition that is not appropriate for a spatial analysis, so rainfall data recorded at weather stations and rainfall gauging stations in the complex and surrounding area were used. The reason for choosing this alternative was determined by the numerous rainfall stations within the monitoring system of the Water Administration of the Someș-Tisa Basin.

The book published in 1951 by St. M. Stoenescu - *The Climate of Bucegi* - represents the first Romanian study on mountain climatology and it was very important for the area under study. Its theoretical foundations are still relevant today, as per 1983, Gh. C. Bazac - *Influence of relief on the main features of Romanian climate*.

Between 1960 and 1980, specialists of the Institute of Meteorology and Hydrology have written a number of papers regarding the influence of relief on precipitation, some published and some in the form of manuscripts. The following years registered the publication of several doctoral dissertations on the problems of climatology, such as F. Moldovan – *The role of the Apuseni Mountains in differentiating climate in the north-western Romania. Study of dynamic climatology*, 1986. More recently, in 2008, the National Meteorological Administration published the work - *The climate of Romania*, for the 1961-2000 reference period.

The relief is the main factor influencing the distribution of climatic parameters in the studied area (Bâzâc, 1983), and high intensity precipitation events are frequent throughout the year (Bâzâc, 1983; Climate of Romania, 2008; Vlăduț and Onțel, 2014; Șerban, 2018).

Average annual amounts of precipitation are determined by the evolution of the atmospheric pressure systems, the dynamics of air masses and fronts. The highest amounts of precipitation are generated by cyclonic activity associated with the polar front in the Iceland area, mobile cyclones activity in the thalweg of the Icelandic depression reaching the Maramureş area as well.

The main objectives of this research are: (1) to determine the influence of daily events on the monthly and seasonal rainfall variability, (2) to investigate whether for the Firiza watershed spatial patterns of rainfall can be parameterized, supported by terrain and location data, and (3) to determine the best strategy to map long-term mean seasonal rainfall in the Firiza using the limited data available.

Data and Methods

Study area

The Firiza river basin holds a special position within Romania (Fig. 1). This assertion no longer needs to be argued if we look at the median area in which it is located: in the northwest part of the country, the short distances from the northwestern border and the favorable exposure to the circulation of the ocean air masses originating in the Atlantic Ocean area, from which it receives a good part of the humidity. Against the background of these climatic-geographical interferences, the spatial development of the Carpathian chain appears as a polarizing element that gives an unmistakable individuality to the neighboring region, up to distances that exceed the limits of the Romanian territory.

Within the Someș-Tisa hydrographic area, the Firiza basin has a northern position and it extends between the latitudes of 47° 52′ 00′′ and 47° 40′ 00′′; longitudinally, it is located in the north-western part of the Someș-Tisa hydrographic area, between 23° 33′ 00′′ and 23° 43′ 00′′ east longitude.

The features imprinted by the major relief of the Firiza basin over the climate are detached or partially deduced from various studies, but the dynamics of qualitative and quantitative variations in time and space of its various elements, the laws and mechanism that govern and generate as well as maintain them have not yet been deciphered and argued at the scale of current needs.

Given the development of a future SDSS for flood prevention and management, the morphology and position of the Firiza river basin have increasingly required the knowledge of the influence of relief on the variation of precipitation and the distribution of average rainfall.

The subject of the present paper was determined by the desire to know in detail the characteristics of the most important input parameter in the hydrological forecast model, because the quality of the forecast depends equally on the accuracy of input data and the hydrologist's skills (Sabău et al., 2020).

A useful hydrological forecast model for all seasons needs a lot of input data, but the precipitation monitoring network in northwestern Romania does not provide the necessary data for all parameters (Fig. 2). Therefore, we were compelled to investigate the influence of relief on precipitation, in order to determine the laws governing the variation and distribution of precipitation and all associated parameters.

A series of parameters of some climatic elements are treated for the entire Someș-Tisa hydrographic

space. However, due to the distribution of the weather stations necessary for a spatial analysis, most of the parameters were analyzed only for the northern part of the area.

The aim of the paper is to explain the mechanisms of atmospheric phenomena, to highlight and explain the laws according to which they take place when exposed to the influence of major relief. Another goal is to determine the proportion of this influence on the precipitation in the surrounding area.

This approach requires long and homogeneous data sets of observations only within the same sequence. The method allows relative values to be reached on the basis of different strings and intervals, valid for highlighting the legalities underlying the atmospheric processes. By similarity, these laws can be extended, generalized, for similar natural conditions.

The small number of stations located on mountain slopes with different orientations limits the possibilities of investigation based on comparative profiles.

In order to highlight or explain some specific characteristics of the precipitation in the studied area, data from the stations located in the areas with the most obvious manifestations of them were used. For example, the catabatic phenomena were studied on transversal profiles (over the Vlădeasa Massif), while in order to highlight their climatic weight, data from weather stations located in the representative areas were used (Vlădeasa 1400, Vlădeasa 1800, and Stâna de Vale for optimal rainfall).

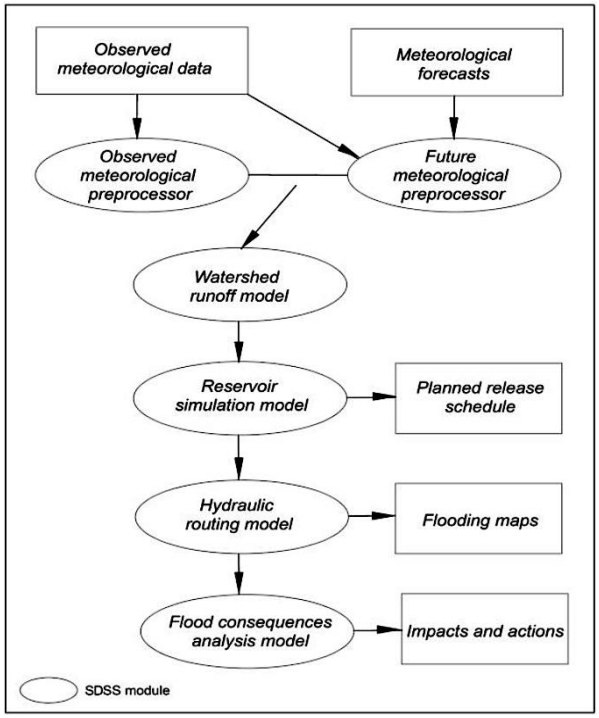

Fig. 2: General schema and components of a SDSS (after Sabău et al., 2020)

Data

Spatial distribution of weather stations within the studied area is not suitable for a spatial analysis (Fig. 3).

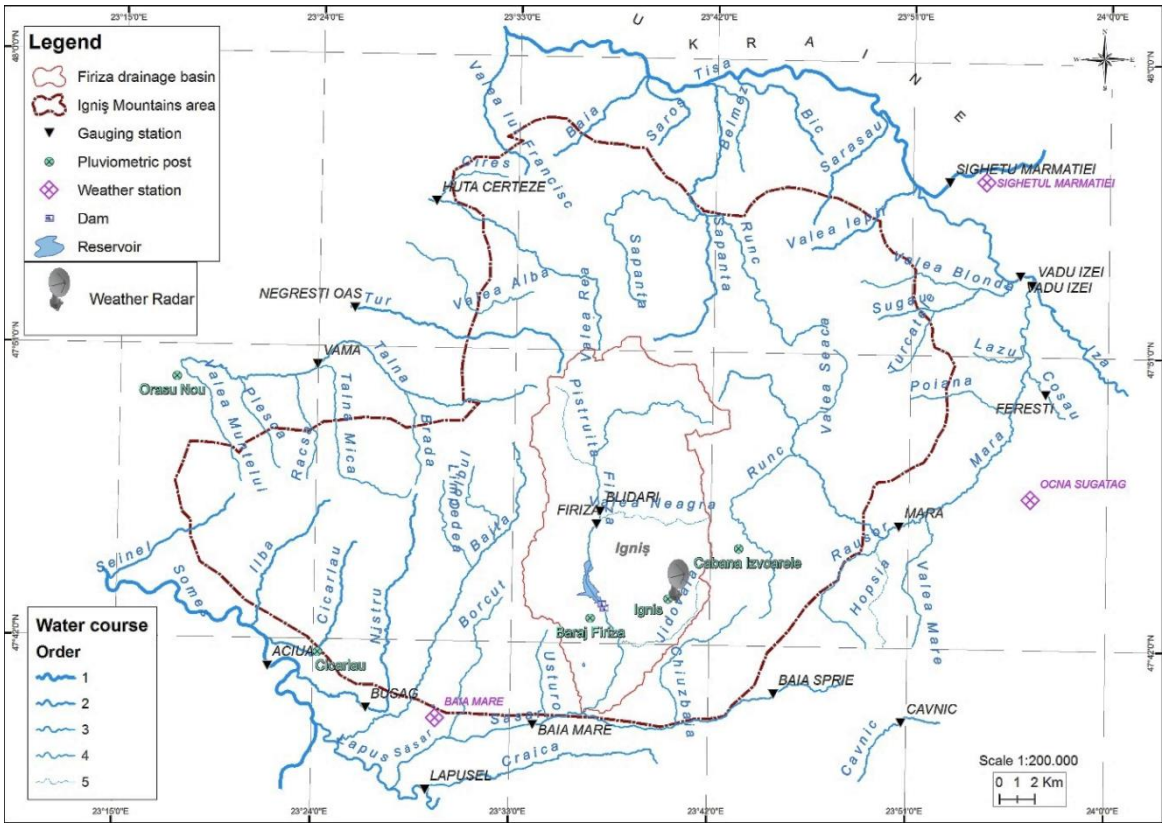

Fig. 3: Hydrometeorological monitoring network in the area under study

Therefore, we also used the precipitation data recorded at the rainfall stations and at the hydrometric stations within and the surrounding area. The authors chose this solution due to the higher density of the stations that measure precipitation and are included in the monitoring system of the Someș - Tisa Water Basin Administration.

Datasets of daily rainfall recorded at 62 rainfall stations were used, as follows: 36 rainfall stations in the Maramureş County, 19 rainfall stations in Satu Mare County, and 7 rainfall stations in Bistrița-Năsăud County. Rainfall stations are part of monitoring network of hydro-meteorological parameters within the Someș-Tisza basin. For the 1961 - 2000 reference period, statistical data from the *Climate of Romania* (2008) were also used.

To perform the analysis, data of numerical and cartographic type were used. The cartographic database contains synoptic maps at European scale, namely the Sea Level Pressure maps, as well as geopotential maps at different pressure altitudes in the troposphere.

For the case study, daily weather data from the European Climate Assessment & Dataset and rp5.ru websites were collected. For the relief analysis and creation of maps derived from the digital model of terrain, we applied the digital terrain model with a spatial resolution of 3 m × 3 m, generated with LiDAR technology within the PPPDI project (*Plan for the Prevention, Protection and Mitigation of Flood Effects*) a national project funded by AXA 5 POS Environment (*POS - Sectorial operational program).*

Methods

For the present paper, elements related to the rainfall characteristics were calculated based on statistical software (Microsoft Office, Statistical Package for the Social Sciences, HEC-SSP) and completed with data retrieved from synthesis and studies of the Someș-Tisa Regional Water Branch. Support for GIS modeling was made up of 1:5000 plans, 1:25.000 topographic maps, orthophotos and other satellite images; coordinates and GPS files from different sources (field trips and references); digital mapping and files conversion were achieved with specific software (GPS Utility, Global Mapper, ArcGIS 10. x).

To establish the atmospheric circulation for the case study, HYSPLIT model was used (Draxler et al., 2012). A simple air parcel 48-hour backward trajectory option was used in order to identify the direction of the influx and the origin of the air masses in the studied area. Based on weather maps provided by wetter.3de archive (Wetter3.de, 2017), temperature and geopotential at 500, 700, 850 hPa levels, moisture at 700 hPa level and Sea Level Pressure were analyzed.

Results and Discussion

The influence of the Carpathian mountain system on the air masses continentalization

The main features of the relief, such as altitude, extension and spatial arrangement in relation to the main directions of the air masses advection generate a decisive influence on the amount and type of precipitation. Thus, if the mountain ranges are oriented perpendicularly to the direction of the atmospheric fronts movement, they force the air masses to escalate, determining the intensification of the atmospheric processes. During these processes, a large part of the moisture load falls in the form of precipitation on exposed slopes.

In order to determine the rate of the relief influence on the continentalization processes and, therefore, on the rainfall potential of the air masses that transport moisture from the Atlantic Ocean over the northwest of Romania to the east, the precipitation data from a series of stations located along three profiles were used. The three profiles that cross the Someș-Tisa hydrographic area are: from west to east; from northwest to southeast, and from north to southwest. The first two profiles start from the western border of Romania, cross the mountain ranges of the Carpathians and reach the edge of the area. The third profile has a north-south orientation, which was extended in the Criș rivers basin to capture the exceptional mountain profile offered by the two stations located on the Vlădeasa Massif (Fig. 4).

The variation curve analysis of the three profiles shows, on one hand, the increases in precipitation on the western slopes of the Carpathians, exposed to the ocean air masses circulation, and on the other hand, the gradual decrease of their rainfall potential as they move eastward.

As a consequence of their westerly position, the Oaș-Igniș-Gutâi mountain range and the western branch of the Apuseni Mountains take priority of the moisture load of the ocean air masses, thus achieving important amount of precipitation. The mountains, located in the background (sheltered), reactivate atmospheric processes, but the rainfall potential of the ocean air is reduced by the mountain range over which they have already passed.

In order to analyze the relief influence on the precipitation, three profiles of the average annual amount of precipitation are presented in Fig. 5, 6 and 7.

Average annual amounts of precipitation are determined by the evolution of the atmospheric pressure systems, the dynamics of air masses and fronts. The highest amounts of precipitation are generated by cyclonic activity associated with the polar front in the Iceland area, mobile cyclones activity in the thalweg of the Icelandic depression reaching the Maramureş area as well.

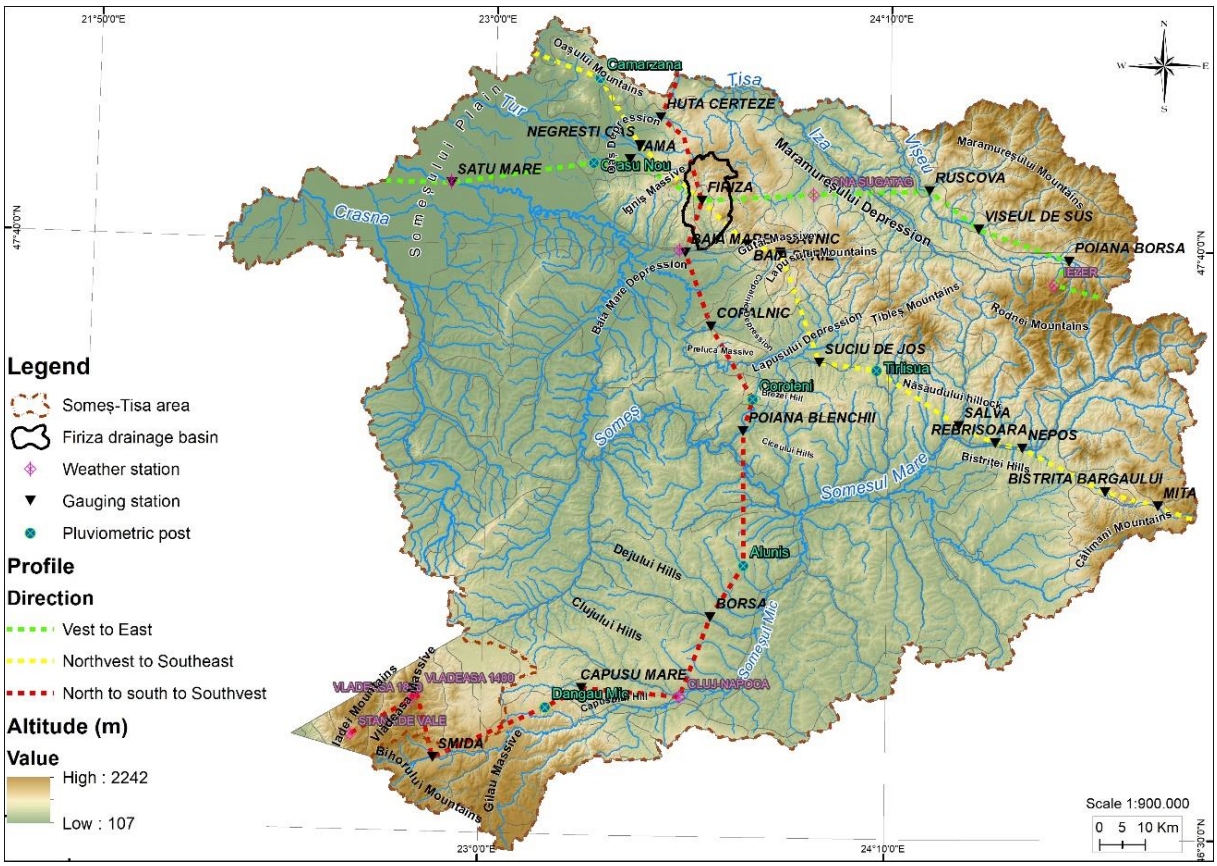

Fig. 4: The position of the three profiles that cross the Someș-Tisa hydrographic space

The climate, specificities, influences

The climate of the Firiza basin is of temperate continental-moderate type and it is subdivided into two areas: 1) mountain and 2) hills and plateau, with a subtype of depression in the Baia-Mare Depression. The analyzed basin is characterized by the type of moderate continental temperate climate, with the specificity created by the mountainous floor of the middle and low mountains (800-1300 m altitude).

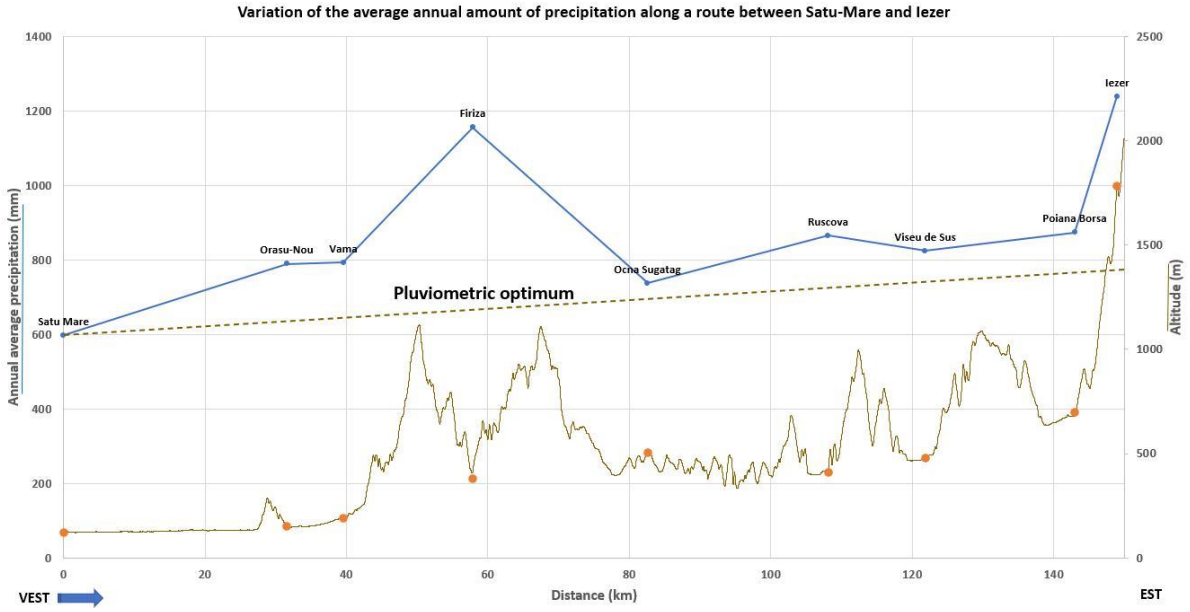

Fig. 5: The variation of the average annual amount of precipitation, along a V-E route

Raw data sources: "Someș-Tisa" Water Branch, Cluj

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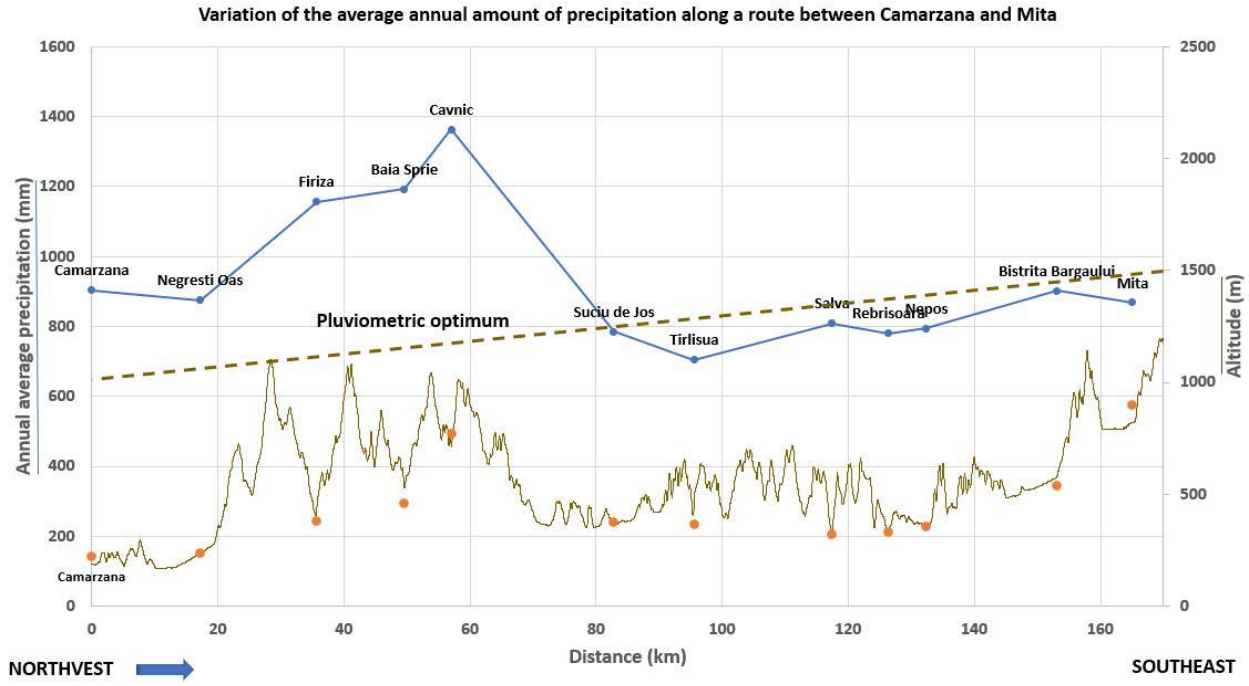

Fig. 6: The variation of the average annual amount of precipitation, along an NV-SE route

Raw data sources: "Someș-Tisa" Water Branch, Cluj

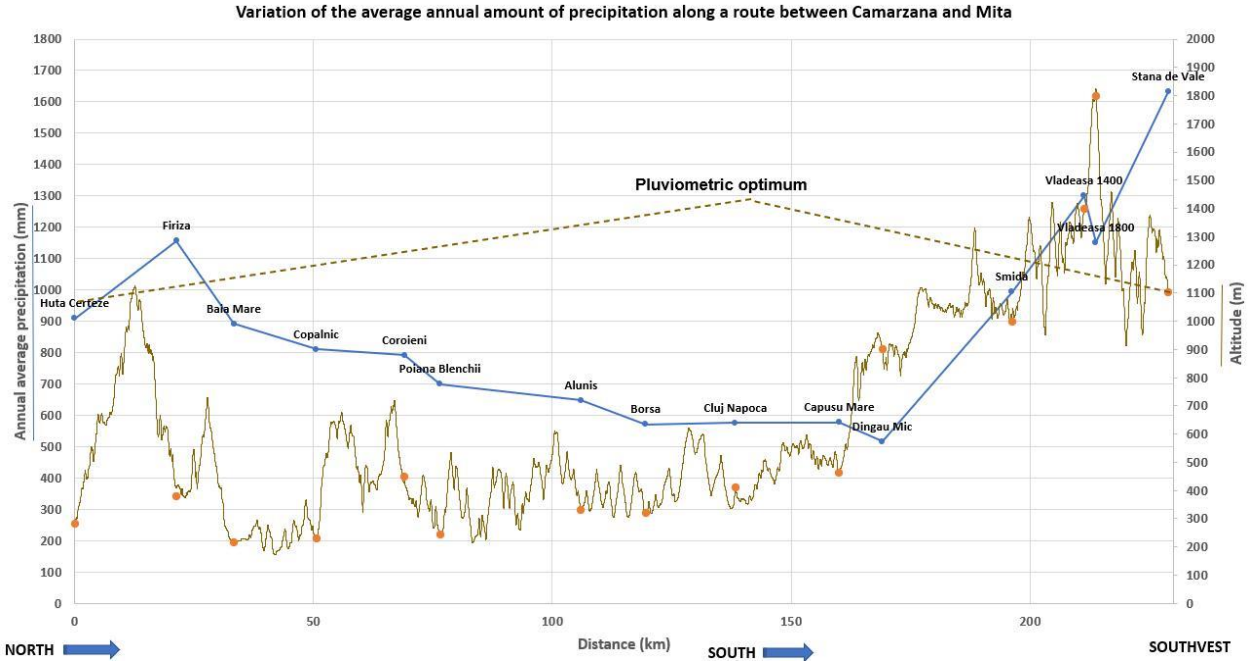

Fig. 7: The variation of the average annual amount of precipitation, along an N-S-SW route

Raw data sources: "Someș-Tisa" Water Branch, Cluj

The area is affected mostly by the western air circulation, with the predominance of maritime-polar or maritime-arctic air advections from the northwest in winter and the advection of the warm air from the southwest of Europe in summer. The values of the climatic parameters depend on the altitude (Fig. 8), the orientation of the slopes towards the general circulation of the atmosphere, and their exposure (Fig. 9).

The Igniș Mountains represent an orographic barrier of the air masses movement from the west. This causes an uneven distribution of moisture, cloudiness and precipitation, the western slopes recording a higher humidity (of 2 to 4%) and rainfall (by 50 to 100 mm) at the same altitude.

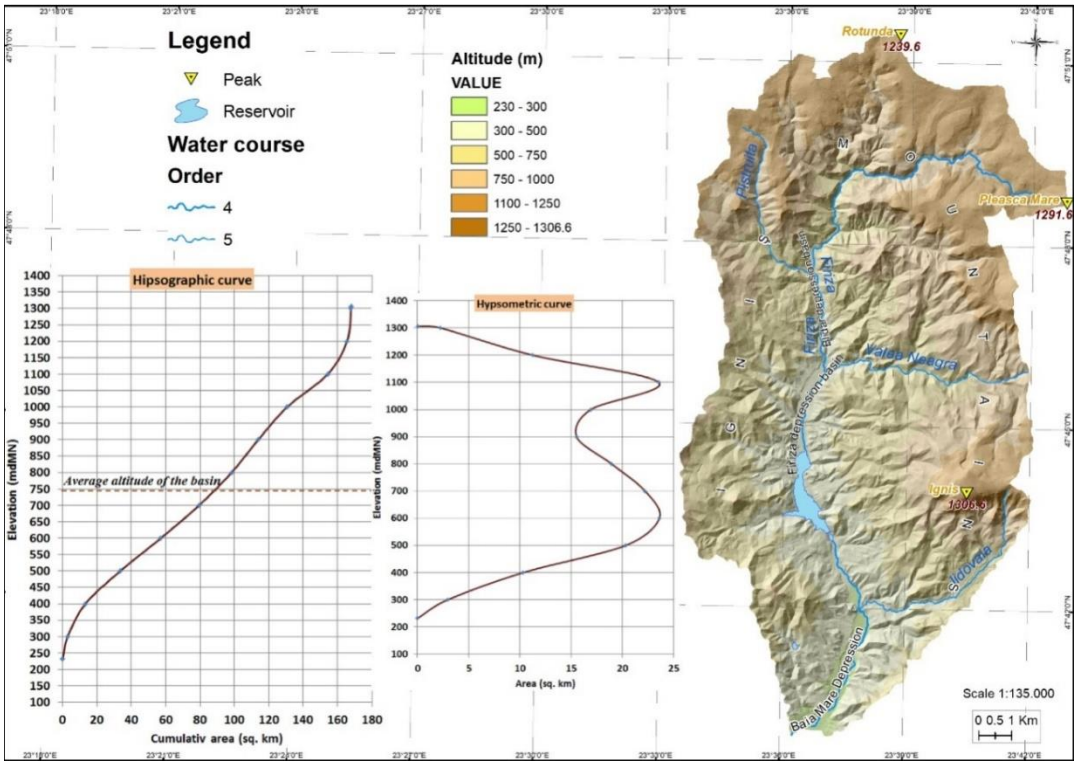

Fig. 8: Hypsometric map with characteristic curves

(altitude source: Topo Map RO & PPPDI-DTM, 2014)

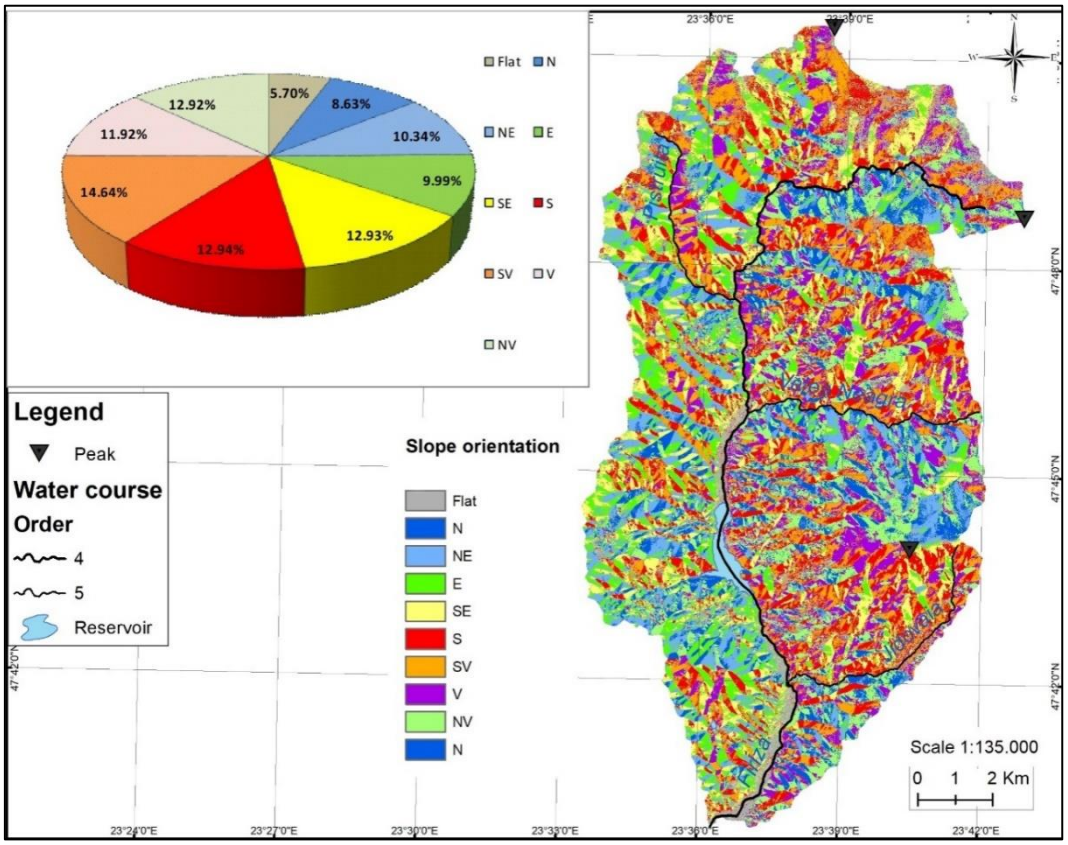

Fig. 9: Aspect (slope direction) map

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Precipitation regime

The average annual precipitation is characterized by significant variations, caused especially by the relief configuration, by the exposure to the dominant atmospheric circulation (in the west) and by elevation. While the average annual value of precipitation in the Baia-Mare Depression is situated at about 892 mm, in the high mountain areas, on the slopes exposed to the oceanic air masses; it reaches at about 1400 mm, (due to favorable exposure to dominant circulation, Fig. 10). For Baia Mare weather station, the monthly and annual average amount of precipitation have the following values (Table 1).

Table 1. Average monthly and annual rainfall (mm) at Baia Mare weather station

Station	J	F	M	A	M	J	J	A	S	O	N	D	Year
Baia Mare	65.7	52.4	50.3	63.1	84.2	103.5	92	77.8	63.5	58.1	72.3	90.1	872.9

Source: N.M.A – National Meteorological Administration

The average annual number of days with precipitation ≥ 0.1 mm is high, correlating with the annual quantities of rainfall. Yearly, the number of days with precipitation ≥ 0.1 mm is of 110-160 days in the lower hilly areas exposed to dominant western circulation, 120-140 days in the higher hilly areas, 150-200 days in the lower mountain regions and 150 ≥ 170 days at the highest altitudes. On average, at Baia Mare weather station, 156.5 days with rain per year are recorded (*Climate of Romania*, 2008).

Spatial distribution of average rainfall

The altitude correlated with the average amount of precipitation highlights the laws of spatial rainfall distribution (Cocuț, 2008; Șerban et al., 2020). Air masses circulation is predominantly from NW to SE, which determines the peculiar spatial distribution of rainfall. The correlation between average multi-annual rainfall and altitude is shown in the Fig. 10.

Regarding the atmospheric precipitation, an increase with altitude to a certain height, known as the rainfall optimum is observed, followed by decrease. In the Someș-Tisa hydrographic area, the rainfall optimum is around 1100 m, so that within the Firiza basin, the amount of precipitation increases with altitude, up to the rainfall optimum.

For the study area five distinct exponential links are highlighted - each one corresponding to a different rainfall gradient (Fig. 10).

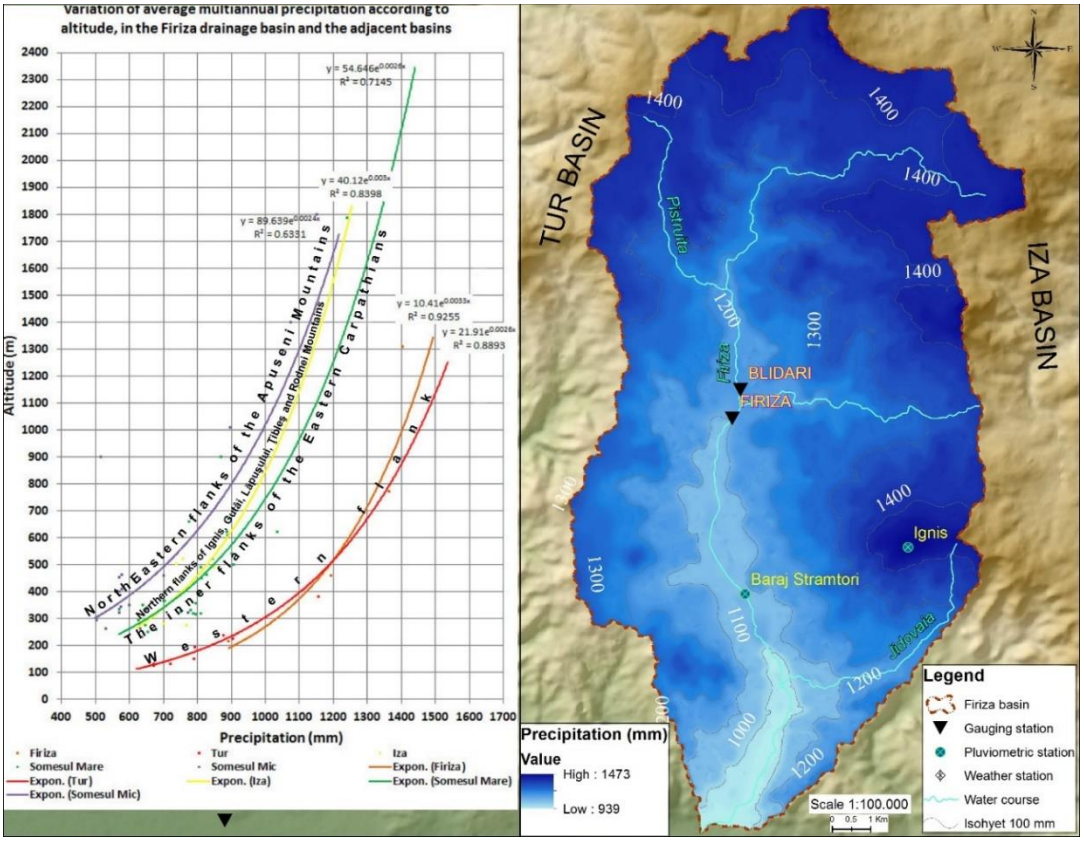

Fig. 10: Average annual rainfall distribution map in the study area and adjacent major basins

Raw data sources: "Someș-Tisa" Water Branch, Cluj

The western flank shows the precipitation gradients with highest values as it is exposed to air masses advections. The central part of the basin is characterized by lower rainfall gradients while the sheltered south-east part of the basin presents the lowest values of precipitation gradients.

The increase of precipitation amount with altitude takes place until a certain height, from which they begin to decrease due to the reduction of the water vapor content of the progressively cooled air in the altitude.

Significant amounts of precipitation are also discharged / also fall over some interfluves in the central and central-western part of the basin. In the lower sector of the basin, the values are slightly reduced, due to the descent of the air masses towards the depression area of Baia Mare, reaching values below 900 mm.

The spatial distribution of the average multiannual precipitation and of seasonal amounts shows that important concentrations are characteristic on the ridges and plateaus in the eastern and northern part of the basin, where the values can easily exceed 1300 mm.

As compared to the annual average values of precipitation recorded in the Baia-Mare Depression (about 892 mm), the precipitation amounts rise on the slopes exposed to the ocean air masses in the high mountain areas, at about 1400 mm. High intensity rainfall events are frequent throughout the year (Posea, 1980; Bâzâc, 1983; *Clima României*, 2008; Zaharia, 2012; Sabău et al., 2018; Șerban, 2018).

The slight reduction of precipitation amounts at a certain altitude is confirmed by the correlation between the two parameters (Fig. 11).

Case Study: Distribution of rainfall in the study area and neighboring mountain frame

To emphasize the relief influence over the amount of precipitation of frontal origins, the thermal convection was excluded by choosing a case study from the beginning of the cold season. For this, a north-western air circulation type was analyzed as well as the rainfall distribution in the studied area.

On the 06.11.2016, 00 GMT the geopotential structure at 500 hPa shows that the eastern half of Europe is under the influence of an upper ridge, generating a south-west air circulation. At ground level, the western part of the continent was under the influence of an Atlantic cyclone, moving eastward, associated to an upper trough (Fig. 12, A). This atmospheric structure generates a south-western flow both at ground level as well as in the middle troposphere. In the lower troposphere, the air advection over the south-east of Europe and the study area has its origin over the Mediterranean Sea, generating a warm and humid air influx (Fig. 13, left).

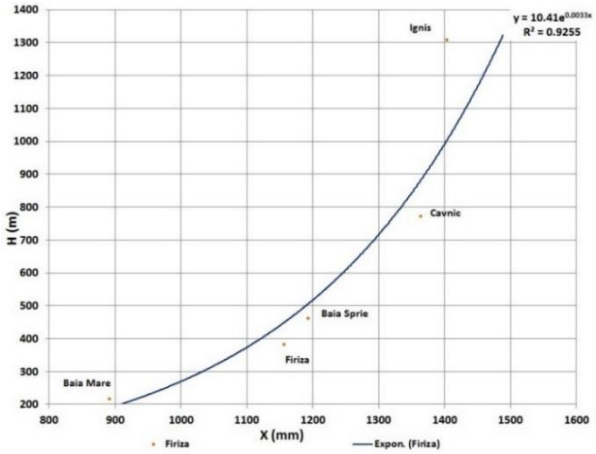

Fig. 11: Relationship between multiannual average precipitation and altitude

The fast movement of the Atlantic cyclone generates precipitation due to its warm and cold fronts over the study area as well as the movement of the upper trough. On the 9th of November, the air circulation becomes western, and on the10th, north-western (Fig. 13, right), generating a cold air advection from the upper troposphere to the ground level (Fig. 12, B).

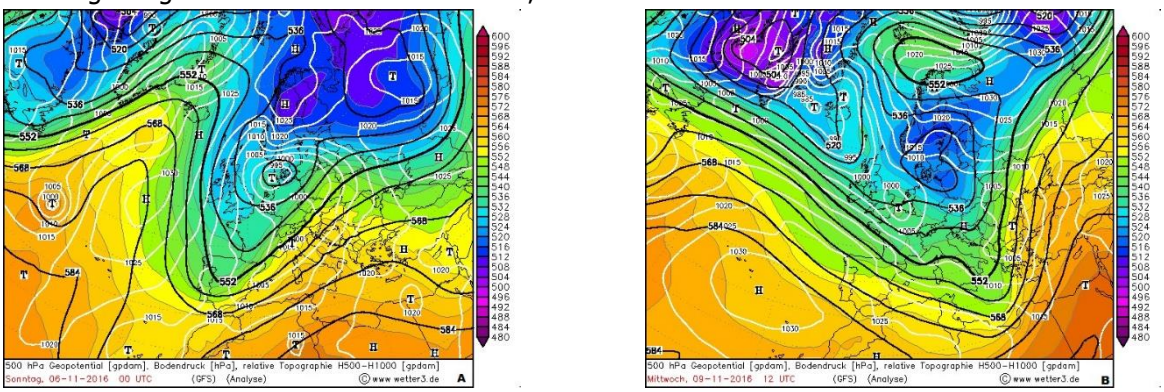

Fig. 12: Sea level pressure (white lines, hPa), 500 hPa geopotential height (black lines, gpdam), and relative topography 500-1000 hPa (colored, gpdam), recorded on 06.11.2016, 00 GMT (A) and 09.11.2016, 00 GMT (B)

Source: http://www1.wetter3.de/Archiv/

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The spatial distribution of rainfall in the study area, for the 06.11.2016, 04 GMT - 7.11.2016, 04 GMT period and for the 62 rainfall stations shows the highest amount of precipitation on the mountain slopes exposed to air circulation, and the lowest - in the low parts of Maramureş Depression (Fig. 14). For example, the Firiza rainfall station, situated at an altitude of 423 m, recorded 63.4 mm, Cavnic rainfall station, located at an altitude of 680 m, recorded 42.3 mm, while rainfall stations situated at lower altitude did not exceed 20 mm. This situation emphasizes the role of the relief in generating high amounts of precipitation in the case of humid air masses that cross the area.

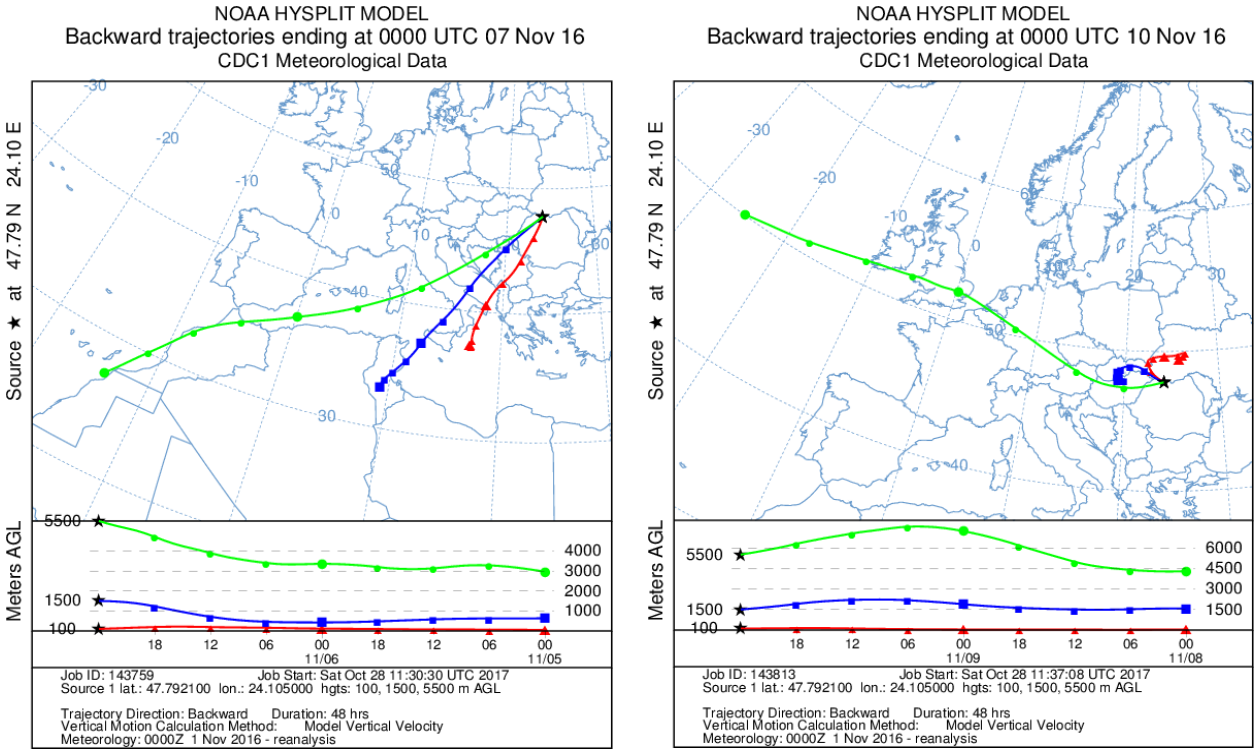

Fig. 13: The backward trajectories computed for air mass movement on 07.11.2016, 00 GMT (left) and 10.11.2016, 00 GMT (right)

Source: https://www.ready.noaa.gov/HYSPLIT.php

In the Firiza watershed area, the amount of precipitation is high due to the exposure to oceanic air masses, the SW-NE alignment and the lower orographic barrier enforced by Oaș Mountains.

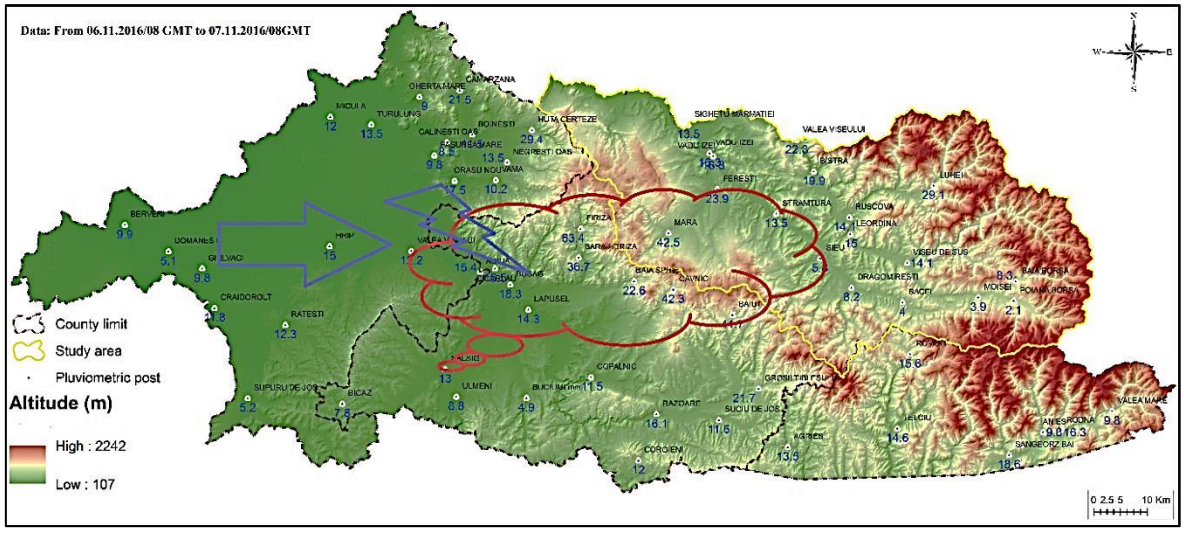

Fig. 14: The precipitation amounts recorded at rainfall stations within the study area for the 06.11.2016, 04 GMT - 7.11.2016, 04 GMT period

Raw data sources: "Someș-Tisa" Water Branch, Cluj

The results confirm the major influence of the relief over the recorded amount of precipitation due to orographic convection generated by the humid air masses ascending exposed slopes of the mountains and different distribution of the rainfall.

Conclusions

In the Firiza watershed area, the amount of precipitation is high due to the exposure to oceanic air masses, the SW-NE alignment and the lower orographic barrier enforced by Oaș Mountains.

Orographic precipitation is generated by the ascent of air masses over the slopes exposed to air masses advection. This process leads to saturation of the air in water vapor and condensation, causing precipitation showers. The characteristics of the orographic precipitation are dependent, therefore, both on the altitude and on the slope, as well as on the orientation of the slopes.

The results confirm the major influence of the relief over the recorded amount of precipitation due to orographic convection generated by the humid air masses ascending exposed slopes of the mountains and different distribution of the rainfall.

Accurate meteorological information is critical to simulating runoff processes within a hydrologic model. All this analysis will highly contribute as an input element in a Spatial Decision Support System for Prevention and Management of Floods in the Firiza Basin (North-Western Carpathians).

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Authors' contribution

All authors have an equal contribution in achieving the present paper.

Conflict of interests

The authors state that they have no conflict of interests.

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Geodiversity assessment by application of geoinformation approach (on the example of Golo Bardo Mountain, Western Bulgaria)

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Abstract

Geodiversity is considered as a complex indicator of the abiotic environment. On the example of information about Golo Bardo Mountain (Western Bulgaria), the article emphasizes the need to develop methods for quantitative assessment of the geodiversity of an area to minimize the subjective nature of the assessment by defining clear criteria that can be quantified. The complex geodiversity assessment of the investigated area was made based on the analysis of lithology, soils, topographic features and drainage network. The analysis is done in a GIS environment. Topographic settings are analysed on the base of digital elevation model with a cell size of 30 m using Spatial Analyst Tools. The elevation model is used for calculating the terrain roughness, slope gradients and aspects of the slopes. Geological component is evaluated considering the petrographic composition of the area. The variety of the abiotic components is calculated by application of grid method (cell size 1000 x 1000 m), using Focal statistics tool, neighborhood type "Variety". Fuzzy logic is suggested to be used for comparison of areas located in different regions and with different landscape conditions.
The results of the geodiversity assessment show that most of the area of the Golo Bardo mountain has moderate geodiversity index. The method used in the article gives reliable results with minimal subjectivity, that can be used for assessment of the distribution of the geodiversity on a particular area and allow to compare different territorial units. The results obtained in the current study show good correlation between areas with high and moderate geodiversity index, and areas with high biodiversity values. The applied methodology and the visualization of the geodiversity index allow for easy understanding of geodiversity by a wide range of stakeholders, even non-geoscientists, and can be successfully applied in the planning of geotourism activities.

Keywords: *geodiversity, terrain roughness, GIS, focal statistics, grid method*

Rezumat. Evaluarea geodiversităţii prin aplicarea unei abordări geoinformatice (asupra exemplului Muntelui Golo Bardo, Bulgaria de Vest)

Geodiversitatea este considerată un indicator complex al mediului abiotic. Pornind de la exemplul informațiilor despre Muntele Golo Bardo (Bulgaria de Vest), articolul subliniază necesitatea dezvoltării unor metode de evaluare cantitativă a geodiversității unei zone pentru a minimiza caracterul subiectiv al evaluării prin definirea unor criterii clare care pot fi cuantificate. Evaluarea complexă a geodiversităţii zonei investigate a fost realizată pe baza analizei litologiei, solurilor, caracteristicilor topografice şi reţelei de drenaj. Analiza se face într-un mediu SIG. Caracteristicile topografice sunt analizate pe baza modelului digital de elevație cu o dimensiune a celulei de 30 m folosind Spatial Analyst Tools. Modelul elevației este utilizat pentru calcularea rugozității terenului, a pantelor și a caracteristicilor acestora. Componenta geologică este evaluată având în vedere compoziţia petrografică a zonei. Varietatea componentelor abiotice este calculată prin aplicarea metodei caroiajului (dimensiunea celulei 1000 x 1000 m), folosind instrumentul de statistică focală (Focal statistics tool), tipul neighborhood „Varietate". Se sugerează utilizarea logicii fuzzy pentru compararea zonelor situate în diferite regiuni și cu diferite condiții de peisaj.
Rezultatele evaluării geodiversității arată că cea mai mare parte a zonei muntelui Golo Bardo are un indice de geodiversitate mediu. Metoda folosită în articol oferă rezultate fiabile cu subiectivitate minimă, care pot fi utilizate pentru evaluarea distribuției geodiversității pe o anumită zonă și permit compararea diferitelor unități teritoriale. Rezultatele obținute în studiul de față arată o bună corelație între zonele cu indice de geodiversitate ridicat și moderat și zonele cu valori mari de biodiversitate. Metodologia aplicată și vizualizarea indicelui de geodiversitate permit înțelegerea ușoară a geodiversității de către o gamă largă de părți interesate, nu numai cercetători în domeniul științelor naturii, și pot fi aplicate cu succes în planificarea activităților de geoturism.

Cuvinte-cheie: *geodiversitate, rugozitatea terenului, SIG, statistici focale, metoda caroiajului*

Introduction

Generally, geodiversity is defined as a set of abiotic components of the environment. This term has been used by geologists and geomorphologists since 1990s as an indicator about the variety of the abiotic environment. It was introduced mainly as an opposite to the term biodiversity and used to emphasize the importance of abiotic components. The definition of geodiversity is considered in many publications and is presented in different approaches – descriptive, analytical, holistic, etc. (Sharples, 1993; Kiernan, 1996; Eberhard, 1997; Gray, 2004; Kozlowski, 2004, Serrano & Ruiz-Flano, 2007, etc.). The development of the concept shows expanding the scope from a synonym of geological and geomorphological diversity to a wider scope of a generalizing concept, including also hydro-morphometric indicators, soils and partly land use. Despite the differences in

interpretation, geodiversity is considered as a complex indicator of the abiotic environment or a corresponding abiotic equivalent of biodiversity (Soms, 2017).

Different approaches and indicators are used for evaluation of geodiversity: qualitative, quantitative, combined qualitative and quantitative. In many cases the qualitative parameters are quantitatively rated taking into account the authors' view and experience as well as the practice presented in the literature (Coratza & Giusti, 2005; Reynard et al., 2007; Brilha, 2015). The quantitative approach is characterized by less expressed subjectivity of the assessment, but requires the processing of a significant amount of digital information (graphic and attributive), the application of mathematical and statistical methods. In this relation geographic information systems (GIS) provide gereat opportunity (Santos et al., 2017; Soms, 2017; Ferrando et al., 2021; Chrobak et al., 2021). On the other hand, the results of this approach depend on the choice of the components of the evaluation and the method of classification, which are determined by the researcher/expert performing the evaluation.

This outlines the need for elaborating methods for quantitative assessment of geodiversity of a given area so that to minimize the subjective character of the assessment by setting clear criteria which can be quantitatively expressed. Though the term is used since 1990, standardized methods for geodiversity assessment have not yet been established. The review of the publication about assessment of geodiversity shows that mainly four components have been taken into evaluation: geological, geomorphological, hydrological and pedological (Ilić et al., 2016, Zwoliński et al., 2016, Ferrando et al., 2021). Some of the authors also consider land use / land cover (Pătroescu & Niculae, 2010; Chrobak et al., 2021; Ferrando et al., 2021). There are differences in the approach of determining the particular units for calculating the geodiversity index but the most often used is the grid method. The size of the grid is different and depends on the scale of the map and the size of the area of interest. In order to minimize the subjectivity of assessment, analytic hierarchy process (AHP) is applied (Chrobak et al. 2021; Ferrando et al., 2021). Despite the fact that determining the weights of the different components of geodiversity is arguable and depends on the experience and the view of the researcher, application of AHP gives reliable results, taking into account the interrelations between abiotic components.

Regarding to the above, the aim of the current study is to contribute to minimizing the subjectivity of geodiversity assessment by application of geoinformation approach with emphasize on the relations between the geological, geomorphological, hydrological and pedological components as well as application of fuzzy logic for determining the classes of geodiversity assessment, which can be used in comparisons between areas with different location and different landscape conditions.

Area of interest

The current study is carried out for the area of the Golo Bardo mountain, located in the western part of Bulgaria (Fig. 1). This is a low mountainous area, with the highest peak Vetrushka, 1158 m (northwestern part of the mountain). Golo Bardo extends from northwest to the southeast direction and has a length of 25 km and 5-6 km width. The ridge surface is narrow and the mountain slopes are predominantly slightly sloping and are cut by streams. Slope gradients between 5 and 15 degrees take nearly 49% of the studied area, 18.8% are areas sloping between 15 and 30 degrees, while flat (0-3°) and nearly flat (3-5°) surfaces take respectively 17% and 14.6%. The mountain is drained mainly by the left tributaries of the river Struma which flows through the west – northwest foothills of the mountain.

Regarding the tectonic features of Golo Bardo mountain and its position in the tectonic zonation of Bulgaria, the mountain is located on the border of three structural zones: Kraishte, Srednogorie and Rhodopes. Bonchev (1971) refers the area of Golo Bardo to the Kraishtidi structural zone. Dabovski et al. (2009) determines the region as a part of the Lyubash-Golo Bardo unit of the Srednogorie zone. According to Ivanov (2017) it is a natural continuation of the Luzhnitsa tectonic unit of the Kraishte zone. Stratigraphically, the area of Golo Bardo is quite diverse. Quaternary, Neogene, Paleogene, Upper Cretaceous, Jurassic-Lower Cretaceous, Jurassic, Triassic, Permian, Devonian, Paleozoic and Neoproterozoic-Lower Paleozoic rocks are revealed. Mesozoic sediments, which are not metamorphosed within the study area, predominate. It is assumed that they are affected by several alpine folding phases, but the exact number of phases, their regional scope and timing are debatable. Considering petrographic aspects, the sedimentary rocks in the study area are represented by argillites, siltstones, sandstones, gravelites, calcareous sandstones, sandy limestones, clayey limestones, marls, limestones, breccias, conglomerates, flysch sediments. The magmatic and metamorphic rocks in the area are represented by gabbro, gabbro diorites, diorites, metagabbros to metadiorites, metabasites, amphibolites, amphibole and green shales, double mica gneisses and migmatites, biotite gneisses, muscovite gneisses, garnet-muscovite shales.

Sediments like clay, sands and boulders are also spread in many parts of the study area. Generally, the considered rocks and sediments can be grouped into the following groups: consolidated carbonate rocks; consolidated carbonate and non-carbonate rocks;

consolidated non-carbonate rocks, tuffs, flish, intrusive, metamorphic rocks, proluvial and deluvial, and alluvial deposits (Fig. 2). Wide areas of carbonate rocks are a prerequisite for development of karst relief.

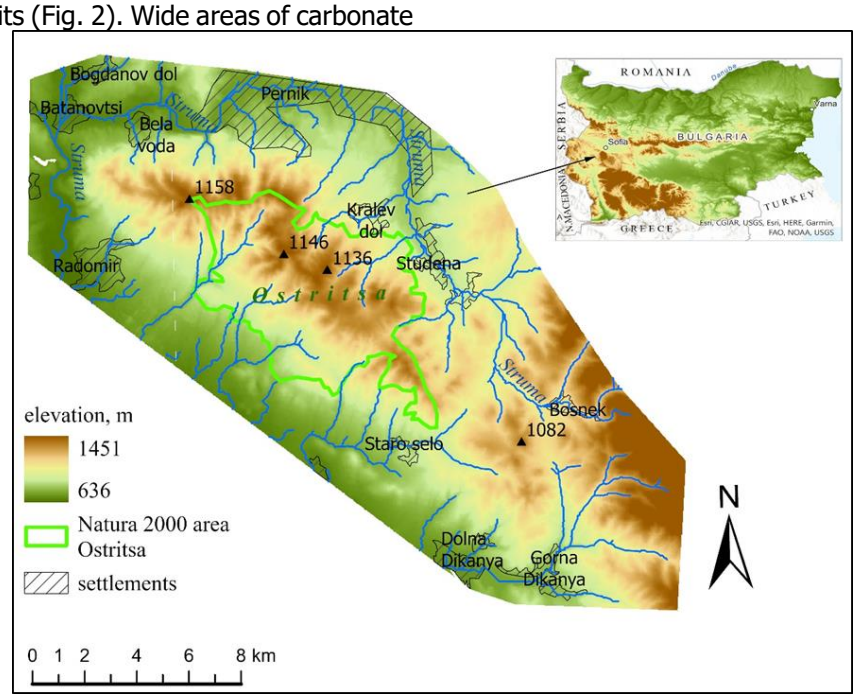

Fig. 1: Study area (terrain data is obtained by United States Geological Survey, Earth Resources Observation and Science Center. (2014). Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global data [Data set]. https://doi.org/10.5066/F7PR7TFT)

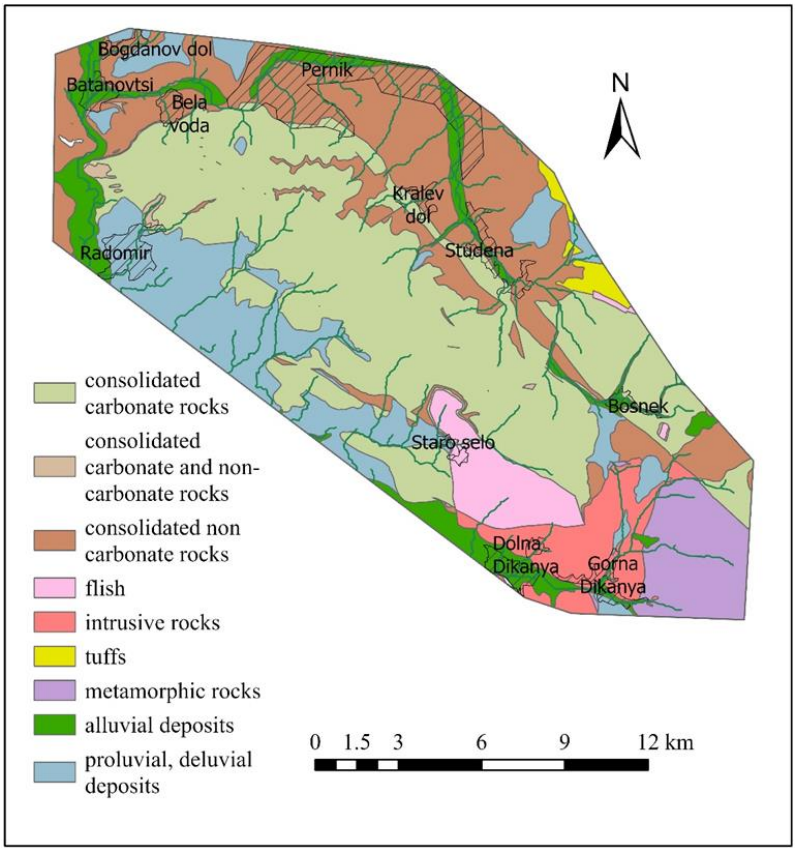

Fig. 2: Petrographic map of the study area (after Milanov et al., 2006; Antonov et al., 2011a, 2011b, 2011c, with amendments)

Soils are presented by, Chromic Cambisols, Chromic Luvisols, Cambisols, Vertisols, Fluvisols and Rendzinas (FAO, 1990). More than 50% (57.5%) of the mountain area are covered by Rendzinas and nearly half of this areas are loamy. The wide distribution of Rendzinas is closely related to the distribution of carbonate rocks. Relatively wide are covered by Chromic Luvisols (around 24% of the study area). They are distributed on the low slopes of Golo Bardo mountain and mainly on the southern and southwestern slopes this soil type has well expressed clayey composition. Nearly 6% of the mountain area are covered by Eroded Chromic Luvisols. Fluvisols take around 7% of the study area and are formed in the valley bottom of the river Struma.

Natural vegetation in Golo Bardo mountain area is presented by forest, pasture and grasslands and bushes. Forests cover 24,5% of the area of interest where 46% of forests are broad-leaed and 42% are coniferous. Natura 2000 area (Council Directive 92/43/EEC), named Ostritsa, is determined in the central high part of the mountain. There is one natural rezerve Ostritsa, established for protection of valuable plant specimens. Other protected area - Kashkavalya, located in the south-eastern part of the mountain and outside of Natura 2000 is also established for protection of conservation-significant plant species.

Data and methodology

In the current study, the geodiversity of the area of interest is evaluated by analysis of lithology, soils, topographic features and drainage network. The complex geodiversity (Gd) assessment is calculated taking into consideration the formula proposed by Serrano and Ruiz-Flano (2007):

$$Gd = \frac{Eg * R}{Ln\ S},$$

where Eg is the number of abiotic elements in the area of interest/spatial unit, R is coefficient of roughness, S is area of the unit (sqkm); Ln = natural logarithm.

The analysis of the lithological settings is done on the base of geological map at a scale of 1:50 000 (Milanov et al., 2006; Antonov et al., 2011a, 2011b, 2011c) and field research. Regarding the origin of the rocks and their physical and mechanical properties, the following groups are determined: consolidated carbonate; consolidated carbonate and non-carbonate; consolidated non-carbonate, tuffs, flish, intrusive, metamorphic, proluvial and deluvial, and alluvial deposits (Fig. 2).

For evaluating the variety of soils, a soil map at a scale 1:400 000 is used (ISSAPP "N. Poushkarov"). Regarding the small area of Golo Bardo mauntain and the generalization of the content of the geological map performed to determine the groups of rocks taken into account in the analysis of lithological features, the used soil map provides sufficiently detailed information about soil diversity analysis, which is comparable to the information about the rock composition of the area of interest.

Topographic settings are analysed on the base of digital elevation model (DEM) with a cell size of 30 m (SRTM). The elevation model is used for calculating the terrain roughness index (TRI), for calculating the slope gradients and aspects of the slopes. Terrain roughness is considered as relative metric based on local neighbourhood of a given pixel and, in this regard, it is used to identify landscape patterns corresponding to environmental factors (Otto et al., 2018). The following formula is applied:

$$TRI = \frac{DEM_{smooth} - DEM_{min}}{DEM_{max} - DEM_{min}}$$

where: DEM_{smooth} is a smoothed elevation raster; DEM_{min} is minimum elevation raster; DEM_{max} is maximum elevation raster.

The above parameters of DEM are calculated in ArcGIS Pro (ESRI Inc, 2021) environment using Focal Statistics analysis. In the current study we accepted rectangle method for determining the area of neighbourhood and set a size of 1000x1000 m.

Slope and aspect rasters are generated on the base of DEM (ArcGIS Pro Spatial Analyst Tools). The slope gradients are calculated in degrees and classified in the following classes: 0-2; 2-5; 5-15; 15-30; 30-4 and >45. Aspect raster is created using eight directions model and also flat surfaces are determined.

The number of abiotic elements in the area of interest is determined by Focal Statistic tool (ArcGIS Pro), Neighborhood – Rectangle, size 1000 x 1000 m, Statistics type – Variety. The variety layers, generated for lithology, soils, slope, aspect and drainage network are summed to obtain the complex coefficient of variety (Eg) and then multiplied by roughness index (TRI) which we used for roughness coefficient (R).

Geodiversity index raster is classified in 3 classes: low, moderate and high, using equal interval method. This method presents the geodiversity like a relative indicator for the different parts of the study area and the extend of the intervals depends on the minimal and maximal values of the geodiversity index, calculated for the considered area of interest. The determined classes of low, moderate and high geodiversity are valid only for the particular area and cannot be referred to the other area with different landscape conditions. In order to be comparable with different areas we suggest using fuzzy logic (Fuzzy Membership tool of ArcGIS Pro Overlay analysis) by which values of geodiversity index raster are scaled

from 0 to 1. Membership type "Large" is applied, by which large values of the input raster have high membership in the fuzzy set. After fuzzification the output raster is classified in 3 classes: low (0 – 0.33); moderate (0.331 – 0.67) and high (0.671 – 1). In this way, the values of geodiversity index will vary between 0 and 1 in each one of the considered areas/regions, and the classes of geodiversity will have one and the same intervals, regardless the peculiarities of the areas.

Results and disscusions

The geodiversity index is calculated based of the maps of the variety of abiotic components, shown on Fig. 3. This approach is considered in many publications, despite the fact that there are differences in the spatial variables – abiotic components (geological, geomorphological, hydrological and soils) used for calculating the number of abiotic elements (Pereira et al., 2013; Stoms, 2017, Chrobak et al., 2021; Manosso et al., 2021).

In the current study, the variety is calculated per area of 1 sqkm. The highest variability is observed on the raster of aspects – from 4 to 9 spatial units per 1 sqkm and in nearly 90% of the study area the calculated number of units is 9. This is an indicator for higher values of horizontal dissection of the relief and dense drainage network. The aspect of slopes together with slope gradients and elevation influence on local climate conditions and mainly on the distribution of solar radiations, air temperature and precipitation. In this relation, it is an important conditioning factor for geomorphological processes and variety ot the relief. Relatively equal is the variety of slopes and lithology. Maximal value of spatial units per 1 sqkm for both factors is 6 but the values are unevenly distributed on the mountain area and the pattern of the rasters shows a bit higher variety of the lithology (Fig. 3). The variety of the soil cover is between 1 and 5. Generally, southern and western parts of the mountain have higher values of soil variety. This partly corresponds to the variety of lithological component and the differences are determined by the influence of vegetation and local climate.

The variety of hydrologic component is determined on the base of availability or absence of streams and in this relation, it is presented in two classes. The pattern of the distribution of both classes shows that two elements per 1 sqkm are observed on 71% of the area of the mountain and on the other part the number of spatial units is 1 per 1 sqkm.

The roughness coefficient for the area of Golo Bardo mountain varies between 0.03 to 0.79. The values are the smallest in the larger bottoms of the river valleys and increase with the increasing of the elevation, and also in the areas with denser stream network. Regarding the calculation of the roughness coefficient in different publication it can be concluded that there is no uniform methodology for calculating the terrain roughness. For example, Grohmann et al. (2011) consider standard deviation of residual topography (Melelli, 2014) takes into account surface area and planimetric area, Stepišnik et al. (2017) use elevation differences, Chelariu & Hapciuc (2017) accept slope gradient for determining the terrain roughness. In the current study, we calculated the terrain roughness on the base of elevation differences, which can be considered as an indicator for the energy of the relief, and in this relation for the variety of the landscapes. We consider that when slope gradients are used for calculating the variety of the abiotic components (Eg), taking into account slope in calculating the roughness can enhance the importance of slope gradient in the complex geodiversity assessment.

Complex geodiversity index is calculated by multiplying the sum of components varieties and roughness coefficient. The surface distribution of the values is presented on Fig. 4. Most of the area of Golo Bardo mountain (80.7%) has moderate geodiversity index. Areas with low and high geodiversity take around 9.7%, each one. High geodiversity is observed in the south-eastern part of the mountain, where they can be related to the high variety of lithology and high values of roughness. High geodiversity values in high central and northwestern part of the mountain are mainly related to the high variety of slopes, as well as of roughness coefficient. Fuzzification of geodiversity raster, in the current case, causes small changes in the spatial pattern and the redistribution of the values of the geodiversity but as a whole the location of the classes of low, moderate and high geodiversity index is preserved. After fuzzification areas with moderate geodiversity index are decreased to 69.3% of the mountain, while areas with low and high geodiversity are increased, respectively to 17.2% and 13.5%. Despite the observed differences fuzzification can give reliable results when two or more regions with different landscape conditions are compared, providing equal intervals of the geodiversity classes.

Comparing the spatial distribution of the geodiversity index with the land cover/land use data (CORINE) shows that the largest part of the areas with high geodiversity is covered by forests, followed by areas with shrubs and rare vegetation, and pastures. Areas with low geodiversity are taken mainly by agricultural and urban areas (Table 1).

Nature protected areas are located mainly in spatial units with moderate and high geodiversity index. Most of the part of Natura 2000 protected area Ostritsa (77%) has moderate geodiversity, 21% present a high geodiversity index and 2% possess low geodiversity.

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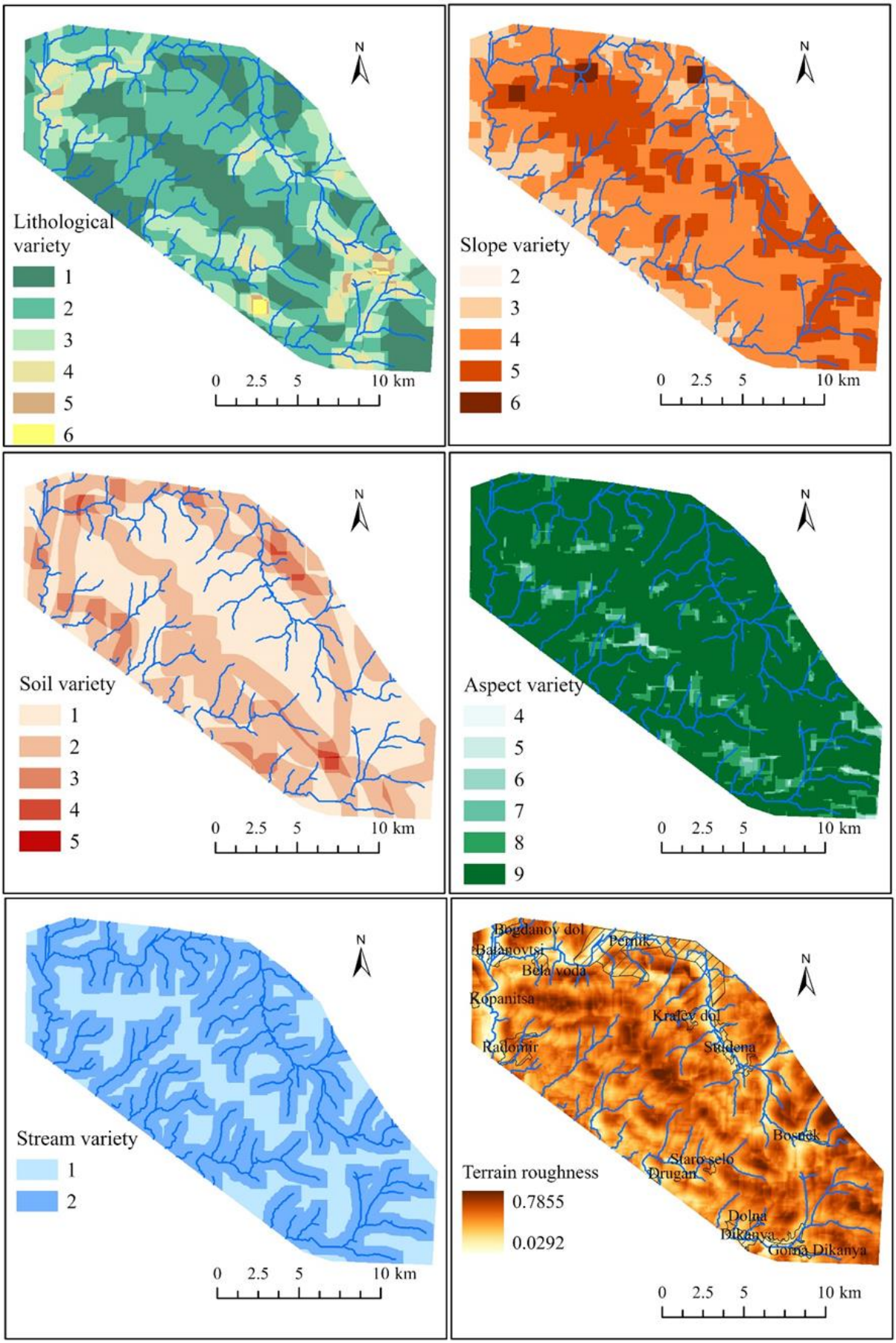

Fig. 3: Variety of abiotic components at Golo Bardo mountain area

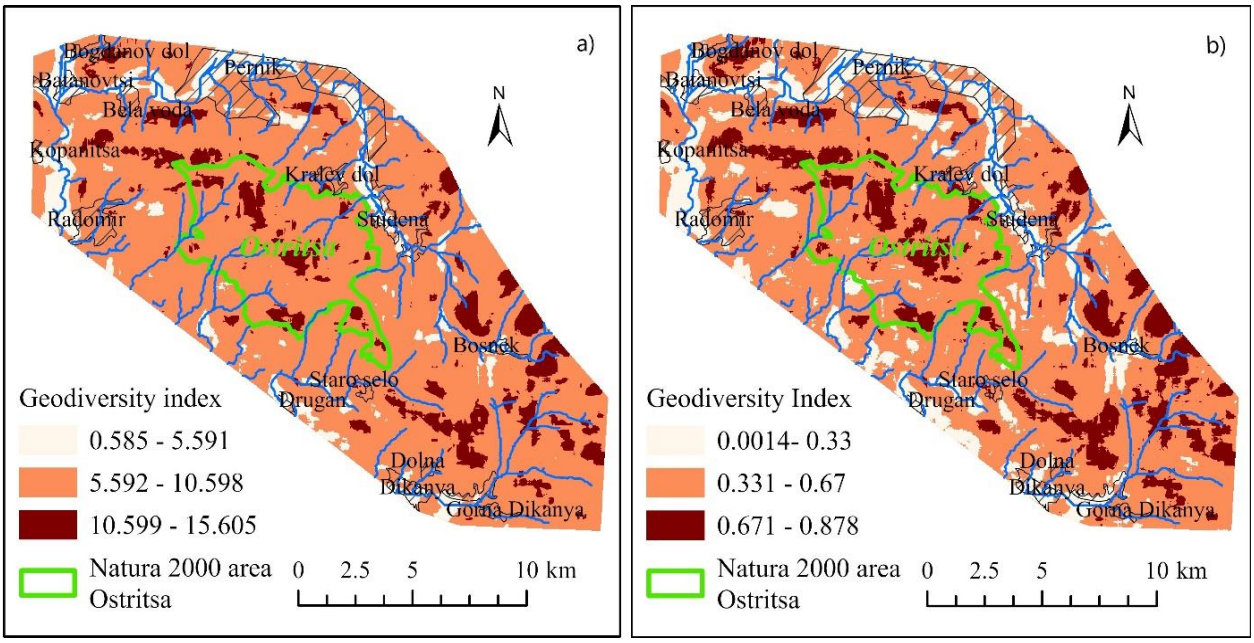

Fig. 4: Spatial distribution of the geodiversity index a) values of geodiversity, classified by equal intervals method; b) fuzzyfication of geodiversity raster, membership type "Large"

Table 1: Distribution of land use/land cover types in percent of the classes of geodiversity index

	Geodiversity index		
Land use / land cover	**Low**	**Moderate**	**High**
Urban areas	37.62	9.04	0.42
Mineral extraction sites	4.93	3.40	2.14
Agricultural lands	44.66	29.30	12.69
Pastures and natural grassland	7.08	19.14	20.61
Forests	2.15	25.00	42.38
Rare vegetation and shrubs	0.81	12.97	20.85
Bare rocks		0.35	0.14
Water bodies	2.76	0.80	0.77

Conclusions

The geodiversity index is calculated for the area of Golo Bardo mountain by applying the grid method and determined size of grid 1000 x 1000 sqm. Four abiotic components are considered: geological (petrographic composition), geomorphological (slope, aspect and elevation differences), hydrological (presence and absence of streams) and pedological (soil types). The obtained values for the raster of geodiversity are classified into three classes: low, moderate and high. Equal intervals classification method is used. According to this method, most of the area of the mountain has moderate geodiversity index. The method gives reliable results with minimal subjectivity, that can be used for assessment of the distribution of the geodiversity on a particular area and allow to compare different parts of this area. This can contribute to better territorial planning. On the other side, application of equal intervals classification is not appropriate for comparison of areas, located in different regions with different landscape conditions. In this case, using fuzzy logic gives better results by assigning values between 0 and 1 of the input geodiversity raster, indicating the strength of a membership in a given set.

The values of the geodiversity index, calculated for this particular study area show that most of the Golo Bardo area has moderate geodiversity. There is a good correlation between areas with high and moderate geodiversity and nature protected areas.

Using of geoinformation tools for calculating geodiversity index and application of quantitative approach minimize subjectivity of the assessment but it has to be taken into account that the results closely depend on the resolution of the initial DEM used for evaluation of the topographic features as well as on the degree of detail of the data about other abiotic components. The choice of the abiotic components and indicators used for the calculation of geodiversity index is debatable and depends on the expert's experience. Despite this imperfection of the process

of the assessment of geodiversity, the applied methodology provides an opportunity for fast assessment of geocomponents and can significantly contribute to better spatial planning and identification of areas with potential for geotourism development. Future research should focus on assessing the impact of data resolution and standardization geodiversity assessment.

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Usage of zeolite raw materials as natural barrier for conservation of nuclear waste

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Abstract

The presence of manganese oxides and hydroxides forming thin crusts up to 4-5 mm thick, deposits and impregnations with black color was found in the pink-reddish clinoptilolite zeolites from the field works in the area of the Most deposit, Bulgaria. The aim of the present research is to study the zeolite raw material in the area of the deposit in order to determine the manganese mineralization. The presence of certain microporous minerals, referred to as octahedral molecular sieves (OMS) and octahedral layered materials (OL) will increase the value of the zeolite raw material from the deposit in order to use them as a sorbent of heavy metals and radionuclides to solve some ecological problems.

Keywords: *Zeolite, Cryptomelane, OMS, OL, Waste*

Rezumat. Utlizarea materiei brute de zeolit ca barieră naturală pentru consevarea deșeurilor nucleare. Prezența oxizilor și hidroxilor de mangan ce formează cruste cu grosimi de până la 4-5 mm, depozite și impregații de culoare neagră au fost semnalate în cadrul depozitelor de zeolit clinoptilolit de culoare roz-roșiatică în timpul lucrărilor de teren din apropierea depozitului Most din Bulgaria. Lucrarea de față studiază zeolitul ca materie primă din zona de origine a depozitului pentru a determina mineralizația de mangan. Prezența anumitor minerale miroporoase, denumite site moleculare octaedrice (OMS) și materiale în straturi octaedrice (OL), va crește valorea materiei prime de zeolit, permițând folosirea acestuia ca absorbant pentru metalele grele și nuclid radioactiv, rezolvând astfel unele probleme de natură ecologică.

Cuvinte-cheie: *zeolit, criptomelan, OMS, OL, deșeu*

Introduction

Nuclear power plants produce highly radioactive waste through the nuclear fission of uranium and plutonium or the fusion of hydrogen with helium. The decomposition of this waste poses a great danger to humans, animals and plants for millennia, so it must be well stored and isolated. Nuclear power plants have been in operation for more than 50 years, but up to date there is no reliable method for storing high-level radioactive waste (Nikolova & Nikishanliev, 2015). The big deposits of zeolite and bentonite near the town of Kardzhali (Bulgaria), their low self-value and their unique ion exchange and adsorption properties, make them attractive for purification of wastewater from ions of heavy metals (Kovacheva-Ninova et al., 2002). Zeolite exchangeable ions are relatively harmless and makes them attractive native materials for removing undesirable heavy metal ions from industrial and processing effluent water. In addition, zeolite loaded with heavy metal ions can be easily regenerated (Nikolova et al., 2002).

Deposits and occurrences of zeolites are established in the vicinity of the villages Most, Perperek (Southern Bulgaria), and Lyaskovets (Central-northern Bulgaria). They have Oligocene age and were formed in marine environment. On the basis of accomplished exploration works the proved reserves in these deposits (contoured by common ion exchange and sorption capacity) are more than 500Mt (Brunkin & Boyadzhiev., 1980, Brunkin et.al. 1983). Natural zeolite added to soil improves its agrochemical and ecological characteristics. As a result of a study conducted with zeolites from the city of Kardzhali (Katsarova et al., 2021), it was established that natural zeolite, as an environmentally pure material, can be used to increase yield, reduce agricultural costs and protect natural soil resources .

Natural zeolites applied together with mineral fertilizers on contaminated soils with Cd>Zn>Cu>Pb significantly improve the quality of agricultural crops compared to the sanitary standards for safety in the Republic of Bulgaria (Dinev et al., 2021).

For the purposes of the present study, the Most deposit was tested. It is located in the Northeastern Rhodopes (Figure 1). Manganese oxide mineralization, a natural raw material combining different types of microporous minerals, has been determined, in view of their potential application for solving various ecological problems. Manganese mineralization has so far not been studied by other authors.

Materials and methods

To determine manganese mineralization, diffractometric X-ray analyses and microscopic scan were performed. This research was made for determine the composition, structural and optical characteristics of the minerals and the microstructural features of the rocks from tested manifestations. Special samples of zeolite rocks containing manganese oxide mineralization were studied (Figure 2). Polarization microscopes POLAM - R-311 and NU – 2 in Department of GPPI, University of Mining and Geology "St. Ivan Rilski", Sofia are used.

With the help of scanning electron microscope SEM - JEOL JSM-6301F (110) at Chalmers University of Technology, Department of Radio and Space Science, Gothenburg, Sweden the morphology of zeolite minerals were studied.

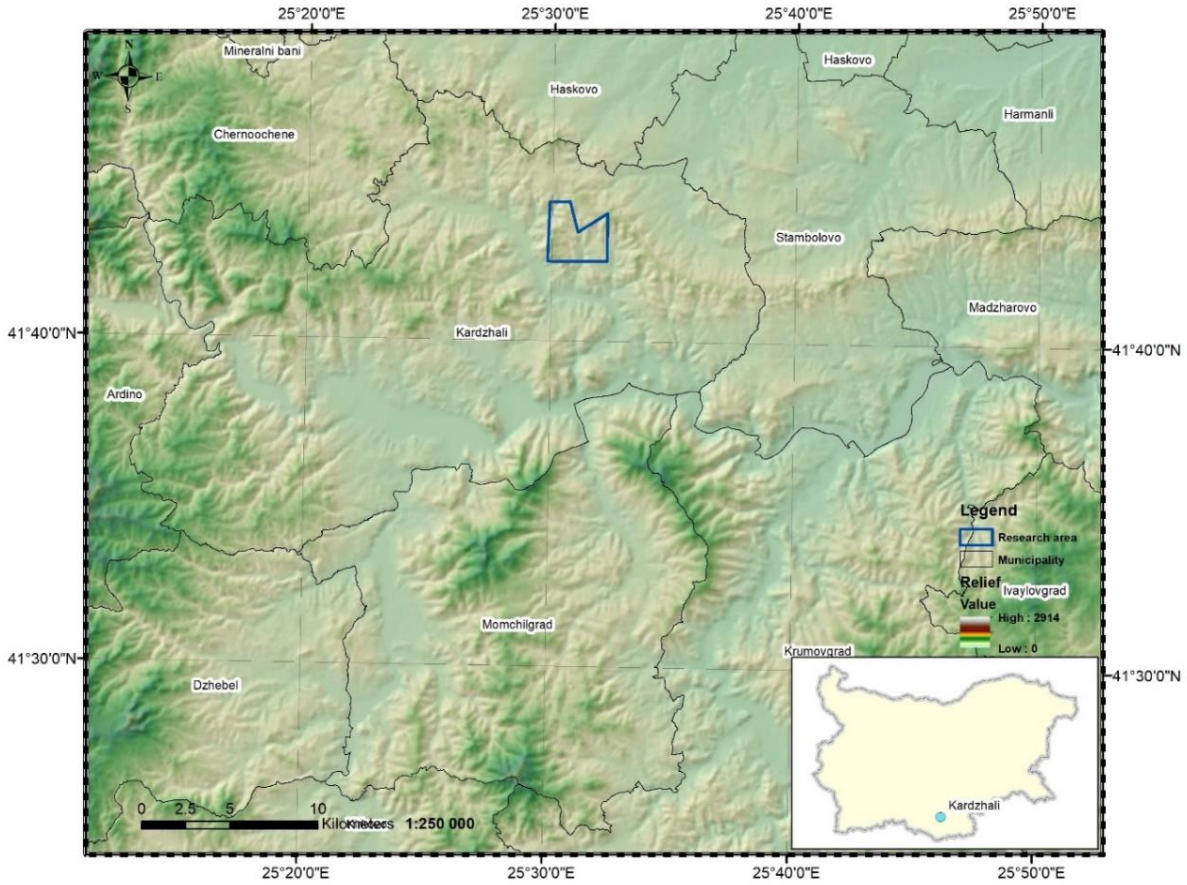

Fig. 1: Shaded relief map of the Northeastern Rhodopes. Political boundaries are shown by black lines. Inset map shows the location of the larger map with reference to Bulgaria. The blue box indicates the boundary of the studied area

Geological framework

SUBDIVISION OF THE METAMORPHIC TERRAINS

THRACE LITHOTECTONIC UNIT

Biotite gneisses (Tr/bg)

Thrace Unit is represented only by rocks of the pre-Triassic-Jurassic basement, which is strongly fragmented by the block movements in the Zvinitsa ring structure. In the exposed in the structure blocks are distinguished porphyritic, equigranular and aplitoid metagranites plus their frame consisting of biotite gneisses irregularly alternating with amphibolites and the incorporated in them lenses of metagabbro (Yordanov et al., 2008).

STRATIGRAPHY OF THE CENOZOIC

PALEOGENE

Terrigenous group

Conglomerate-sandstone formation (cgsE3)

The formation is built of multiple alternations of rusty yellow equigranular sandstones and subordinate siltstones. In places the sandstones grade into pebbly conglomerates.

The sandstones are the major rock type. In most places they are indistictly bedded. Their structure is massive and their texture is aleuritic to coarse-psammitic. By composition they are polymict, the clastic

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grains corresponding to the composition of the metamorphic basement. The sandstones commonly grade into grey-yellow, fine-grained to silty, strongly calcareous varieties.

Svobodinovo Volcano-Sedimentary Group

Padartsi Formation (PdE3)

The formation is built of predominant thinly rhythmic alternation of sandstones, siltstones, marlstones, calcareous tuffs, and intermediate tuffs. It is distinguished for the presence of distinct horizontal bedding. The sandstones are grey, beige or creamy, commonly with massive structure and medium to thick stratification. The siltstones display similar characteristics. They differ from the sandstones by their grain size and by forming mainly thin- to medium-bedded packages. The marls occur in the form of thin continuous layers. They are grey, light beige to beige, laminated, micro-grained or dense. The tuffs are grey-yellowish or green-greyish psammitic rocks which occur in the form of layers and lenses of variable thickness.

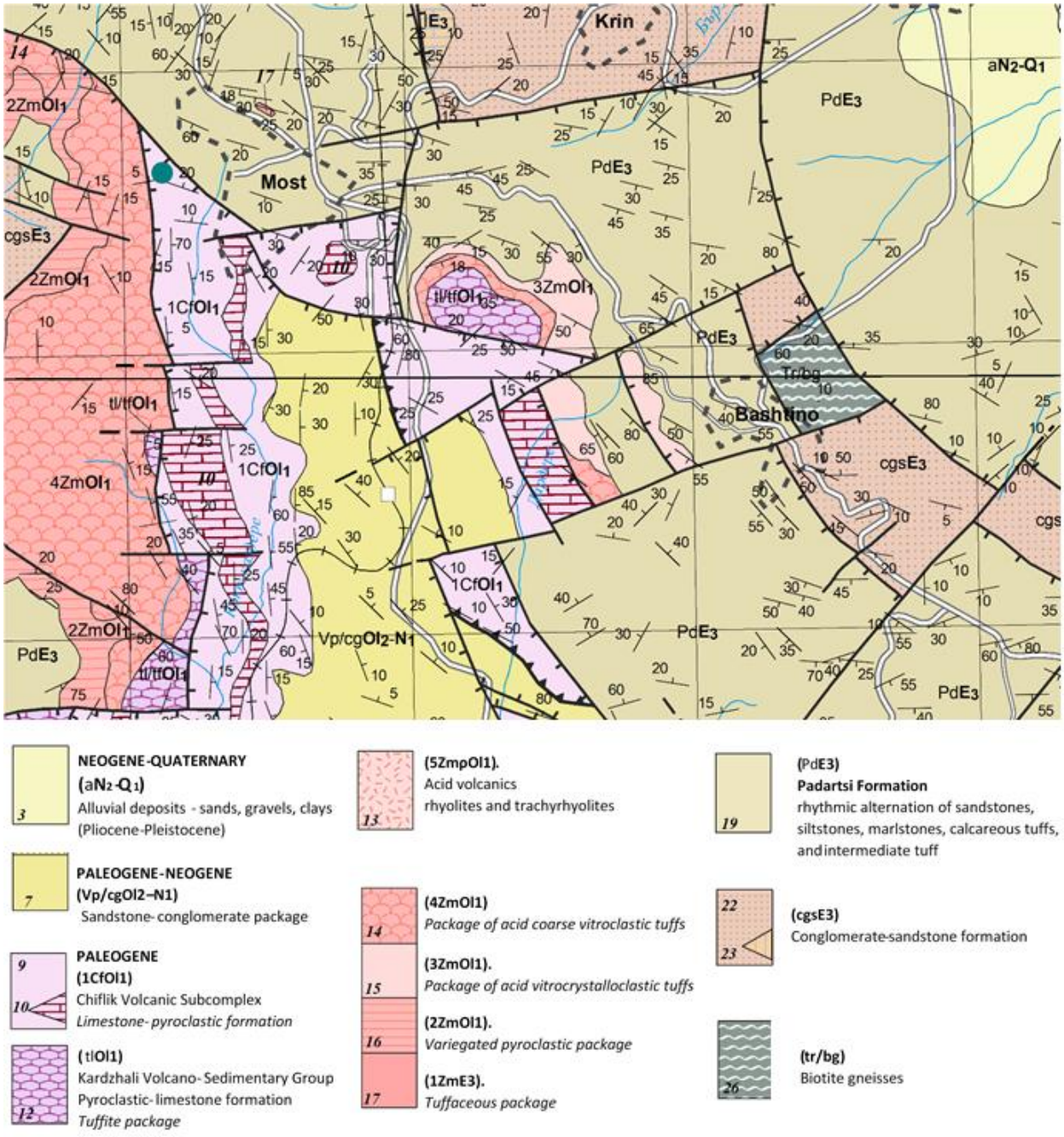

Fig. 2: Geological map of the studied area (on Yordanov, B. et al. Map sheet K-35-76-V (Knizhovnik). Geology and Geophysics JSCo, Sofia, 2008.)

Kardzhali Volcano-Sedimentary Group

Zimovina Volcanic Complex

Tuffaceous package (1ZmE3)

The package is built of relatively thin beds or lenticular discontinuous bodies of acid tuffs interlayered in the upper levels of the section of the Padartsi Formation. The tuffs are white to pale reseda, massive fine ash to ash, with crystalloclasts of biotite and plagioclase, totally altered virtroclasts, and sporadic lithoclasts

Package of acid vitrocrystalloclastic tuffs (3ZmOl1)

The pyroclastics overlie with sharp lithologic boundary sediments of the Padartsi Formation. They are respectively covered in concordant manner by rocks of the other packages of the tuffite-tuffaceous formation.

The unit is built of a shortly changing in vertical and lateral direction sequence composed of various by colour (grey, ochre, reseda and whitish), size, and clast type acid tuffs.

Package of acid vitrocrystalloclastic tuffs (3ZmOl1)

The tuffs overlie concordantly, with sharp lithologic contact sediments of the Padartsi Formation.

The package comprises ash to coarse ash, mainly reseda to whitish pyroclastics with ashfall origin.

Package of acid coarse vitroclastic tuffs (4ZmOl1)

These specific rocks are products of thick pyroclastic flows. The unit overlies concordantly, with sharp lithologic contact, or intertongues with rocks of the package of acid vitrocrystalloclastic tuffs, or normally, with sharp lithologic contact sediments of the Padartsi Formation. It is covered concordantly by rocks of the limestone-pyroclastic formation of the Chiflik Volcanic Subcomplex, or by the tuffite package of the pyroclastic-limestone formation.

Acid volcanics (5ZmpOl1)

The unit is composed mainly of fluidal rhyolites, trachyrhyolites, lavabreccias (vent facies), and perlites.

Pyroclastic-limestone formation (tlOl1)

In the complete volume of this unit are distinguished two packages – lower, predominantly limestone, and upper, predominantly tuffaceous, but only the second one is represented in the area of the map sheet.

Tuffite package (tl/tfOl1)

The package is built of yellow ochre, greyish or creamy, calcareous tuffites and fine ash to ash tuffs, commonly with high carbonate content.

Nanovitsa Volcanic Complex

Chiflik Volcanic Subcomplex

Limestone-pyroclastic formation (1CfOl1)

In the range of the map sheet the formation is composed mainly of varied acid pyroclastics and reef-like limestones. Massive to thick-bedded tuffs and subordinately thin- to medium-bedded ashfall tuffs predominate. Continuous layers and lenses of acid pyroclastics, which are enriched in intermediate accessory lapilli, are observed between them (Yordanov et al., 2008).

PALEOGENE-NEOGENE

Valche pole Formation

Conglomerate package (Vp/cgOl2–N1)

The lithology of the package comprises mainly alternating varied sandstones, conglomerates, calcareous and clayey siltstones, as well as sporadic interlayers of acid tuffs.

Predominant are polymict sandstones with white to yellow-grey color, which are thick-bedded in the lower levels, showing horizontal and cross bedding (Yordanov et al., 2008).

NEOGENE-QUATERNARY

Alluvial deposits (aN2-Q1)

The deposits cover with erosional, uneven contact Neogene and Paleogene sediments plus metagranites. Their upper boundary with the alluvial deposits of Pleistocene age has the same pattern.

At the base the Pliocene-Pleistocene deposits are built of unsorted to poorly sorted, well-rounded polymict gravels (with various clast size) and inequigranular rusty brown sands (Yordanov et al., 2008).

Results

Pale green zeolites are composed mainly of glass volcanic debris, fewer crystalloclasts and least lithoclasts. The glass fragments are prismatic in shape, small oysterite to siltstone in size. Between them are isometric corner fragments, some of which are pumice. The glass is acidic, isotropic. Thin edges of anisotropic clay products from the montmorillonite group are observed around the glass fragments. They are also increased on the walls of pumice stones.

Clinoptilolite has formed in the internal cavities of the glass pieces or in the gaps between several glass fragments at the expense of the glass. It is microcrystalline, almost isotropic. Its crystals are most often oriented from the glass walls to the inside of the gaps (Figure 3a, b, c, d). Debris was found, which was completely changed into clinoptilolite. In them the periphery to the interior has an orientation of the crystals, while in the central parts they are in disarray.

Crystal clasts are plagioclase, potassium feldspar, biotite, amphibole, muscovite and others. They are small to microscopic.

Lithoclasts are rhyolite and other rocks fragments and are in limited quantities.

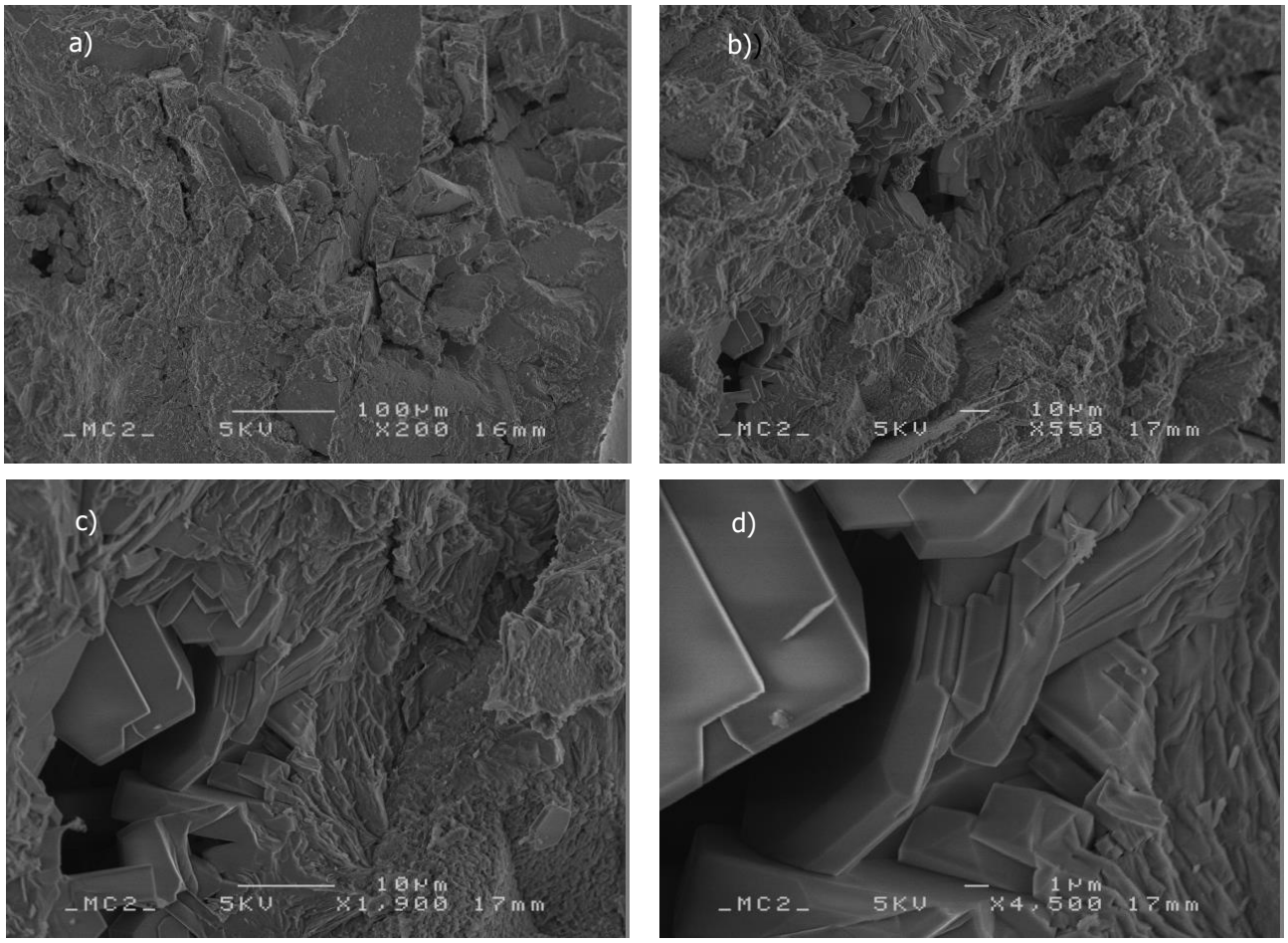

Fig. 3: SEM of (sample №2008 / 1) - "Most" deposit a) glass volcanic fragments SEM x 200; b) SEM x 550 glass volcanic debris; c) clinoptilolite crystals oriented inwards in glass debris cavities, SEM x 1 900; d) clinoptilolite crystals, SEM x 4,500

In reddish-pink clinoptilolite rocks, the clinoptilolite is formed at the expense of volcanic glass, being evolved in the debris and in the gaps between them. It is represented by fine, elongated prisms or tiles, oriented perpendicular to the contact with the glass table. Cord-like formations of anisotropic clay minerals from the montmorillonite group, which have a creamy-yellowish color, are observed almost everywhere in the boundary between the fragments. Crystal clasts are represented by plagioclase, potassium feldspar, pyroxene, quartz, biotite, etc., and lithoclasts by volcanic rocks.

In some places, in the pink-reddish clinoptilolite zeolites West of the village of Most, the presence of manganese oxides and hydroxides, forming thin crusts up to 4-5 mm thick, deposits and impregnations with black color was carried out. Data from diffractometric X-ray analyse shown that they are mainly cryptomelane ($KMn_8O_6 + H_2O$).

Cryptomelane is yellowish-white with a fine-fiber structure, anisotropic, under a microscope, in reflected light. In the central part of completely changed, zeolitized pieces of volcanic glass its also found as well as in the gaps between them (Figure 4a, b). Cryptomelane is often deposited in the central part of cavities lined with transversely grown, elongated prismatic or plate clinoptilolite individuals. In places, cryptomelane fills oval or elliptical cavities in clinoptilolite zeolites (Figure 4c, d).

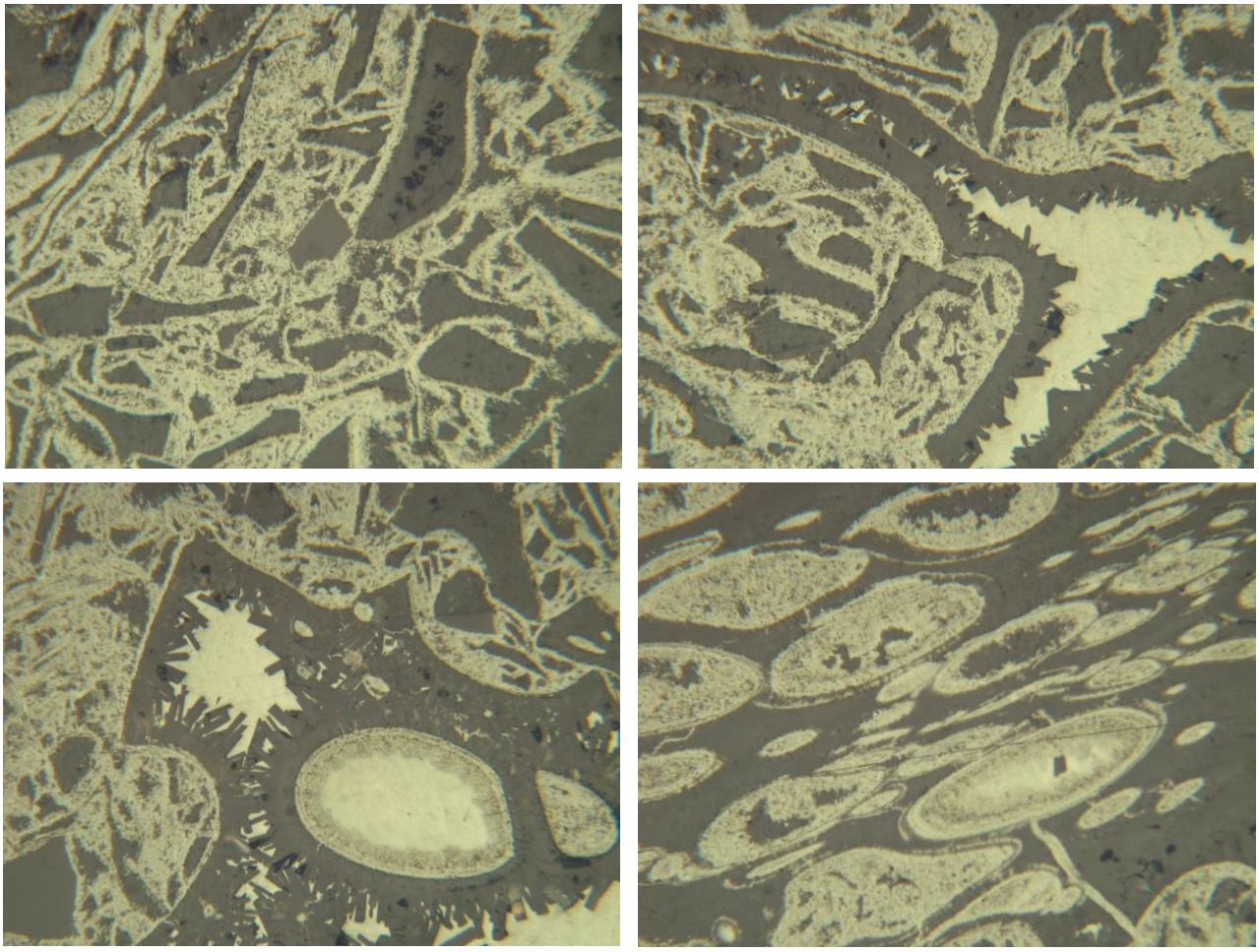

Fig. 4: Sample №2008/4. Cryptomelane in clinoptilolite zeolites from the Most deposit; (a) cryptomelane (yellowish white) deposited in gaps between zeolitised glass particles (dark gray); b, c) cryptomelane (yellowish-white) deposited in the central part of cavities lined with transversely growing elongated prismatic clinoptilolite individuals (dark gray); d) cryptomelane (yellowish white) filling elliptical voids in clinoptilolite zeolites. Reflected light without analyzer. Visible field length 0.53 mm

Discussion

In the current research for the Most deposit, the presence of manganese oxide mineralization was established for the first time.

Manganese mineralization is represented mainly by cryptomelane and todorokite, which are microporous minerals, referred to octahedral molecular sieves (OMS) and octahedral layered materials (OL). They are considered as modern, extremely promising materials with possible applications such as molecular and ionic sieves, sorbents of heavy metals (Pb, Cd, As, etc.) and radionuclides. Unlike of the zeolites, which are aluminosilicate tetrahedral molecular sieves with a pore size of about 3.5 Å, manganese hydroxides are octahedral molecular sieves, which are characterized by a larger pore size, respectively for OMS - 2 (cryptomelane) - 4.6Å and for OMS -1 (todorokite) - 6.9Å.

A case study of a potential repository for highly active radioactive waste is that in the Yucca Mountains, Nevada, due to the cation-exchange capacity of natural zeolites, clinoptilolite and mordenite. In fact, the presence of zeolites in the Yucca Mountains and the cationic exchange of minerals first drew attention to volcanic tuffs as possible repositories for radioactive waste (Bish, 1999). Studies of natural zeolites in the Yucca Mountains of the United States over the past thirty years illustrate that many different aspects of zeolite mineralogy are fundamentally important in the isolation of radioactive waste (Bish et al., 2003). It is interesting from this point of view to study the sorption of heavy metals and radionuclides from natural zeolites, such as those available in Bulgaria

Conclusion

The natural zeolite raw material containing cryptomelane and/or todorokite combines different types

of microporous minerals and is of great interest in order to clarify its application possibilities to solve a number of problems - purification of heavy metals contaminated mine and industrial waters, soil reclamation, insulation materials and coverage in radioactive waste repositories.

Unlike of the zeolites, which are sorbents for short-lived radionuclides, manganese hydroxides are selective sorbents for long-lived radionuclides and are important as a component of the geological environment that may potentially store high-level radioactive waste.

The importance of zeolites in our research of the region in ecological aspect extends far beyond the simple cation-exchange interactions to the applications for solving the problems of storage and isolation of radioactive waste. The present work provides a basis for further research on volcanic tuffs in the area as a possible repository for radioactive waste.

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Associated impact of the COVID-19 induced lockdown on air quality of Kolkata Metropolitan Area (India)

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Abstract

As a pandemic, COVID 19 spread worldwide in early 2020. Primarily densely populated countries had remained vulnerable due to this biological hazard. Many people were forced to stay home owing to nature of the disease and no respite. A nationwide lockdown was implemented in India for 29 days (March 24th to April 21st) of 2020 during the wake of the COVID-19 pandemic. During the nationwide lockdown, industries, transport, and other commercial activities were suspended, except for necessary services. During the entire pandemic situation, an affirmative impact was observed as the air quality was reported to have improved worldwide. The complete economic lockdown to check COVID-19, brought unforeseen relief from severe condition of air quality. An apparent, reduction in level of PM2.5 and Air Quality Index (AQI) was experienced over Mumbai, Delhi, Kolkata, Hyderabad, and Chennai.

Present work explores the various metrics of air pollution in Kolkata, West Bengal, India (imposed as a result of containment measure for COVID-19). The polluting parameters (e.g., PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, and NH_3) were chosen for seven monitoring stations (Ballygunge, Fort William, Victoria, Bidhannagar, Jadavpur, Rabindra Bharati, Rabindra Sarabar), which are spread across the metropolitan area of Kolkata. National Air Quality Index (NAQI) has been used to show pre-and during-lockdown air quality spatial patterns. The findings showed major changes in air quality throughout the lockdown period. The highest reduction in pollutants emission was observed for: PM_{10} (-60.82%), $PM_{2.5}$ (-45.05%) and NO_2 (-62.27%), followed by NH_3 (-32.12%) and SO_2 (-32.00%), CO (-47.46%), O_3 (15.10%). During the lockdown, the NAQI value was reduced by 52.93% in the study area.

Keywords: *air pollution, COVID-19, lockdown, National Air Quality Index, Kolkata Metropolitan Area*

Rezumat. Impactul asociat lockdown-ului generat de Covid-19 asupra calității aerului din zona metropolitană Calcutta

Pandemia de Covid-19 s-a răspândit la nivel mondial la începutul anului 2020, iar statele dens populate au rămas vulnerabile în fața acestui biohazard. Multe persoane au fost forțate să rămână acasă datorită modului de răspândire a bolii. Prin urmare, un lockdown la nivel național a fost implementat în India pentru 29 de zile (24 martie – 21 aprilie 2020), la începutul pandemiei de COVID-19. În această perioadă, au fost suspendate toate activitățile industriale, de transport si comerciale, cu excepția serviciilor esențiale. Pe întreaga perioadă a pandemiei a fost observat un impact pozitiv asupra calității aerului la nivel mondial și național, perioada de lockdown generând o îmbunătățire a poluării aeriene severe. Aparent, o reduce a nivelului de PM 2.5 și a Indicelui de calitate a aerului afost înregistra și la Mumbay, Delhi, Kalcutta, Hyeabad și Chennai.

Lucrarea de față analizează diferiți parametri pentru poluarea aerului în Calcutta, Bengalul de Vest, India (ca urmare a măsurilor restrictive impuse de Covid-19). Parametrii de poluare (ex. PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, NH_3) au fost aleși pentru 7 stații de monitorizare (Ballygunge, Fort William, Victoria, Bidhannagar, Jadavpur, Rabindra Bharati, Rabindra Sarabar) situate în zona metropolitană Calcutta. Indicele calității aerului la nivel național (NAQI) a fost utilizat pentru a arăta tiparele spațiale privind calitatea aerului în perioada înainte și în timpul lockdown-ului. Cea mai mare reducere la emisiile de poluanți a fost observată pentru PM_{10} (-60.82%), $PM_{2.5}$ (-45.05%) și NO_2 (-62.27%), urmat de NH_3 (-32.12%) și SO_2 (-32.00%), CO (-47.46%), O_3 (15.10%) și O_3 (-32.12%). De la începutul până la finalul lockdown-ului, valoarea NAQI s-a redus cu 52.93% în aria analizată.

Cuvinte-cheie: *poluarea aerului, Covid-19, lockdown, indicele calității aerului la nivel național, zona metropolitană Calcutta*

Introduction

The detrimental environmental impact is predominantly caused by air pollution, which is a serious global problem for both developing and developed countries. As per the report of WHO (2014b), the annual concentration level of PM_{10} is found maximum in Peshawar (Pakistan) (540 ug/m^3) followed by Rawalpindi (Pakistan) (448 ug/m^3), Mazar-e-Sharif (Afghanistan) (334 ug/m^3), and Gwalior (India) (329 ug/m^3). Globally, annual levels of PM10 increased by 6 percent during 2009 to 2012 in various cities of world (WHO, 2014b). It has been reported that, 193,000 people died in Europe in 2012 as a consequence of airborne particulate matter (Ortiz et al., 2017). Premature deaths occurred due to $PM_{2.5}$ exposure in 2012 in 40 European countries and the EU 28 e.g. Germany (59500 deaths), Poland (44600 deaths), France (43400 deaths), Italy (59500 deaths), United Kingdom (37800 deaths) etc. (EAA,

2015). A new National Emissions reduction Commitments (NEC) Directive (2016/2284/EU) entered into force on 31 December 2016 replacing earlier legislation, (Directive 2001/81/EC). The new NEC Directive sets 2020 and 2030 emission reduction commitments for five main air pollutants (nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2), ammonia (NH_3) and fine particulate matter ($PM_{2.5}$) (EAA, 2017).

Urban areas are the hub of air pollution for its unabated growth of vehicles and industries. The megacities of Asia (Shanghai, Beijing, Delhi, Karachi (Pakistan), Tokyo, Mumbai etc. and Africa (Lagos, Cairo, Algiers, Casablanca etc.) will have a predicted 90% population increase by the end of 2050 (World Urbanization Prospect 2018 Revision). India faces the challenge of economic development along with ever-increasing population growth leading to the enhanced pollution level. Unprecedented rises by 15% have been noted in the domestic made vehicle sector (SIAM 2013). According to Amann et al. (2017), a rapid rise of 200% in the transportation sector is expected between the years 2015 and 2030, which will lead to an increase in the traffic population by 10.5%/year (MoSPI, 2015). The ever-increasing urbanization will lead to an increase in power generation by 11.1%/year (CEA 2015; 2016). In India industrial emissions lead to 51% of pollution, while vehicular emissions, crop burning, and festival fireworks are responsible for 27%, 17%, and 5% of pollution respectively (Indian Express, 2019). Thus, urbanization is an important catalyst of air pollution for Indian cities.

Air pollution is the leading contributor to premature deaths of 2 million Indians/year (Health Impact Institute, 2018 & WHO, 2021). According to the Census report of India 2011, 53 Indian megacities Mumbai, Delhi, Kolkata Bangalore etc. have been identified as hotspots of air pollution. The city of Kolkata in the West Bengal state of India is one of the hotspots of air pollution, which has been seriously affected by air pollution (Goyal, et al., 2003; Amann, 2017; Gulia, 2018; Kanawade, 2020). According to the World Health Organization (WHO), 140 million Indians are forced to breathe air that is more than ten times the WHO acceptable limit, resulting in premature deaths and poor public health effects such as severe lung illnesses, breathing issues, severe asthma, pneumonia, and so on (WHO, 2016; Heal, 2012; Dholakia, 2013). High air pollution is the reason for paramount public health desires (Heal, 2012; Dholakia, 2013; Rizwan, 2013).

Thus, air quality improvement and management are the primary concern of urbanization both in the developed and developing world. The extent of air pollution can be assessed through the statistical technique of 'Air Quality Index which is derived from various air quality measurements indices such as "Pollutant Standards Index (Ott and Hunt, 1976; USEPA 1994), Green Index (Green 1966), Penstock Air Quality Index (Fenstock 1969), Ontario Air Pollution Index (OAPI) (Shenfeld 1970), and Common Air Quality Index, (CAQI) (van den Elshout et al., 2008)". India initiated the National Air Quality Monitoring Program in 1984 and 2014 an index of air quality monitoring was developed as "National Air Quality Index (NAQI) by CPCB (Central Pollution Control Board)". Proper and timely monitoring of air pollution levels is indispensable for sustainable economic management and for policymakers to take suitable steps towards sustainable environmental goals.

Lockdown has a significant influence on air quality all across the world. Recent studies have revealed a link between improvements in air quality and partial or complete lockdowns, as well as the resulting decline in activities and emissions from sources such as road traffic and industrial operations. After the global lockdown, a considerable drop in NO_2 and other major pollutants are seen. The decrease in transportation emissions in cities is mostly accountable for this (Yaron 2020; Kerimray et al 2020). Delhi, India is used as the case study location in Mahato et al. (2020) investigation of air quality during lockdown conditions. According to the research, $PM_{2.5}$ and PM_{10} levels are now 50% lower than they were before to the lockdown. Using satellite and ground measurements, Ramesh P. and Chauhan (2020) provide a research to assess the quality of the air throughout India during the lockdown. Additionally in various other works the impact of COVID-19 on the air quality of various places of India has been studied (Singh et al 2020; Mahato et al 2020; Kumari et al 2021).

Recent data released by NASA (National Aeronautics and Space Administration, 2020) and ESA (European Space Agency, 2020) indicates that pollution in some of the epicenters of COVID-19 such as Wuhan, Italy, Spain and USA etc. has reduced up to 30%. In spite of pandemic, its indirect effect has played a positive role on nature by healing nature of pollution and thus can be termed as "Blessing in disguise". In India such kind of studies has been conducted in various cities. However the megacity of Kolkata lacks such work. Our work thus attempts to investigate COVID-19 lock down effect as a panacea of reduction of air pollution.

In this work, the authors have implemented the NAQI to assess the nature of air quality change in the Metropolitan area of Kolkata city during the nationwide 'lockdown owing to COVID-19'. Lockdown mechanisms were implemented in India in stages, in the first stage from "24th March to 14th April2020; second stage 15th April to 3rd May2020 and third stage 4th May to 17th May 2020". This unprecedented step

forced to halt all the economic and commercial activities, thereby drastically reducing the urban air pollution level.

Study Area

Kolkata the capital city of the state of West Bengal, India is located at 22°57'26" N and 88°36'39" E on the eastern bank of Hooghly River. The city (Fig. 1) is spread on an area of 206.08 Km^2.The city of Kolkata has a tropical monsoonal climate having mean annual temperature of 25° C. The maximum temperature during summer touches up to 40° C while the minimum temperature is 10° C. The average annual rainfall is 1836.5 mm with the maximum rainfall occurring in August (328 mm). Throughout the year, winds in Kolkata blow at an average speed of 7 km/h. mostly southeast and southwest winds are blowing (Gupta et al 2008). 1428 W/m^2 is the average solar radiation measurement (Gupta et al 2006.) According to the Indian Metrological Department, the south-west and north-east monsoons have an impact on both the summer and winter climate. The city is located in the alluvial plain of the lower Ganga basin.

According to the 2011 census, the city's population is 4.5 million (inside city boundaries) and the Kolkata metropolitan area has a headcount of about 14.1 million people (Census of India, 2011). The density of population is 24000/Km^2 and the city is India's seventh most populous city. It is the cultural and educational center of India and is also home to the country's third-largest urban economy. Steel, heavy engineering, mining, minerals, cement, pharmaceuticals, food processing, agriculture, electronics, textiles, and jute are just a few of the sectors that have sprouted up in the capital. According to the International Association of Public transport (2013), Kolkata's public transportation system is considered to be the most progressive in India (Little, 2014). As a result of its increasing urbanization and industrialized activities, as well as its overcrowding, pollution is a serious concern in Kolkata. The pollution level (Table 1) of the city is seven times more than the limit set by WHO. The city is in the 25th rank in terms of air pollution (WHO, 2016).

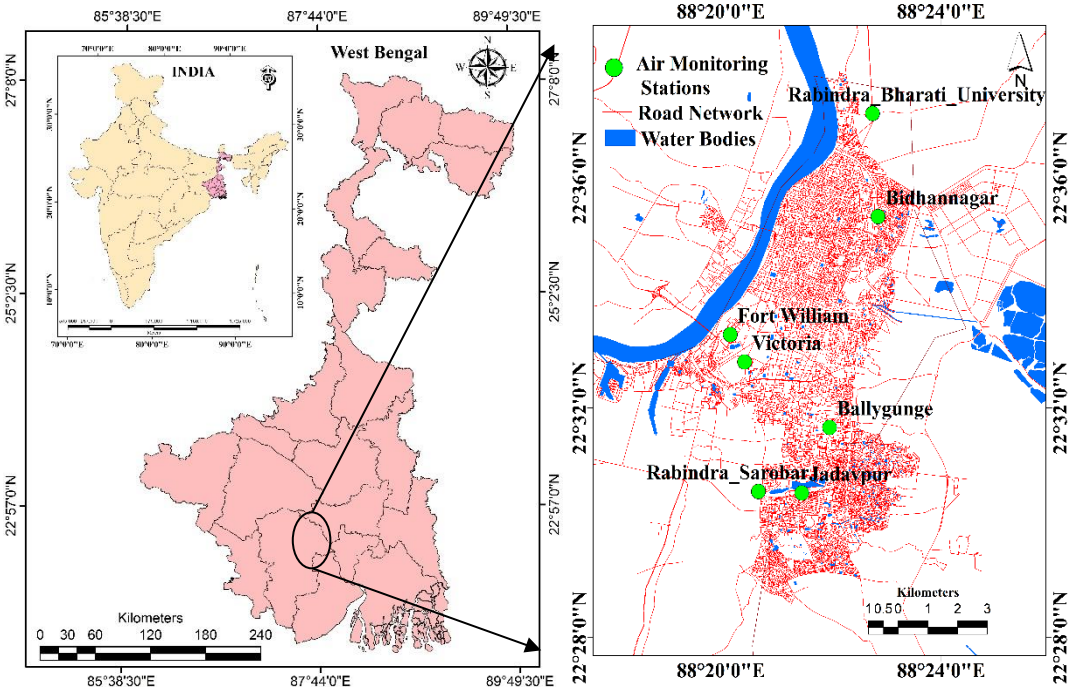

Fig. 1: Location of West Bengal state in eastern part of India (left side) and the study area (Kolkata city) in southern part of West Bengal (right side)

Materials and methods

Data from eight sites covering the whole megacity were used to determine the air quality status (CPCB, 2015) of Kolkata city throughout the lockdown period. The central pollution control board set the national standard of air pollutants given in Table 1. For the calculation of AQI the concentrations of air contaminants on a daily and hourly basis are necessary to be incorporated (Mahato et al., 2020). The Central Pollution Control Board collected Particulate Matters ($PM_{2.5}$ and PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Ozone (O_3), and Ammonia (NH_3). The Air

Quality Index (AQI) is computed using suspended contaminants and the number of individual pollutants, then processed into an index using a logical aggregation method (Ott, 1978). Five pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO) were used to create the AQ sub-index (Sharma, 2001). The detailed methodology is presented in Figure 2. Pune IITM has just developed a new indexing approach based on the O_3 sub-index (Beig et al., 2010).On a five-point scale, the IITM-AQI has classified air quality as very unhealthy, very poor, poor, moderate, and good. The updated Indian National Air Quality Standards of the Pollution Control Board (2015) took twelve factors into account while calculating air quality standards, including Particulate Matter (PM) larger than 2.5 microns ($PM_{2.5}$), Ammonia (NH_3), Particulate Matter (PM) larger than 10 microns (PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Benzo(a)Pyrene (BaP), Arsenic (As), Ozone (O_3), Lead (Pb), Benzene (C_6H_6), and Nickel (AQI). Only four of the twelve parameters have yearly norms, whereas the remaining eight have both short-term (1/8/24 hours) and annual standards (except for CO and O_3) (Table 1).

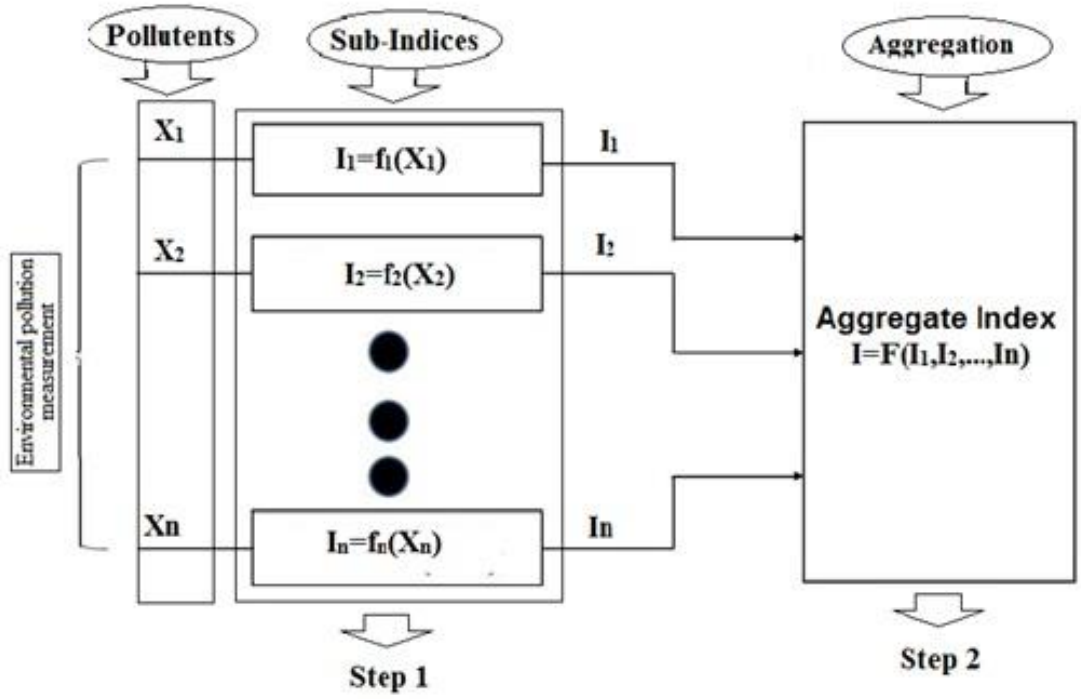

Fig. 2: Flow chart of the methodology

Table 1: Revised Indian National Air Quality Standards (INAQS)

Pollutants	Time Weighted Average	Industrial, residential and other are	Economically sensitive area
		The concentration of ambient air	
$PM_{2.5}$ (µg/m^3)	24 hrs	60	60
PM_{10} (µg/m^3)	24 hrs	100	100
SO_2 (µg/m^3)	24 hrs	80	80
NO_2 (µg/m^3)	24 hrs	80	80
O_3 (µg/m^3)	1 hrs	180	180
CO (mg/m^3)	8 hrs; 1 hrs	2; 4	2; 4
NH_3 (µg/m^3)	24 hrs	400	400

Source: CPCB (2015)

The current study studied the AQI levels during the lockdown period and correlated them to the levels before the lockdown. The parameters are chosen mostly based on the previously stated goals, the time duration, the consistency of monitoring data, and accessibility. Furthermore, six NAQI categories developed by the CPCB (2015) are used to present the projected health exposure, also known as Health Breakpoints, in the current scheme (Table 2).

Table 2: National AQI classes, health breakpoints for the seven pollutants and range, health impacts (Scale: 0-500)

AQI Class	Concentration Range						
	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	CO (mg/m^3)	NH_3 ($\mu g/m^3$)
Good (0–50)	0–50	0–30	0–40	0–40	0–50	0–1	0–200
Satisfactory (51–100)	51–100	31–60	41–80	41–80	51–100	1.1 - 2	201–400
Moderately polluted (101– 200)	101–250	61–90	81–380	81–180	101–168	2.1–10	401–800
Poor (201–300)	251–350	91–120	381–800	181–280	169–208	10–17	801–1200
Very poor (301–400)	351–430	121–250	801–1600	281–400	209–748*	17–34	1200–1800
Severe (401–500)	>430	>250	>1600	>400	>748	>34	>1800

** CO in mg/m^3 and other pollutants 24 hourly average values for PM_{10}, $PM_{2.5}$, NO_2, SO_2, and NH_3 8-hourly values for CO and O_3.*

Source: CPCB (2015)

Results

Changing trend and concentrations of pollutants for the pre-lockdown and during lockdown period

A continuous trend of reduction in pollutants was recorded due to the commencement of lockdown. The changing character of major air pollutant components: $PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO, and O_3 were monitored in two phases, during pre-lockdown (3rd March to 17th March) and during-lockdown (31st March to 21st April). Study shows that the pollution level of the city has witnessed a major reduction of pollution (Table 3).

A significant change in concentration of $PM_{2.5}$ and PM_{10} was recorded at Pre-Lockdown and during Lockdown. On 3rd March $PM_{2.5}$ and PM_{10} were computed very high and beyond the permissible level (181.71, 141.29), while with the commencement of lockdown the concentration of $PM_{2.5}$ and PM_{10} fell drastically (50.38, 55.83). It fell further to 23.67 and 30.57 on 21st April.

Table 3: Concentrations of major pollutants during the pre-lockdown and lockdown period and AQI

Air Pollutants (Average of 24 hours)	Pre-Lockdown			Commencement of Lockdown	During Lockdown				Change (%)
	3rdMar	10thMar	17thMar	24thMar	31stMar	07thApr	14thApr	21thApr	
$PM_{2.5}$	187.71	116.00	121.57	50.83	58.60	63.43	40.86	23.67	-60.82
PM_{10}	141.29	103.14	113.71	55.83	74.20	73.29	49.43	30.57	-45.05
NO_2	59.86	44.86	46.43	18.50	25.00	18.71	9.29	11.00	-62.27
NH_3	6.71	5.57	5.57	5.17	5.20	4.14	3.29	3.00	-32.12
SO_2	18.00	13.14	21.14	12.50	14.20	13.57	8.43	7.86	-32.00
CO	44.71	54.86	43.00	25.50	35.20	20.57	16.71	15.14	-47.86
O_3	37.71	25.71	22.14	21.17	32.00	30.43	25.86	34.57	15.10
AQI	187.71	118.57	126.00	51.14	59.00	74.57	49.43	44.57	-52.93

Source: Computed by authors

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Thus, the trend of average percentage was counted as -60.82% and -45.05%. NO_2 and NH_3 were beyond the standard permissible limit of WHO on 3rd March (59.86, 6.71). Rapid diminution was recorded from 24th March (Commencement of lockdown) and it reduced down to 11.00 and 3.00 on 21st April. In comparison between the two phases (Pre-Lockdown and during Lockdown), the highest and lowest changer in the concentration level of pollutants was NO_2 -62.27%, and NH_3 -32.12%. For SO_2 average concentration during pre-lockdown and lockdown was 17.52 and 11.02 respectively (Fig. 3). Only one parameter O_3 had no significant change during the whole surveyed period. The AQI as computed from the sub-indices indicated a positive change in air quality in Kolkata. During the phase of pre-lockdown, air quality was in the range of moderately polluted.

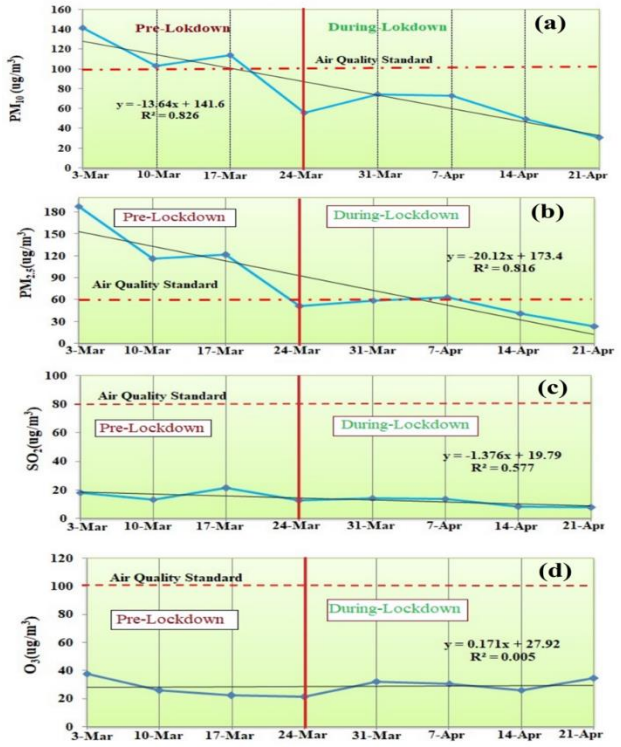


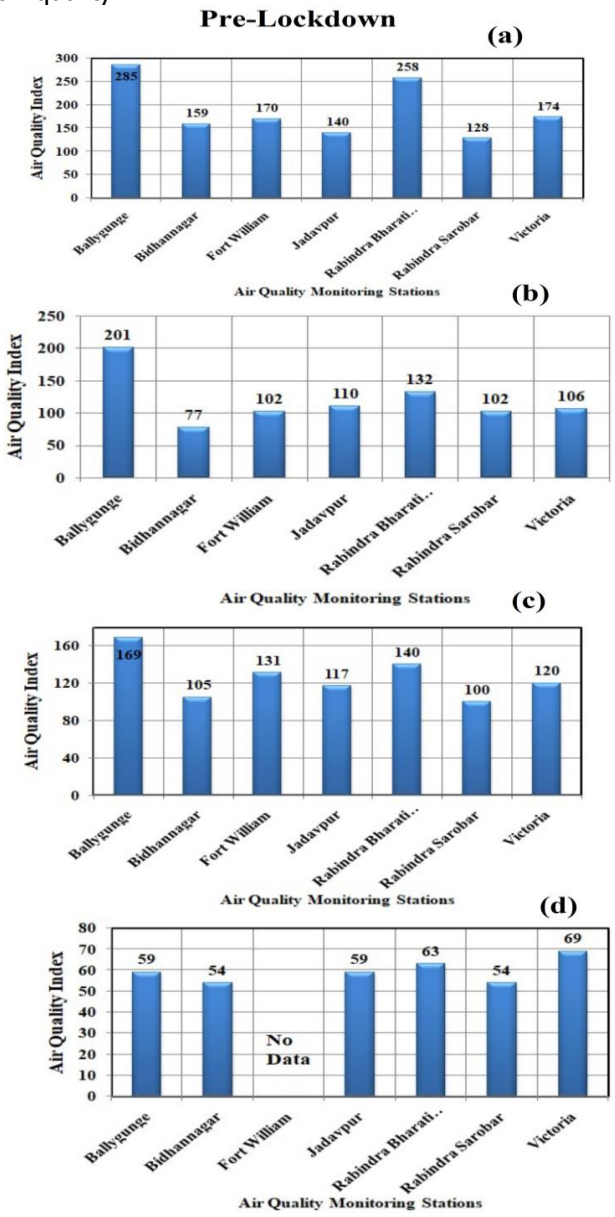
Fig. 3: Concentrations of pollutants for the pre-lockdown and during lockdown period – (a) PM_{10} (ug/m^3, 24 Hrs average), (b) $PM_{2.5}$ (ug/m^3, 24 Hrs average), (c) SO_2 (ug/m^3, 24 Hrs Average), (d) O_3 (ug/m^3, 8Hrs average)

A rapid change was assessed in AQI from the commencement of lockdown (AQI 51.14) On 31st March and 17th April, the level was satisfactory (AQI 59.00, 74.57 respectively).

By the end of 21st April, the air quality developed further and was categorized as 'good' (44.57).

Pre-lockdown and lockdown period spatial patterns of the National Air Quality Index (NAQI)

The spatial pattern of NAQI was counted at seven stations of the study area in two phases as stated earlier. During the pre-lockdown period at different considered times, the air quality index value was high. On 3rd March average air quality for the study area was "moderately polluted" (118.71). Of the seven stations, Ballygunge and Rabindra Bharati recorded "poor air quality" and the remaining stations came under "moderately poor" (Fig. 4). On 10th March average air quality was "moderately polluted" (118.57). At Ballygunge, air quality was recorded as "poor" (201), at Bidhannagar air quality was recorded as "satisfactory" (77) and the rest of the stations (Fort Willam, Jadavpur, Rabindra Bharati, Rabindra Sarabar, and Victoria) recorded "moderately polluted". On 17th March all the stations recorded "moderately polluted air quality".



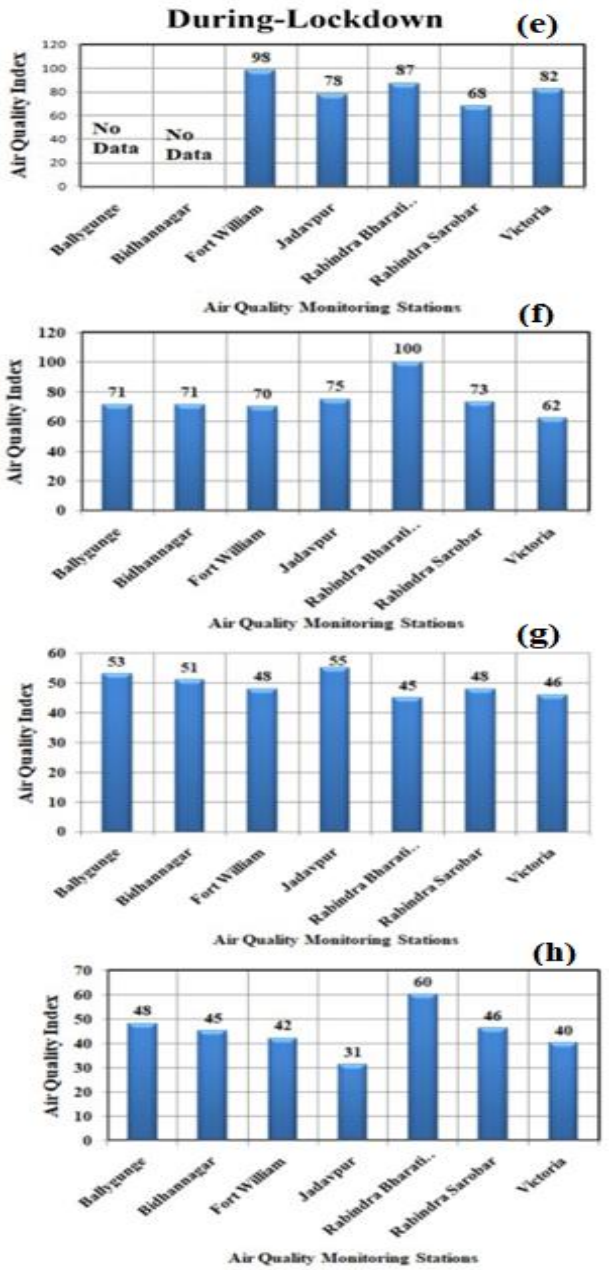


Fig. 4: Trend of air quality during pre (a, b, c, d) & post (e, f, g, h) lockdown period

A rapid change in air quality started from the day of lockdown commencement. A drastic change in AQI was computed on different dates during the lockdown period. On 31st March, 7th April, 14th April, and 21st April the average air quality was 82.60, 74.57, 49.42, and 44.57 respectively. The air quality could be categorized as "satisfactory" from 31st March to 7th April, while 14th April to 21st April was assigned as "good". The continuous development in air quality is the result of lockdown practice.

Co-relationships between air contaminants in the environment

Pearson's correlation coefficient is used to express the correlations between all air pollutant concentrations during the lockdown and before the lockdown (Table 4). The average $PM_{2.5}$ and PM_{10} concentrations over 24 hours are significantly associated with the daily average concentration of NO_2 (0.3974,0.972). NH_3 (0.868, 0.893) and CO (0.805,0.846). For SO_2 a strong correlation was detected with PM_{10} (0.857), NO2 (0.817), and NH_3 (0.8.16). An overall strong co-relation of the daily average concentration of NO_2 and NH_3 was found with all pollutants ($PM_{2.5}$, PM_{10}, SO_2, CO) except O_3. Daily 24 hrs average SO_2 and 8 hrs CO concentration was highly co-related with PM_{10}, NO_2, and NH_3. A less significant co-relation of SO_2 was recorded with $PM_{2.5}$ and CO (0.777, 0.688) and CO with SO_2 (0.688). There was no relation of O_3 concentration with the other pollutants ($PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO).

Table 4: Correlation of concentration of pollutants

Pollutants	$PM_{2.5}$	PM_{10}	NO_2	NH_3	SO_2	CO	O_3
$PM_{2.5}$	1	0.979**	0.974**	0.868**	0.777*	0.805*	-0.420
PM_{10}	0.979**	1	0.972**	0.893**	0.857**	0.846**	-0.383
NO_2	0.974**	0.972**	1	0.898**	0.817*	0.897**	-0.458
NH_3	0.868**	0.893**	0.898**	1	0.816*	0.853**	-0.456
SO_2	0.777*	0.857**	0.817*	0.816*	1	0.688*	-0.252
CO	0.805*	0.846**	0.897**	0.853**	0.688*	1	-0.571
O_3	-0.420	-0.383	-0.458	-0.456	-0.252	-0.571	1

*Note: The correlations are expressed as Pearson's correlation coefficient, where, ** and ***denotes significant correlations at:**. Correlation is significant at the 0.01 level*. Correlation is significant at the 0.05 level*

Conclusions

Air pollution is a serious global problem. In India with its growing population and economic development air pollution is a major concern. The urban areas with high population concentration and industrial development are highly affected.

During the lockdown, data from eight stations spanning the whole megacity of Kolkata was used to evaluate the air quality state of the city.

The present research looked at AQI levels during the lockdown and compared them to levels prior to the lockdown. Herewith, for the lockdown and pre-lockdown periods we highlighted a positive effect of containment measure for COVID-19, indirectly on air pollution (e.g., the concentration of PM10, PM2.5, SO2, NO2, and CO) in Kolkata, West Bengal, India.

Since the start of lockdown, there has been a steady decrease in pollution levels. PM2.5, PM10, NO2, NH3, SO2, CO, and O3 were measured in two phases: before the lockdown (3rd March to 17th March) and during the lockdown (31st March to 21st April).There was rapid reduction in the concentration of all the major pollutants during the lockdown phase as compared to the pre lockdown phase. Only O3, did not alter significantly during the course of the study. The level of O3 was 37.71 as calculated on 3rd March, 2020 which came down slightly to 34.57 on 21st April,

2020. As a result of reduction of pollutants, there was substantive improvement in the AQI level.

On 3rd March average AQI for the study area was "moderately polluted" (187.71).However by the end of 21st April, the air quality developed further and was categorized as 'good' (44.57) indicating that the city's pollution level has decreased significantly.

Statistical analysis showed an overall strong co-relation of the daily average concentration of NO2 and NH3 with all pollutants (PM2.5, PM10, SO2, CO) except O3.Thus from the research work undertaken it can be said that the lockdown had a substantial positive effect in the air quality of an otherwise polluted megacity.

Author contribution

DDLS: Conceptualization-Original draft, program running. **JR**: Data curation& Data validation and Software. **BB**: Writing-review & editing, supervision. **AS**: Editing. **DP**: Writing

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Urban public transport development in Poland in 2004-2020 Co-financed by EU: geography and disparities

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Abstract

This paper deals with the projects in the field of urban public transport, which were implemented in Poland after its entrance to the European Union with financial support from the European Regional Development Fund, European Cohesion Fund, and Connecting Europe Facility instrument. These projects were classified by type of activities and main transport mode, and their geography across the country was considered. Urban public transport projects supported by the EU, no doubt, changed the face of a lot of Polish cities and towns in recent years. Despite this fact, they were distributed very unevenly throughout the country.

Keywords: *Poland, European Union, urban public transport, European Cohesion Policy, absorption of EU Funds*

Rezumat. Dezvoltarea transportului public urban în Polonia în perioada 2004-2020 co-finanțat de către UE: caracteristici geografice și disparități

Lucrarea prezintă proiectele din domeniul transportului public urban, care au fost implementate în Polonia după integrarea în Uniunea Europeană, cu sprijinul financiar al Fondului European Regional pentru Dezvoltare, Fondul European pentru Coeziune și Mecanismul de Conectare a Europei. Aceste proiecte au fost clasificate ținând cont de tipul de activități și modul de transport, precum și distribuția lor teritorială la nivelul țării. Proiectele privind transportul public urban, finanțate de către UE, au avut un impact considerabil asupra multor orașe mari și mici din Polonia în ultimi ani. Cu toate acestea, ele au fost raspândite foarte inegal la nivelul țării.

Cuvinte-cheie: *Polonia, Uniunea Europeană, transport public urban, Politica de Coeziune Socială, absorbția fondurilor UE*

Introduction and literature review

The role of urban public transport in mobility in Polish cities and towns remains crucial. In 2019, the last year before the COVID-19 pandemic, buses, trolleybuses, trams in overall Poland, and the only metro system in Warsaw carried 4 107 million passengers (GUS 2020, ZTM 2020). Even this number is not full because it does not include passenger flow of commuter trains within cities and urban agglomerations, cumulative data on which for the whole country are not available. In 2021 15 tram and 3 trolleybus systems exist in Poland while in every population centre with no less than 50 thousand inhabitants bus system is in operation. According to GUS (2020), 57,3 thousand kilometres of urban bus lines, 2,3 thousand kilometres of tram lines as well as 479 and 33 kilometres of trolleybus cables and Warsaw metro lines respectively existed in 2019.

In the late Polish people's republic usage of mass transit definitely prevailed over car trips. In 1987, for example, 88% of inner-city trips in Poland were made by urban public transport (Pucher, 1995). In the 1990s and early 2000s urban public transport in the country faced a massive crisis expressed mostly on the deterioration of infrastructure and fleet. Three main reasons for such a state can be mentioned. Firstly, responsibility for maintenance on urban public transport was placed on local authorities, but they did not receive any opportunities for raising external financing (Radzimski & Gadziński, 2019). Besides, after the fall of communism in Poland car ownership had extremely grown from 5,3 million vehicles in 1990 to 10 million in 2000 (GUS 2018, 2021a). The private car was not only considered as faster and more efficient transport mean compared to mass transit. Vehicle ownership was regarded as very prestigious as it could show motorists' considerably higher social status (Domański, 2012). The enormous growth of car park had only exacerbated the degradation of urban public transport in Poland.

After the entrance to EU Poland became one of the major recipients of financial aid from European funds and should be the "showcase" of European structural policies and their achievements (Churski, 2008). In Polish academic literature, ecstatic assessments of this financial aid can be found. For example, it is compared with the Marshall Plan of financial support of Western Europe after World War II (Życki, 2019). Golinowska (2019) gave thanks to the EU for

investment in even the "civilization jump" of Poland. These metaphorical expressions do not supersede the critical review of aspects of EU investments in Poland. Bachtler & McMaster (2008) highlighted the trend towards gradual regionalisation, i.e. giving local authorities more credentials to select projects for EU co-financing according to their vision of the local circumstances, but also saw it as the source of tension between regions and central government because of existing of parallel decision-making structures on regional and central level. However, the most part of EU funding was spending on the major metropolitan areas of Poland (Churski, 2017). Among the probable reasons of this trend the higher population density and hence bigger opportunity for users to benefit from investment (Churski et al., 2016), disparity in human capital between large and medium cities on the one hand and smaller population centres (Wołek, 2018) and the bigger investment attractiveness of voivodeship capitals compared to cities and towns without this status (Przybyła et al., 2020) are identified. Bachtler et al. (2019) expressed that in the next version of EU Cohesion Policy for every certain medium- and underdeveloped region its local opportunities and challenges had to be better recognised by differentiating their support and allocating of financial resources.

Balance between investments in the technical infrastructure and the development of institutions in Poland was also reflected critically. According to Churski (2017) and Rodríguez-Pose (2013), the support of local institutes within European funding was not enough, and this situation may lead to difficulties in the maintenance of technical infrastructure in the future. Kozak (2012) stated that not the construction of "hard" infrastructure, but the improvement of "soft" factors such as social and human capital should be the main development factor in underdeveloped regions. Mucha et al. (2019), furthermore, underscored the fact that investments in urban public transport in Poland co-financed by EU had been made in almost the one-time period and that in future country would face the problem of the one-time modernisation of this infrastructure without aid of EU.

Either way, it was understandable that the development of urban public transport infrastructure in Poland was one of the priorities during all three EU budget periods – 2004-2006, 2007-2013, and 2014-2020.

All projects co-financed by EU funds should be part of the operational programmes which are "detailed plans in which the Member States set out how money from the European Structural and Investment Funds will be spent during the programming period. They can be drawn up for a specific region or a country-wide thematic goal" (EC, 2015b). Each project should be part of sub-measure and category. The source of co-financing, in most cases European Regional Development Fund (ERDF) or European Cohesion Fund (ECF), depends on them.

In 2004-2006 projects on the development of urban public transport in Poland were included in two programmes, "Integrated programme of regional development" (hereinafter ZPORR, from Polish "Zintegrowany Programme Operacyjny Rozwoju Regionalnego") and "Transport" (Table 1). ZPORR covered the development of bus, trolleybus, and tram infrastructure as well as of Warsaw metro. Programme "Transport" was focused on the inter-city network but encompassed several projects on the commuter railways in urban agglomerations. Towns with a population of fewer than 50 thousand inhabitants in fact did not have an opportunity to raise funding for the renovation of mass transit. Besides, projects were approved on the level of the Polish government. That aggravated the concentration of urban public transport development in major population centres and led to its underfinancing in poorer regions (Schötz-Sobczak, 2005).

These shortcomings were taken into account in the budget period 2007-2013. The operational programme "Development of Eastern Poland" was adopted especially for the support of less developed Warmian-Mazurian, Podlaskie, Lublin, Subcarpathian, and Holy Cross voivodeships. On the country-wide level urban public transport development projects were included in the operational programme "Infrastructure and environment" (POIiŚ, from Polish "Program Operacyjny Infrastruktura i Środowisko"). Smaller towns outside of urban agglomerations received an opportunity to claim the co-financing of urban public transport development within POIiŚ at least in sub-measure "Development of intelligent transport systems". Furthermore, apart from the country-wide level 16 regional operational programmes (ROP) for each voivodeship were adopted, and in their case approval of projects took place on the regional level. The special algorithm was applied for division of funds between ROPs: 80% of funds were divided based on the proportion of population levels, 10% were divided in proportion of population size between voivodeships with GDP per capita less than 80% of average Polish in 2001-2003, and the rest 10% were allocated to poviats (administrative units of lower level than voivodeships) with unemployment rate 150% higher than average Polish in 2003-2005 (MRR, 2007a). In 2014-2020 more complicated algorithm, however, also based on population size, GDP per capita and unemployment rate, was applied (MIR, 2014c).

In 2014-2020 ROPs were also mandated apart from country-wide programmes. Besides, one financial instrument not within European Cohesion Policy was used. Connecting Europe Facility was

aimed at the development of Trans-European Transport Network (TEN-T) that will bring together the main communication lines of the continent. Focused mostly on the freight traffic, CEF Transport nevertheless included several projects on the development of commuter passenger railways in the biggest Polish agglomerations.

Table 1. EU programmes covering mass transit development in Poland in 2004-2020

Programme	Sub-measure	Category	Fund	Declared area of intervention for sub-measure
Countrywide and sub-regional level				
2004-2006				
Transport	1.1 "Modernisation of railway lines in relations in urban agglomerations and between them"	-	ERDF	Agglomerations of major cities
ZPORR	1.1 "Modernisation and expansion of the regional transport systems"			Cities bigger than 50 thousand inhabitants and their environs
	1.6 "Development of public transport in agglomerations"			Agglomerations bigger than 500 thousand inhabitants
2007-2013				
POIiŚ	7.1 "Railway transport" (certain projects in urban agglomerations only)	16. Railways, 17. Railways (TEN-T), 18. Rolling stock	ECF	Entire Poland
	7.3 "Urban transport in agglomerations"	52. Promotion of eco-friendly urban transport	ECF	Nine agglomerations of voivodeship capitals
	8.3 "Development of intelligent transport systems"	28. Intelligent transport systems	ERDF	Entire Poland
Development of Eastern Poland	3.1. "Public transport systems"	25. Urban transport	ECF	Capitals of voivodeships of Eastern Poland
2014-2020				
POIiŚ	5.1. "Development of railways (TEN-T)", 5.2. "Development of railways (outside of TEN-T)" (certain projects in urban agglomerations only)	024. Railways (basic TEN-T network), 025. Railways (complex TEN-T network), 026. Other railways, 027. Rolling stock	ECF	Entire Poland
	6.1. "Development of public transport in cities"	043. Green urban transport infrastructure and its promotion, 044. Intelligent transport systems	ECF	13 agglomerations of voivodeship capitals (excluding Eastern Poland)
Eastern Poland	2.1 "Sustainable urban transport"	043. Green urban transport infrastructure and its promotion, 044. Intelligent transport systems	ERDF	Capitals of voivodeships of Eastern Poland
Not in Cohesion Policy:				
CEF Transport	-	-	CEF	Entire Poland
Regional level				
2007-2013				
16 ROP	Various names	25. Urban transport, 28. Intelligent transport systems, 52. Promotion of eco-friendly urban transport	ERDF	Entire voivodeships
2014-2020				
16 ROP	Various names	043. Green urban transport infrastructure and its promotion, 044. Intelligent transport systems	ERDF	Entire voivodeships

Sources: MRR, 2004, 2007b, c; MGP, 2004; MIR, 2014a, b, 2015a; Mucha et al., 2019, p. 101, own elaboration

The research problem within current investigation can be stated as uneven involvement of different Polish cities, towns and voivodeships (the administrative-territorial entities of NUTS 2 level) in projects co-

financed by EU to promote urban public transport during the period under review. The research question can be worded as follows: "What are the territorial differences in the development of urban public transport in Poland within EU financial support in 2004-2020?". It is split into the two sub-questions:

1. What kind of projects were carried out?
2. How are these projects disseminated across whole Poland?

Methodology

For answering the research question, cartographical approach, whose goal is "to produce scientific insights by facilitating the identification of patterns, relationships and anomalies in data" (Maceachren & Ganter, 1990) was utilised. GIS-software ArcMap 10.5 was used as a cartographical tool.

Spatial data on the location of projects were required for mapping. Tables with data on activities in 2007-2013 and 2014-2020 were downloaded from the website "Portal Funduszy Europejskich" ("European Funds Portal") supported by the Polish Ministry of funds and regional policy. These datasets contained information on the name of the project, operational programme, sub-measure and category, and implementation area. File on the budget period 2014-2020 also comprised a short summary of the project in which data on the number of acquired fleet units or other objects was sometimes included. Data on projects implemented in 2004-2006 were not available as an integral set and were taken from the website "Mapa dotacji UE" ("Map of EU grants"). In most cases details concerning the content of the project and, in particular, procured rolling stock should be found in the documentation on the websites of local authorities or even in local media.

Besides, information on projects supported within the CEF Transport was drawn from the page of this financial instrument on the website of the European Commission.

Pursuant to Sejm Rzeczpospolitej Polskiej (2011), in Poland movements within cities and neighbouring communes are also considered as urban transportation. For this reason, projects aimed at the development of agglomeration transport were also taken into account within the current study. For the limitation of these agglomerations borders of so-called functional areas ("Obszary funkcjonalne" in Polish) around the voivodeship capitals were applied. According to Polish National Spatial Development Concept, functional areas are "spatially continuous settlement systems, composed of administratively separate units. They cover a city, an urbanised zone related to it and centres of close neighbourhoods" (MRR, 2011). Borders of functional areas around voivodeship capitals are defined and can be found, for example, in strategies of integrated territorial investments. Only two deviations from officially set boundaries were done within the current investigation. Firstly, Świnoujście was excluded from Szczecin agglomeration because roads between these two cities run through territory outside of the functional area. Besides, for Katowice agglomeration borders of the legally established communal union "Metropolitan area of Upper Silesia and Zagłębie" were used.

Not all projects within sub-measures from Table 1 are examined. They were taken into account only if met at least one of five criteria based on the categorisation developed by Mucha et al. (2019):

1. Procurement of new fleet and rolling stock and renovation of available units;
2. Construction of new or upgrade of currently existing tram or commuter railway lines, bus lanes, trolleybus routes, stops and stations of all modes (excepting bus and railway terminals);
3. Installation of intermodal hubs: bus and railway terminals, interchange stations, P+R and B+R close to bus stops or commuter rail platforms.
4. Development of intelligent transport systems: installation of electronic ticket systems, ticket machines, traffic control systems, systems of passenger information.
5. Development of infrastructure for technical service of fleet and rolling stock (depots, parks, traction substations, stations for charging electric buses).

Railway projects were considered in case of meeting next criteria: 1) they are designed to the development of commuter or inner-city passenger traffic; 2) they are located in metropolitan areas voivodeship capitals, or at least no less than 50% of activities (by length of installed tracks or number of built platforms) were carried out within borders of these agglomerations. Projects located partially or fully in rural areas were taken into account only if these areas were located in urban agglomerations.

Research results

Thanks to EU co-financing 844 urban public transport projects with a total value of 19.97 billion euros were implemented in Poland in 2004-2020. ERDF, ESF, or CEF instrument provided 12.10 billion euros, while the rest 7.87 billion were paid from state and local budgets or by private investors. It could be assumed that Poland had received the largest EU financial support for urban public development among all new member states. At least from 2007 to 2020, Poland received 8.27 billion euros from ERDF and ESF for the development of urban public transport (excluding railway projects). It was almost a half of the total investments with this purpose from ERDF and ESF in new members of the EU excluding Cyprus and Malta, which amounted to 16.62 billion

euros (EC, 2022ab). By investments from these funds to the development of urban public transport in EU new member states in 2007-2020 per capita, Poland is outdone only by Hungary (217 and 231 euros per person respectively), according to data of EC (2022ab) and World Bank (2022).

In most cases projects in Poland encompassed several activities. The most popular one was the acquisition of fleet, which was included in almost half of the projects (Table 2). Despite that, installation of park+ride and bike+ride complexes and larger intermodal hubs became the most popular activity during the 2014-2020 budget period.

Table 2: Activities within EU-supported urban public transport projects in Poland in 2004-2020

Activity / Budget period	Number of projects				%			
	2004-2006	2007-2013	2014-2020	Total	2004-2006	2007-2013	2014-2020	Total
Purchase or renovation of fleet and rolling stock	27	161	230	418	57.4%	66.0%	41.6%	49.5%
Stops, platforms, lines	34	87	155	276	72.3%	35.7%	28.0%	32.7%
Intermodal hubs, P+R, B+R	6	30	352	388	12.8%	12.3%	63.7%	46.0%
Intelligent transport systems	11	74	171	256	23.4%	30.3%	30.9%	30.3%
Infrastructure for technical maintenance	9	34	95	138	19.1%	13.9%	17.2%	16.4%
Total	47	244	553	844	100%	100%	100%	100%

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019, own elaboration

Almost half of them (416) were concentrated in the four most populated voivodeships – Greater Poland, Mazovian, Silesian, and Lesser Poland (Fig. 1).

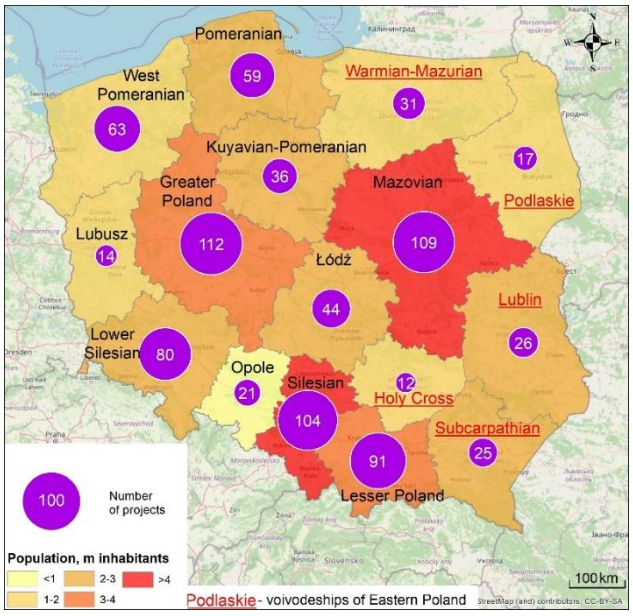

Fig. 1: Number of urban public transport projects in Poland in 2004-2020

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; GUS, 2021b, own elaboration

The biggest number of projects (112) is carried out in the Greater Poland voivodeship which is the biggest by square but not by the number of inhabitants while the most populated Mazovian voivodeship is in the second place (109). In smaller provinces, fewer projects were realised. In Holy Cross, the lowest number of projects (12) was implemented although it is not the least populated province. In Opole, the only voivodeship with less than one million inhabitants, 21 projects are carried out.

In 2014-2020 considerable increase in urban transport projects compared to the previous budget period 2007-2013 took place in almost all regions (Fig. 2). It was the most substantial in Silesian (from 23 to 80) and in Greater Poland (from 26 to 82) voivodeships. In the entire country the number almost doubled from 244 to 553 – thus, 65% of EU-supported activities on the development of urban public transport in Poland accounted for the period 2014-2020.

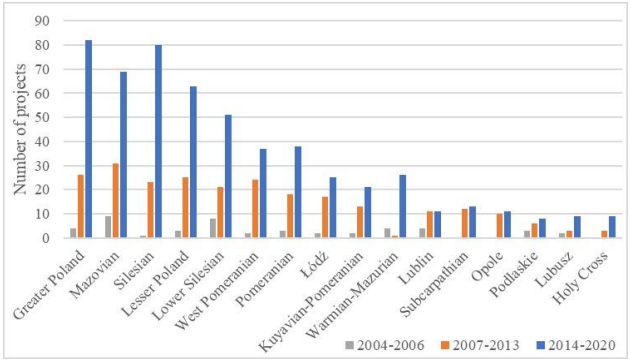

Fig. 2. Number of urban public transport projects in Poland in 2004-2020 by voivodeship and budget period

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; GUS, 2021b, own elaboration

However, in monetary terms, the ranking of provinces looks different. 6.55 billion euros or almost

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one-third of expenditures was spent in Mazovian voivodeship, primarily in Warsaw. Łódź and Pomeranian voivodeships are in the second and third place with 1.91 and 1.90 billion euros respectively (Fig. 3). In Greater Poland that leads by the number of projects, their total cost was "only" 1.33 billion euros, fewer than in Lesser Poland and Silesia (1.63 and 1.56 billion euros respectively). In the least populated Opole voivodeship, the lowest amount (0.16 billion euros) was spent.

The reason for such distinction in expenditures on projects lies in the transport modes and scope of constructional works. In particular, in Warsaw, three projects aimed at the building of the second metro line were carried out. Their combined value reached 3.06 billion euros which is almost 47% of the total expenditures on the urban public transport development within EU programmes in Mazovian voivodeship. In terms of Pomeranian and Łódź voivodeships, it should be mentioned that in these regions as well as in Mazovia, Greater and Lesser Poland, and Silesia utmost costly projects on the renovation or the installation of new railway lines for the commuter transport were realised. In addition, upgrade and construction of new tram tracks, as well as procurements of new rolling stock, took place in all cities with tram networks. As these works are generally more expensive than the installation of new bus stops and acquisition of new buses, they also boosted the total expenditures on mass transit.

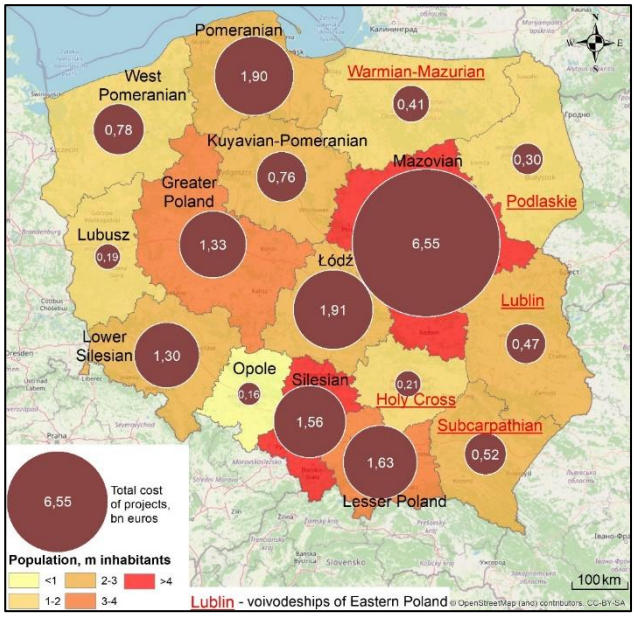

Fig. 3: Total cost of EU-supported urban public transport projects in Poland in 2004-2020

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; GUS, 2021b; ECB, 2022, own elaboration

Growth of total cost in entire Poland in 2014-2020 (10.32 billion euros) compared with 2007-2013 (8.71 billion) was not so significant compared with the number of projects and in several voivodeships was even negative (Fig. 4). This fact shows that increase in the number of projects took place mostly owing to the relatively cheap activities.

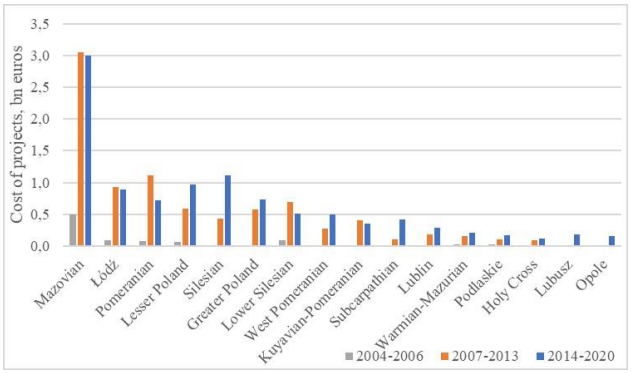

Fig. 4: Cost of urban public transport projects in Poland in 2004-2020 by budget period

Sources: EC 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; ECB, 2022, own elaboration

Regional operational programmes included 612 of 844 realised projects (Table 3). It can be explained by the massive increase of projects within ROPs. At the same time, the costliest projects were normally included in the national-level programme "Infrastructure and environment" (Table 4). Within its framework activities worth 15.89 billion euros were carried out which is almost 80% of total expenditures.

Coverage of Polish cities and towns by urban public transport development activities within EU funding rose steadily since 2004. In the budget period 2004-2006 even not all voivodeship capitals participated in programmes "Transport" and ZPORR with regard to mass transit (Fig. 5). From 2014-to 2020 aside from metropolitan areas of every province centre activities took place in 164 cities and towns. Cumulatively since 2004 EU-supported urban transport development projects had the most widespread distribution in Lower Silesian voivodeship where at least one of them was realised in 28 population centres outside of Wrocław agglomeration. The lowest value of this indicator can be observed in Lubusz voivodeship where only three towns apart from Gorzów Wielkopolski and Zielona Góra metropolitan areas were covered by these activities.

The number and total cost of projects within either programmes on the national level or ROP demonstrate a high correlation with the population of provinces (Fig. 6). On the regional level, it hardly might be different because the voivodeship population was one of the factors for the calculation of the total budget of ROP – although it did not affect the planned

distribution of funds by categories. Only the correlation coefficient of total expenditures on the national level and population is lower than 0.8. It can be explained by the fact that Pomeranian and Łódź voivodeships where a lot of commuter railway works took place are located only in the middle of the ranking of Polish provinces by population.

Table 3: Number of EU-supported urban transport projects by programme and voivodeship

Voivodeship / Budget period / Level of programme	Number of projects														
	2004-2006			2007-2013				2014-2020					Total		Total
	Transport	ZPORR	Total	POIiŚ	DEP	ROP	Total	POIiŚ	CEF Transport	EP	ROP	Total	National	ROP	
Greater Poland	0	4	4	7	0	19	26	10	0	0	72	82	21	91	112
Mazovian	4	5	9	17	0	14	31	14	3	0	52	69	43	66	109
Silesian	0	1	1	6	0	17	23	12	0	0	68	80	19	85	104
Lesser Poland	0	3	3	10	0	15	25	7	1	0	55	63	21	70	91
Lower Silesian	0	8	8	7	0	14	21	6	0	0	45	51	21	59	80
West Pomeranian	0	2	2	5	0	19	24	7	0	0	30	37	14	49	63
Pomeranian	1	2	3	8	0	10	18	12	0	0	26	38	23	36	59
Łódź	0	2	2	5	0	12	17	2	0	0	23	25	9	35	44
Kuyavian-Pomeranian	0	2	2	8	0	5	13	4	0	0	17	21	14	22	36
Warmian-Mazurian	0	4	4	0	1	0	1	0	0	2	24	26	7	24	31
Lublin	0	4	4	0	2	9	11	0	0	4	7	11	10	16	26
Subcarpathian	0	0	0	1	1	10	12	3	0	3	7	13	8	17	25
Opole	0	0	0	0	0	10	10	4	0	0	7	11	4	17	21
Podlaskie	0	3	3	0	2	4	6	0	0	3	5	8	8	9	17
Lubusz	0	2	2	0	0	3	3	5	0	0	4	9	7	7	14
Holy Cross	0	0	0	0	1	2	3	0	0	2	7	9	3	9	12
Total	5	42	47	74	7	163	244	86	4	14	449	553	232	612	844

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; own elaboration

Table 4: Total cost of EU-supported urban transport projects in Poland in 2004-2020 by programme and voivodeship

Voivodeship / Budget period / Programme	Cost of projects, m euros														
	2004-2006			2007-2013				2014-2020					Total		Total
	Transport	ZPORR	Total	POIiŚ	DEP	ROP	Total	POIiŚ	CEF Transport	EP	ROP	Total	National	ROP	
Mazovian	390	108	498	2 821	0	226	3 047	2 603	128	0	268	3 000	6 051	495	6 546
Łódź	0	96	96	875	0	56	931	572	0	0	315	887	1 542	371	1 914
Pomeranian	4	71	75	908	0	199	1 107	455	0	0	265	720	1 438	464	1 902
Lesser Poland	0	70	70	519	0	70	589	415	243	0	311	970	1 248	381	1 629
Silesian	0	18	18	263	0	169	432	580	0	0	526	1 106	861	695	1 556
Greater Poland	0	17	17	432	0	149	581	441	0	0	290	731	891	439	1 329
Lower Silesian	0	94	94	640	0	48	688	301	0	0	215	516	1 036	262	1 298
West Pomeranian	0	8	8	215	0	57	272	381	0	0	116	497	604	173	777
Kuyavian-Pomeranian	0	3	3	339	0	62	401	202	0	0	157	359	545	219	764
Subcarpathian	0	0	0	4	83	16	103	202	0	133	82	417	422	98	520
Lublin	0	7	7	0	126	59	184	0	0	144	137	281	277	195	473
Warmian-Mazurian	0	32	32	0	162	0	162	0	0	148	65	213	342	65	407
Podlaskie	0	20	20	0	88	20	108	0	0	115	58	173	223	78	301
Holy Cross	0	0	0	0	85	4	89	0	0	80	40	120	165	43	208
Lubusz	0	5	5	0	0	8	8	160	0	0	18	178	165	26	191
Opole	0	0	0	0	0	10	10	78	0	0	72	150	78	82	160
Total	395	548	943	7 017	543	1 153	8 713	6 391	372	620	2 935	10 318	15 887	4 087	19 975

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; ECB, 2022, own elaboration

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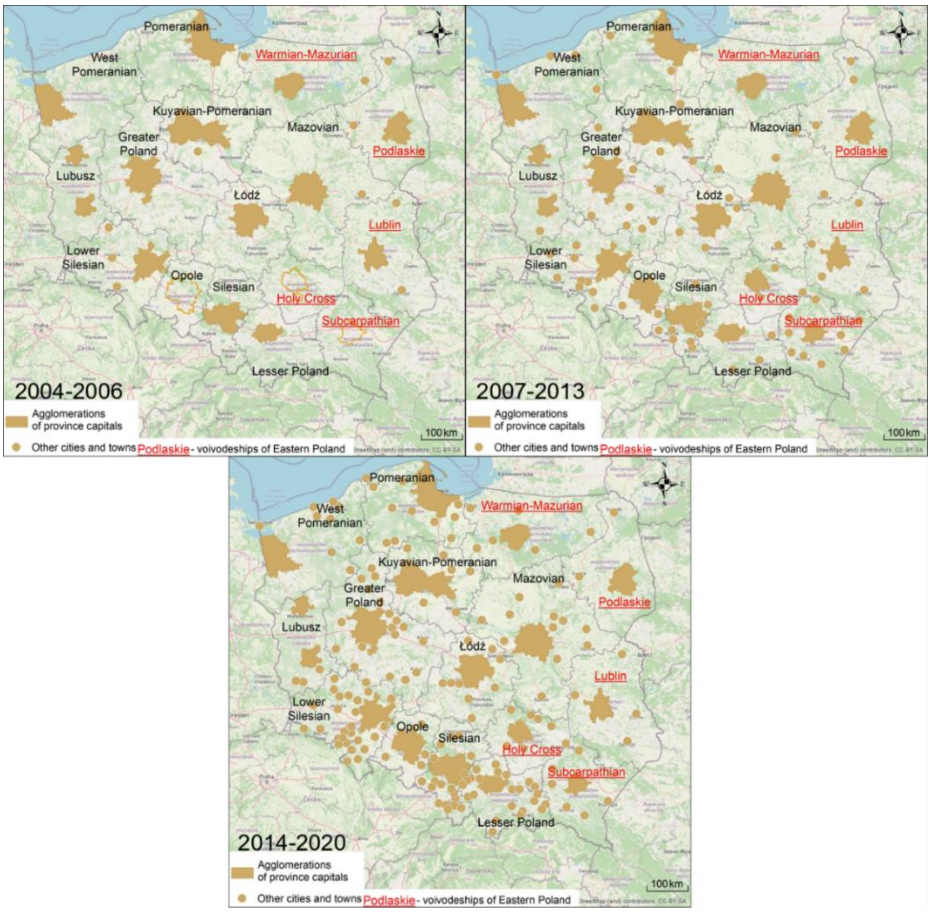

Fig. 5: Coverage of province capitals and other cities and towns of Poland by EU-supported urban public transport projects in 2004-2020

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; own elaboration

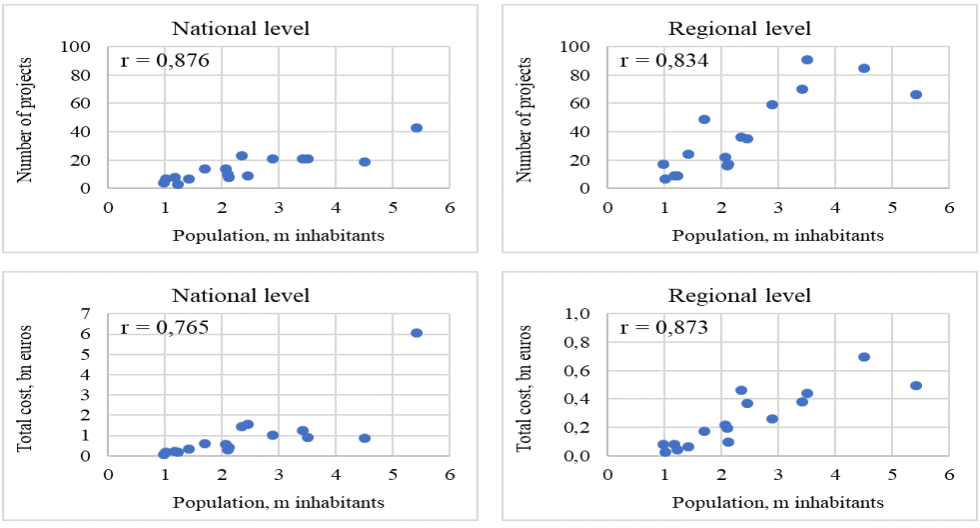

Fig. 6: Correlation of number and cost of EU-supported urban public transport projects with population of voivodeships

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; GUS, 2021b; ECB, 2022, own elaboration

Despite the growth of the number of cities and towns which were covered by urban public transport projects, the majority of these projects – 502 of 844 - are nevertheless concentrated in provincial capitals and their agglomerations (Table 5). In certain voivodeships such as Lower Silesian, Warmian-Mazurian,

Subcarpathian, Opole, and Holy Cross centres and their agglomerations gained less mass transit activities than towns outside of them combined. This fact should not be misleading: the total cost of projects in capitals and their environs was much higher than in other towns cumulatively in all provinces without exception (Table 6). For example, in Lower Silesia (31 projects in Wrocław agglomeration, 49 outside) project "Integrated tram system in Wrocław and agglomeration - Stage I" was carried out in 2007-2013 and included procurement of 39 low-floor trams and reconstruction of 37 km of rails was worth more than rest of 49 activities in other parts of the voivodeship. In Warmia-Mazuria number of projects in the Olsztyn metropolitan area was almost two times less than externally, but these activities included the building of the Olsztyn tram system from scratch and are incomparable in monetary terms with the purchase of several buses for the small town. Only in Silesian voivodeship total expenditures on projects outside of major agglomeration exceeded one billion zlotys, and almost half of this amount was spent on the reconstruction of the tram system in Częstochowa.

Table 5: Number of EU-supported urban public transport projects in Poland in 2004-2020 by location within voivodeships

Voivodeship / Budget period	Number of projects								
	2004-2006		2007-2013		2014-2020		Total		
	Centre and aggl.	Other cities	Centre and aggl.	Other cities	Centre and aggl.	Other cities	Centre and aggl.	Other cities	Total
Greater Poland	4	0	13	13	51	31	68	44	112
Mazovian	8	1	21	10	55	14	84	25	109
Silesian	1	0	12	11	53	27	66	38	104
Lesser Poland	3	0	18	7	30	33	51	40	91
Lower Silesian	5	3	8	13	18	33	31	49	80
West Pomeranian	2	0	17	7	19	18	38	25	63
Pomeranian	3	0	15	3	27	11	45	14	59
Łódź	2	0	12	5	14	11	28	16	44
Kuyavian-Pomeranian	1	1	10	3	13	8	24	12	36
Warmian-Mazurian	1	3	1	0	9	17	11	20	31
Lublin	1	3	7	4	7	4	15	11	26
Subcarpathian	0	0	2	10	7	6	9	16	25
Opole	0	0	4	6	5	6	9	12	21
Podlaskie	1	2	3	3	5	3	9	8	17
Lubusz	2	0	2	1	7	2	11	3	14
Holy Cross	0	0	1	2	2	7	3	9	12
Total	34	13	146	98	322	231	502	342	844

Sources: EC, 2015a, MFiPR, 2020, 2021, Mapa Dotacji UE, 2019, own elaboration

Table 6: Cost of EU-supported urban public transport projects in Poland in 2004-2020 by location within voivodeships

Voivodeship / Budget period	Cost of projects, m euros								
	2004-2006		2007-2013		2014-2020		Total		
	Centre and aggl.	Other cities	Centre and aggl.	Other cities	Centre and aggl.	Other cities	Centre and aggl.	Other cities	Total
Mazovian	497	1	3 019	28	2 874	126	6 390	156	6 546
Łódź	96	0	925	5	846	40	1 868	46	1 914
Pomeranian	75	0	1 094	13	631	88	1 801	101	1 902
Lesser Poland	70	0	570	19	868	101	1 508	121	1 629
Silesian	18	0	369	63	917	189	1 303	253	1 556
Greater Poland	17	0	556	25	617	114	1 190	139	1 329
Lower Silesian	89	5	651	36	437	80	1 177	122	1 298
West Pomeranian	8	0	259	13	460	37	728	50	777
Kuyavian-Pomeranian	2	1	378	23	295	64	676	88	764
Subcarpathian	0	0	87	16	369	48	456	64	520
Lublin	2	5	169	15	261	20	432	41	473
Warmian-Mazurian	5	26	162	0	176	38	343	64	407
Podlaskie	16	4	94	14	154	19	264	37	301
Holy Cross	0	0	85	4	80	40	165	43	208
Lubusz	5	0	8	0,4	163	14	176	15	191
Opole	0	0	4	6	103	48	107	54	160
Total	900	43	8 431	282	9 251	1 067	18 583	1 392	19 975

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019, ECB, 2022, own elaboration

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It became possible to make an attempt at the evaluation of costs of development of each transport mode in 2004-2020 within EU co-funding. This calculation cannot be precise because certain projects in metropolitan areas included activities on several transport modes. For example, expenditures on the development of three Polish trolleybus systems in Lublin, Gdynia, and Tychy cannot be counted because activities there were usually combined with the development of bus systems. Besides, the installation of intelligent transport systems, as well as the construction of intermodal hubs, also covered several means of transport in major cities. All such projects are combined into the category "without main mode" which can be regarded as a likeness of "measurement bias" in the current context. Nevertheless, this calculation provides an insight into the distribution of projects and their expenditures by specific modes. As appears in Figure 7, 12.16 billion euros, or almost 61% of all expenditures were spent on the development of trams and passenger railways, while bus transport was led by a number of projects. 13 tram systems in voivodeship centres (12 existed since XIX-XX centuries and one newly installed in Olsztyn) "accumulated" 5.76 billion euros, while less than 0.2 billion was invested into three systems in Częstochowa, Elbląg, and Grudziądz which are not provincial capitals. A similar situation is observed with buses, however, the disparity there is not so huge. 138 projects in provincial capitals accumulated more than 2.5 times more money than 333 projects in other towns.

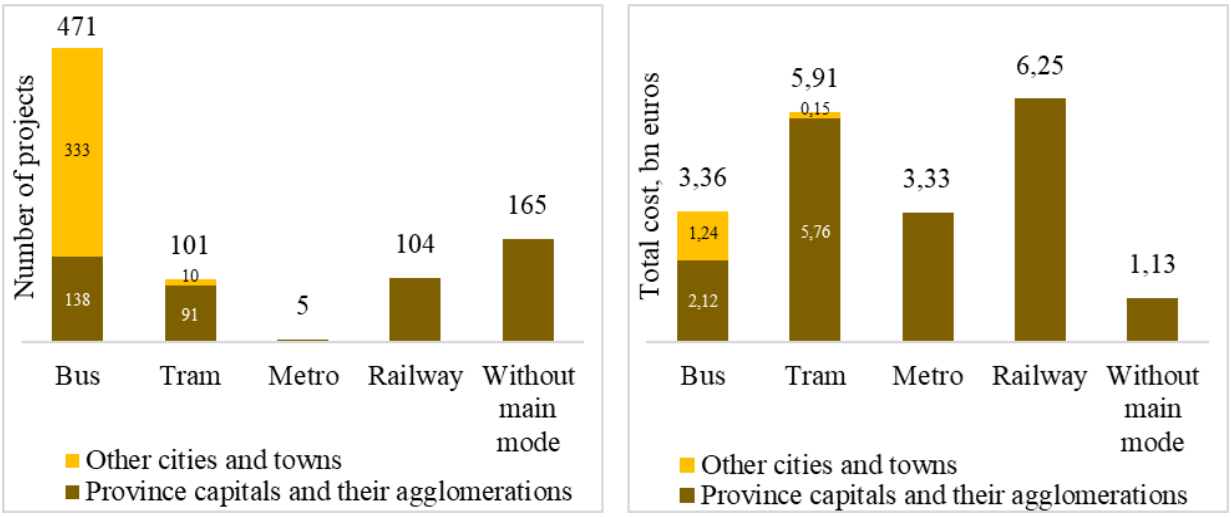

Fig. 7: Number and cost of EU-supported urban public transport projects in Poland in 2004-2020 by main transport mode

Sources: EC, 2015a; MFiPR, 2020, 2021; Mapa Dotacji UE, 2019; GUS, 2021b; ECB, 2022, own elaboration

It should be stated that conclusions about the influence of the implemented transport projects on the modal split in Polish cities could hardly be done. Modal split is the most important indicator that shows shares The reason is that comprehensive traffic studies (KBR – "kompleksowe badania ruchu"), as well as auxiliary studies in Polish cities, are carried out irregularly and without a common methodology (Goras, 2019). The recent data on modal split in voivodeship capitals, if they are available, are provided in Table 7. If possible, the last complete data on modal split before Poland's joining the EU were presented too. In the case of Łódź, the total amount of shares exceeds 100 – for 1995 it could be a result of a misprint in the data source, while in 2014 respondents were allowed to name several transport modes.

Unambiguous conclusions about either the significant growth of the role of urban public transport in Polish cities or its total inability to take over passengers from private vehicles cannot be made. The reason is also in the lack of data on modal split in the late 2010s when almost all projects of the budget period 2007-2013 had been finished yet, new projects began and the effects of the accelerated urban public transport development became evident for the observers. It could be only concluded that the potential of such an indicator as a modal split which should be used for regular monitoring of changes during the realisation of urban public transport development projects had not been sufficiently harnessed.

The most of time when programmes had been implemented the goals of sustainable development were in one or another way declared in strategic documents and legal acts. In the Act of 16 December 2010 on public transport sustainable public transport development was defined as "the process of transport de-

velopment taking into account social expectations regarding the provision of universal access to public transport services, aimed at the use of various means of transport, as well as promoting environmentally friendly means of transport equipped with modern technical solutions" (Sejm Rzeczpospolitej Polskiej, 2011). Communes with population more than 50 thousand people were obliged to work out plans of sustainable urban public transport development ("transport plans"). In the programming document "Krajowa Polityka Miejska 2023" (Engl. "National urban policy") sustainable urban mobility was named as one of the priorities in the thematic axe "transport policy in cities". Besides, the development of low-emission transport was among the priorities in the axe "Low emission and energy efficiency" (MRR, 2015b). According to the Strategy for Responsible Development for the period up to 2020 that was adopted in 2017, "solutions supporting a larger share of ecological transport in cities, and, in particular, in public transport" (MR, 2017) should be created.

Table 7: Modal split in major Polish cities

City	Year	Transport mode				
		Pedestrian	Public transport	Private vehicle	Bicycle	Other
Warsaw	1998	20.5	52.5	25.8	0.4	0.8
	2005	21.6	54.6	22.6	0.9	0.3
	2015	17.9	46.8	31.7	3.1	0.5
Cracow	1994	29.2	48.6	19.2	1.6	1.4
	2003	25.9	42.6	27.1	1.5	2.9
	2013	28.4	36.3	33.7	1.2	0.4
Łódź	1995	24.0	55.0	23.0	no data	no data
	2014	39.0	40.0	30.0	3.0	0.3
Wrocław	2006	no data	56.2	43.8	no data	no data
	2010	18.7	35.3	41.6	3.5	0.9
	2017	21.0	31.0	41.0	6.0	1.0
Poznań	2000	10.0	36.1	52.0	1.9	no data
	2013	13.0	43.0	40.0	4.0	no data
Rzeszów	2000	23.6	40.2	36.2	no data	no data
	2009	22.5	31.8	43.7	1.9	0.1
Gdańsk	1994	27.9	39.2	27.5	no data	5.4
	2016	20.8	32.1	41.2	5.9	no data
Katowice	1998	37.5	33.0	29.0	0.2	0.3
	2015	30.8	24.5	43.3	1.4	2.1
Zielona Góra	2005	19.8	47.1	33.1	no data	no data
Szczecin	2010	19.0	35.0	43.0	1.0	2.0
Białystok	2000	23.6	40.2	36.2	no data	no data
	2007	20.0	35.0	45.0	no data	no data
Olsztyn	2000	45.0	23.0	32.0	no data	no data
	2009	21.5	37.4	41.1	no data	no data

Sources: Goras, 2019; SITK, 2016; UMP, 2013; ZDiT, 2018

In 2014-2020, in comparison with the previous budget period, a bigger emphasis on sustainable urban mobility was put. As evidence of that, more than two-time growth in the number of projects in the category of activities "Infrastructure for technical maintenance" which was provided with the installation of charging stations for e-buses, as well as growth in the category of activities "Intermodal hubs, P+R, B+R" (Table 2), which should, directly and indirectly, ensure the increase of use of transport modes with less emission per passenger, could be stated.

Conclusion

At the level of the whole country, it is possible to talk about the pattern of the compliance of expenditures per voivodeship and the population size of these provinces. Nevertheless, certain distortions such as incomparability of total cost of urban public transport projects in any voivodeship with Warsaw can be captured. Furthermore, territorial disproportions in the access to funding within different programmes were not eliminated. For

example, the growth of competitiveness was among the goals of programmes "Development of Eastern Poland" and "Eastern Poland", but concerning the urban public transport, it seemed that in reality rather "non-increase" of the gap between urban public transport in Eastern Poland and other voivodeships occurred. The only significant project of installation of the new transport system was carried out in Olsztyn which received a completely new tram network. Capitals of Eastern Polish voivodeships had access to the funds from programme "Infrastructure and environment" only concerning the commuter railway transportation. In the case of other urban public modes, programmes "Development of Eastern Poland" and "Eastern Poland" became replacements but not an addition to the "Infrastructure and environment".

A much stronger disparity can be observed between major agglomerations and smaller cities and towns. This disparity was initially embedded as unequal access for these two groups of settlements to funds within different operational programmes and their sub-measures corresponding to urban public transport. This resulted in the concentration of the most expensive and complicated projects in major metropolitan areas of Poland.

Concerning this concentration, one could speak about the "two-side causal link". On the one hand, voivodeship capitals are centres of population and human capital and growth points of the Polish economy. Consequently, higher requirements for the quality of urban public transport there in comparison with towns are applied. On the other hand, geographically large areas of voivodeship capitals and their environs predispose to the larger sizes of urban public transport networks and to the usage of such transport modes as tram or commuter railway which are costly in terms of the line (re)construction and their maintenance. Simply as a result of the larger number of deteriorated parts of these networks after the period of underinvestment in transport in the 1990s, these networks required much funding for renovation and further development.

Nevertheless, beyond the borders of agglomerations of voivodeship capitals urban public transport development mostly came down to the upgrade of the bus fleet and renovation of stops. Relatively expensive activities such as the installation of new transport modes passed these areas almost by. Currently existed tram networks in two cities outside of provincial central metropolitan areas (Grudziądz and Elbląg) stay underinvested because needs for the renovation of tracks and rolling stock could not be covered within ROPs of respective voivodeships while the nationwide programme "Infrastructure and environment" remained unavailable for them. It is undeniably the main paradox of the urban public transport development in Poland in 2004-2020 within EU funding: the biggest cities such as Warsaw, Cracow, Wrocław, Gdańsk, and their environs could theoretically rely more on the internal financial resources in the advancement of mass transit. Small towns face permanent financial difficulties and only thanks to the EU support undertook transport renovation at least to some extent. Despite that, the biggest part of EU funding for urban public transport was deployed to the major centres instead of places where it was more indispensable.

However, the fact that during the programme period 2014-2020 cities and towns outside of metropolitan areas managed to approve and at least start to implement much more projects with higher total cost than in 2004-2013 cannot be questioned. This corresponds to the conclusion of Gorzelak & Smętkowski (2018) that after 2012 level of territorial disproportions in Poland at least did not grow. With regard to Poland the polar-diffusion regional development is frequently mentioned (Gorzelak & Smętkowski, 2018, Śleszyński, 2018, Herbst & Wójcik, 2013). According to MRR (2009), this way of development should combine the support of growth poles - major agglomerations in the case of Poland - with the creation of conditions for diffusion, i.e. alignment of socio-economic circumstances across the country. Despite the, in a sense, the declarative character of this definition, it can be assumed that "reinforcement" of ROPs in 2014-2020 concerning urban public transport development together with a still high concentration of projects in voivodeship capitals is consistent with this model of regional development to a certain extent.

The case of Poland shows that relatively rapid modernisation of urban public transport systems in a country with a population level higher than 30 million inhabitants can occur and cover not only bigger cities, but also small towns. The willingness of EU funds to support this development could be a "sign of hope" for the countries which aspire to become members of the EU. The existence of long-term climate target plans in the EU demonstrates that at least in the aspect of emission of carbon reduction urban public transport development will be more or less taken into account.

Based on the research results, the next recommendations could be given:

1) In the case of investments in the urban public transport development financial opportunities of cities and towns should be taken into account with more thorough differentiation. The additional assessment of the ability of the largest cities to resort to the EU funding to a lesser extent and rely on the local financial resources would be beneficial. Theoretically, it could release more financial resources for the less developed areas;

2) Greater emphasis should be put on the export of transport management practices. It could be particularly important in smaller towns and less developed areas, while the largest cities inherently faster attract the human capital and, as a result, can theoretically quicker "absorb" new practices without any external stimulation. However, the need for high-quality management of urban public transport does not depend on city size and its financial opportunities;

3) A system of methodologically unified, regular, and timely assessment of indicators that should reflect the effectiveness of urban public transport development, also in terms of sustainable mobility, should be created. Due to the high overall cost, it is impossible and unnecessary to carry out such investigations in each city and town, so panel monitoring in chosen areas that reflect certain groups of populated places could be beneficial.

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Multidimensional approach for measuring female-based urban poverty in recently urbanizing societies: Sehore City of Madhya Pradesh, India as case study

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Abstract

The present study deals with selected aspect of measuring the prevalence of female-based multidimensional poverty in upcoming township of Sehore Municipal Council (Sehore M.C.) with limited economic opportunities reflected in economic poverty as such. The female-based urban poverty is also reflected even in households which are not below poverty line (BPL) and households with higher female work participation, suggesting that not only economic factors are at play when discussing the high rates of female-based socio-economic deprivation in the study area.

The parameters selected for this research were considered to be relevant for the evaluation of female-based multidimensional poverty given the local conditions. The study is based on the methodology of multidimensional poverty index (MPI) given by UNDP (2010) in which six domains including housing poverty, economic poverty, educational poverty, health poverty, lack of time for relaxation and lack of empowerment and decision-making power, are selected to evaluate female-based MPI. In order to bring out spatial variation in concentration of female-based MPI, seventeen congested and crowded localities across four wards with varying percentage population of females and female workers were surveyed. The results show that fifteen localities (88%) scores as multidimensionally poor on female-based MPI; one locality is severely poor; and one is vulnerable to multidimensional poverty. Out of the six analysed domains, the contribution of lack of empowerment and decision-making power domain are contributing the most to the female-based MPI (nearly 24%). The study concludes with the justification for selecting the indicators in evaluating the female-based MPI in new-urbanizing society in India along with area specific suggestions to tackle with existing problem of female-based urban poverty in Sehore M.C.

Keywords: *Sehore M.C.; female-based urban poverty; Multidimensional Poverty Index; spatial mapping; new-urbanizing society*

Rezumat. Abordare multidimensională pentru măsurarea sărăciei femeilor din mediul urban în societățile recent urbanizate: orașul Sehore din Madhya Pradesh, India, ca studiu de caz

Prezentul studiu tratează un aspect al măsurării răspândirii sărăciei multidimensionale a femeilor în viitoarea localitate a Consiliului Municipal Sehore (Sehore M.C.), cu oportunități economice limitate reflectate în sărăcia economică ca atare. Sărăcia femeilor din mediul urban se reflectă chiar și în gospodăriile care nu se află sub pragul sărăciei și în gospodăriile cu o participare mai mare a femeilor la muncă, ceea ce sugerează că alți factori decât cei economici sunt în joc atunci când se discută ratele ridicate ale deprivării socio-economice a femeilor din zona de studiu.

Parametrii selectați pentru această cercetare au fost considerați relevanți pentru evaluarea sărăciei multidimensionale a femeilor, având în vedere condițiile locale. Studiul se bazează pe metodologia indicelui sărăciei multidimensionale (IPM) calculat de de UNDP (2010) în care șase domenii incluzând sărăcia locativă, sărăcia economică, sărăcia educațională, sărăcia în sănătate, lipsa timpului pentru relaxare și lipsa de împuternicire și putere de decizie, sunt selectate pentru a evalua MPI-ul femeilor. Pentru a scoate la iveală variația spațială a MPI-ului femeilor, sunt chestionate șaptesprezece localități congestionate și aglomerate din patru districte, cu un procent diferit de populație feminină și de femei lucrătoare. Rezultatele arată că cincisprezece localități (88%) au fost înregistrate ca fiind sărace din punct de vedere multidimensional pe baza MPI-ului femielor; o localitate este extrem de săracă; iar una este vulnerabilă la sărăcia multidimensională. Dintre cele șase domenii, contribuția lipsei de împuternicire și a puterii de decizie contribuie cel mai mult la MPI-ul femeilor (aproape 24%). Studiul se încheie cu justificarea selectării indicatorilor în evaluarea MPI a femeilori în societatea nou urbanizată din India, împreună cu sugestii specifice zonei pentru a aborda problema existentă a sărăciei femeilor din mediul urban în Sehore M.C.

Cuvinte-cheie: *Sehore M.C.; sărăcia femeilor din mediul urban; indicele sărăciei multidimensionale; cartografiere spațială; societate nou urbanizată*

Introduction

Although the concept of 'feminization of poverty' (Cagatay, 1998) which infers that the proportion of female is higher than that of males within the poor is often debated, it is no surprise to see women as most deprived in terms of overall wellbeing and not only in terms of prevalence of income poverty. The increasing gender bias has emerged as the major cause of female poverty and prompts to bring up the issue of women development again at the forefront, especially in the urban context.

There are various dimensions of urban poverty across which females are deprived including social empowerment, time for relaxation, lack of decision-making power, control over assets as well as income (UNIFEM, 2008). As suggested by Masika, De Haan and Baden (1997), men and women experience

poverty differently. Since the responses and experiences of poverty are dissimilar for men and women, it is important to look into the ways females experience poverty. Also, since poverty has an urban face, female poverty needs to be relooked at from the urban point of view and its geographical spread (Rustagi, 2007; Chant, 2013) in order to frame proper policies for tackling the menace of disempowerment and deprivation amongst the female population especially in case of urban areas. This becomes more pertinent in the light of United Nations Sustainable Development Goals which plan to reduce poverty in all its form everywhere by the year 2030 with the help of pro-poor and gender sensitive development strategies (UNSDGs, 2015).

The evolution of urban poverty as a multidimensional concept holds more importance for females, as more often, women are income-deprived and face gender discrimination because of existing socio-cultural disparities between men and women. As gender equality and poverty are intrinsically linked (Nieuwenhuis et.al., 2019), even in urban areas which offer a number of opportunities for promoting women empowerment, discrimination against women on the lines of gender and class are widespread (Chant, 2017) resulting in the widely acknowledged concept of 'feminization of poverty' in urban areas. The positive impact of urbanization is troubled by the burden of poverty faced by women (Banerjee and Guha, 2009; Sridhar, 2016).

It is against this background that the Multidimensional Poverty Index (MPI) given by UNDP (Alkire and Santos, 2010) becomes an excellent tool to assess the multiple deprivation aspects of poverty, narrowing down the gap disparities in socio-economic development on regional and sectoral levels. Since 2010, MPI for global comparison across countries is provided yearly by the Human Development Report based on three key dimensions regarding health, education and standard of living, comprising ten indicators. Therefore, the methodology to assess female-based multidimensional poverty is based on MPI given by UNDP (2010).

The significance of MPI for the present study lies in the fact that it belies the general tendency to give primacy to monetary status as the measurement of poverty which fails to provide a holistic picture. Thus, as per the evidence, the issue of female poverty is a multidimensional one and hence it needs to be measured from a multidimensional perspective. It is often the case that women within the households receive smaller portions of food or have less investment in their education and health as compared to their male counterpart (Paramo and Boudet, 2018). Thus, it is pertinent to study the issue of female poverty in terms of multidimensional approach.

The selected area belongs to Madhya Pradesh which in 2011 recorded 27.63% urban population (national average 31.1%) and is placed at the lowest category on the female empowerment index as given by the McKinsey Global Institute (Woetzel et.al., 2015). Under this scenario, Sehore Municipal Council (Sehore M.C.) lying within the urban economic sphere of influence of two metropolitan cities of Bhopal and Indore is showing signs of an upcoming urbanizing society despite a tradition bound society, lack of economic opportunities especially for women and lack of gender sensitive infrastructure. Sehore M.C. recording an overall urban female work participation rate of 12.8%, is showing wide variation in both female work participation rates with contrasting picture of posh localities not sending females to job market. Therefore, the issue of female poverty in Sehore M.C. is assessed through a multidimensional approach tailoring indicators relevant to the local setting (Peterman and Seymour, 2018), for an in-depth analysis of the spatial pattern of female deprivation as an example to assess the effect of socio-cultural aspects in future socio-economic development of Sehore M.C., an urbanizing city of Madhya Pradesh.

In this context, the aim of the study is to observe the prevalence of female-based multidimensional poverty in the surveyed localities of Sehore M.C. which has been achieved through the following objectives: (i) to select relevant indicators and to identify the determinants of female-based multidimensional poverty; (ii) to measure the female-based multidimensional poverty index (MPI) in terms of deprivation scores and identify spatial pattern; (iii) to test the research hypotheses framed through multiple linear regression analysis; (iv) to give problem specific and area relevant suggestions to alleviate urban female poverty in critically identified female-based multidimensional poverty areas of Sehore M.C. Consequently, the study aims to assess whether multidimensional poverty index has reflected the prevalence of urban female poverty in terms of selected indicators specific to the given socio-economic conditions of females in the study area. The study also tries to assess what role the economic indicators play in predicting the female multidimensional poverty in the study area.

Literature Review

The existing gender bias in the society has made female deprivation more blatant (CEPAL, 2004). The large gender inequalities exist not only in terms of economic indicators, but also regarding women well-being, such as survival and education, their mobility for recreation as well as for work, the double burden of paid work and unpaid care work (Klasen, 2007). Thus, gender inequality and female-based poverty

are intrinsically linked to each other (Nieuwenhuis et al., 2019).

The multidimensional poverty aspect has gained momentum through Human Development Report (UNDP, 2010). The economic parameters have remained a primary indicator of poverty, yet there are various dimensions over which deprivation is based. Deprivations affect women in particular as the existing gender inequalities in the society have posed a worrying picture for women, especially in developing countries like India.

Against this background, the concept of 'feminization of poverty', first floated by Diana Pearce (1978) needs to be taken into account. The concept has come to mean three things with the subsequent evolution: women compared to men have a higher incidence of poverty; women's poverty is more severe than men's; over time, the incidence of poverty among women is increasing compared to men (Pierce, 1978; Cagatay, 1998). The United Nations Development Fund for Women (UNIFEM, 2005), primarily responsible for women development, encourages the mainstreaming of gender issues while asserting that 'feminization of poverty' is the biggest concern women face in today's world and describes it as the burden of poverty borne by women, especially in developing countries, ascribing the cause to the lack of capacity building of women internationally. The UNDP (2005) defines 'feminization of poverty' as a condition wherein the change in poverty levels is biased against households headed by female. But with the recent widening of understanding on the subject, it has been observed that limited focus on households headed by females does not offer an authentic display of female deprivation which is wider spread and needs to be assessed irrespective of the headship (Tinker, 1990; Chant, 2003).

The UNIFEM (2005) identifies seven main causes of this problem out of which absolute poverty, society's attitudes and immobility of women independently for work are most relevant keeping under view the study area of Sehore M.C. The burden of unpaid care work, migration of women in search of employment, higher proportion of females in informal employment, lack of support from family, lack of education especially beyond secondary in urban areas, as identified by Verick (2014) and unequal treatment of women almost in all spheres, are the important drivers of female-based multidimensional poverty. Following the contention of Bradshaw (2002) that female poverty is multidimensional and multi-sectoral, there is a need to recognize the various dimensions of female poverty that particularly emerge in an urban area (Chant, 2013), making thus clear that poverty faced by women in urban areas has a multidimensional nature.

Against this background, the present study deals with the issue of female poverty based on the Multidimensional Poverty Index (MPI) given by the UNDP (2010) which is flexible to decompose and use for various groups such as males and females, rural and urban etc. It is also noted that the recognition of poverty as being multidimensional has led to a better understanding of the concept holistically (Altamirano Montoya and Teixeira 2017). The multidimensional approach and decomposition of data has further led to broadening of the concept by allowing for cross comparisons within sub-groups and regions (Alkire and Santos, 2011).

The list of indicators comprised in the methodology of MPI is area-specific, a choice based on relevant dimensions proposed by standard international and national agencies such as UNIFEM (2008), UNDP (2010), Socio-Economic Caste Census (2011), NFHS-4 (IIPS, 2016), UN-HABITAT (2017) etc. The modified indicators as proposed by Aguilar (2015) are applied in consonance with the suitability for the study area in Sehore M.C.

There have been a number of studies based on measuring multidimensional poverty amongst females over various regions including Sub-Saharan Africa (Batana, 2013); Ethiopia (Aguilar, 2015). Multidimensional poverty amongst females has also been assessed based on NFHS data in India (Dehury and Mohanty, 2017) but there is definitely a dearth of studies on female-based multidimensional poverty particularly focusing on upcoming urban areas in India or newly upcoming urban areas like Sehore M.C. The present study attempts to address the issue of multidimensional poverty amongst females from the perspective of a small upcoming urban area such as that of Sehore M.C.

The study is thus focused on finding the relevant indicators for the assessment of female-based multidimensional poverty index in Sehore M.C. Although situated near two metros of Bhopal and Indore, Sehore M.C. is suffering from lack of work opportunities for both males and females. But due to the fact that females are multiply burdened by the lack of empowerment and decision-making power, time poverty, lack of recreation and time for themselves, considering the dual responsibility of paid and unpaid care work (Lawson, 2008), which leads to health crisis amongst women, calls for attention towards the multidimensional deprivation faced by women in the upcoming Sehore M.C. in terms of urban development.

Data and Methods

The study is based on primary data collected through a self-structured questionnaire based on the selected indicators of female-based urban poverty measures. The survey was conducted during 2017 and 2018 in which 17 localities across four wards with

a varying female population and female workers are selected from Sehore M.C. The adopted indicators reflect on urban female poverty issues. There has been no change in the administrative set-up of the region since the time of survey. The socio-economic fabric of the study area also remains the same.

The questionnaire collected six-stage data at area; locality; building; house; household and female-based levels. Since the study is female-based, the female-based level of the questionnaire is the most elaborate and intensive inquiring about various aspects including work-related aspect, health and nutritional status, social status, their management skills, awareness and decision-making power amongst females. The respondents belonged to the financially weaker class with the exception of a few households living in congested localities in insalubrious conditions with a higher degree of female working population mostly belonging to low literacy and educational level.

For the purpose of building the female-based multidimensional poverty index we used the selected indicators from the data collected through the primary data and classified them into six-domains (Table 1). Although the standard Multidimensional Poverty Index (UNDP) measures deprivations across three basic dimensions of health, education and living standard, a large amount of literature on gender- and female-specific indices generation indicate that certain parameters are alo crucial and therefore need to be a part of the study, such as the time constraints as well as management practices and awareness amongst women.

Selection of indicators: The standard indicators are adopted from various international and national agencies for developing a female-based multidimensional poverty index. The indicators are divided into 6 domains including housing poverty, economic poverty, educational poverty; health poverty; lack of time for relaxation; and lack of empowerment and decision-making power. The adopted indicators particularly reflect on female-based urban poverty issues such as health poverty, time poverty (lack of time for relaxation) and lack of empowerment. The indicators are selected so that they can relate to the prevailing deprivation conditions in the Sehore M.C. area and more specifically to the surveyed area as follows:

Table 1 The list of indicators for Female-based Multidimensional Poverty Index

Indices for female-based multidimensional approach to urban poverty

1. Housing Poverty	2. Economic Poverty	3. Educational Poverty	4. Health Poverty	5. Lack of Time for Relaxation	6. Lack of Empowerment and Decision Making Power
•1. % of householdshared/rented housing •2. % of semi-pucca and kuchcha housing •3. % of households with no LPG connection •4. % of households with exclusive kitchen • 5. % of households with no toilet/bathroom within home * 6. % of BPL HH * 7. % of workers in unorganized sector	•1% of non-working females •2. % of females working in unroganzied sector •3. % of females working under compulsion	•1. % of Illiteracy Females •2. % of females not having Education till Graduation •3. % of women not having Technical/Vocational Training	•1. % of females Not haivng normal Body Mass Index (BMI) •2. % of females never Consuming Milk; Pulses/Beans; Green Vegetables; •3. % of females having no access to Health services; •4. % of females haivng no access to Anganwadi •5. % of females having no awareness about common ailments	•1. % of females spending more than 4 hours on unpaid domestic chores •2. % of females working more than average working hours for women. •3. % of women whose work is not shared by other females of the huosehold	•1. % of females having no Freedom to visit Market place alone •2. % of females having no Freedom to visit Health facility alone •3. % of females having no Control over of personal income •4. % of females having no Exposure to Media% of females with decision deficit on Major Household Purchasing Decision •5. % of females with decision deficit on Education/Expense of Children •6. % of females having no decision on Purchasing Medical treatment •7.% of females having no decision on Purchasing daily food items

Sources:

Indicators of Urban Poor Communities and their Accessibility, UN Habitat (1)

Multidimensional Poverty Index, Human Development Report, United Nations Development Programme (UNDP) (2)

Urban Indicators, Socio - Economic Caste Census, 2011(1, 2)

National Family Health Survey-4 (4, 6)

Political Component, African Gender Status Index (6)

UNMP/TFEGE (2005) (3, 5)

UNDP (2005) En Route to Equality: A Gender Review of National MDG Reports 2005 (New York: UNDP) (4, 5)

(Anganwadi- Healthcare Centres; Semi-pucca and Kuchcha houses refer to houses which are not solid and permanent. Most often they are made of mud, reed, grass, straw, thatch etc.).

Sampling frame: As the study focuses on the analyses of female-based multidimensional poverty, which is mainly influenced by the economic condition of the household, localities with varying percentage of female population and female workers have been selected randomly. Within these four selected wards, 17 congested and crowded localities (localities with high population density) are selected with both having female workers and non-workers with their basic household information affecting overall poverty of females on selected demographic and socio-economic parameters as follows:

1. Selection of wards with varying percentage of female workers and female population.
2. From the selected wards, localities which are congested and crowded are selected.
3. From the localities, households with both working women as well as households without working women are selected for the survey for the present study.

The sampling framework for the area and population under study is presented in Table 2:

Table 2 The sampling frame of the study

Selected Ward	Total Number of Households within ward	Size of Households for Survey (15% of the total households in ward)	Locality Selected within wards	Sample size of Households within Locality	% of Female Population in locality
Ward 27	427	64	Gadi Adda	20	54.44
			Chandrashekhar Marg	22	54.81
			Lohar Gali	22	52.81
Ward 31	743	110	Deewan Bagh	22	49.67
			Firdous Nagar	22	57.14
			Jamshed Nagar	22	50.00
			Peter's Compound	22	50.57
			Dulha Badshah	22	57.52
Ward 32	651	98	Jhuniabadi	20	55.79
			Banspura	20	53.61
			Sipahipura	20	51.00
			Qazipura	20	51.96
			Talayya Mohalla	18	58.88
Ward 33	527	80	Bhopali Phatak	20	58.62
			Jalali Mohalla	20	55.56
			Jamanpura	20	51.82
			Gohapura	20	59.09

Computation of Female-based Multidimensional Poverty Index: The methodology for the calculation of female MPI is based on the Multidimensional Poverty Index (MPI) given by the UNDP (Santos and Alkire, 2011). As per the methodology for the assessment of MPI, the following formulae have been used:

Weighting of dimensions and indicators

In the Female-based MPI the six dimensions are equally weighted, so that each of them receives a 1/6 weight. Thus, the indicators within each dimension are equally weighted:

$$\sum_{i=1}^{n} w_i = 1$$

$$H = \frac{q}{n}$$

Poverty cut-off point

For the Female-based MPI, a locality is identified as poor if it has a deprivation score(c_i) higher than or equal to 1/3 or 0.33, where (c_i) is given as-

$$c_i = w_1 I_1 + w_2 I_2 + \ldots + w_n I_n$$

WhereI_1=1 if the person is deprived on the indicator I_1.

For those whose deprivation score is below the poverty cut-off of 0.33, it is censored to "0" to calculate the censored deprivation score($c_i(k)$).

Computing the final MPI score

The multidimensional headcount ratio *(H)* for the deprived population is calculated as:

Here *q* is the number of females who are multidimensional poor (if censored deprivation score ≥ 0.33) and *n* is the total females.

The second component is called the intensity (or breadth) of poverty (*A*). It is the average deprivation score of the multidimensional poor females and can be expressed as:

$$A = \frac{\sum_{i=1}^{n} c_i(k)}{q}$$

Where $c_i(k)$ the censored deprivation score of the i^{th} individual and q is the number of females who are multidimensionally poor.

The final score of MPI is given as:

$$\mathbf{MPI} = \boldsymbol{H} \times \boldsymbol{A}$$

The MPI score reflects the proportion of weighted deprivations that the poor experience in a society out of all the total potential deprivations that the society could experience.

The deprivation scores $(c_i(k))$for the localities are mapped in GIS Environment to spatially depict the level of female-based multidimensional poverty in the study area.

Decomposing the MPI score by domains

For the purpose of decomposing the MPI scores by domains, censored headcount ratio (CH) is calculated as the number of persons who are MPI poor and deprived in the domain divided by the total population.

$$\textit{Censored Headcount Ratio } (\mathrm{CH_i}) = \frac{\textit{Number of MPI Poor and deprived on indicator}}{\textit{Total population}}$$

The contribution of each domain to the MPI is given by-

$$\text{Contribution of domain i to MPI} = \frac{\textit{Weight of domain i X Censored Headcount Ratio of domain i}}{\textit{MPI}} \text{ X } 100$$

Identification of the Problem in the Study Area

Sehore M.C. belongs to Malwa Plateau region which is well known for the cultivation of wheat (Fig.1). The Seevan river, a tributary of the Parbati, passes through the middle of the city thus serving as its lifeline. According to 2011 Census, Sehore M.C. is reclassified as Class I city with 108,909 inhabitants.

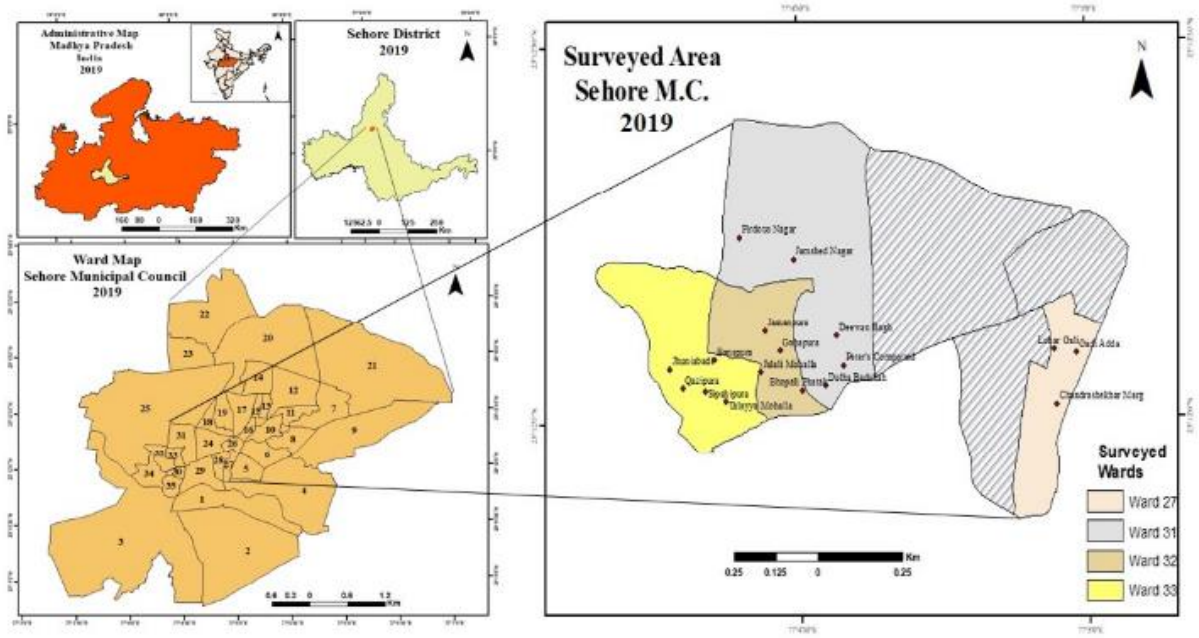

Figure 1: The location of the study area, Sehore M.C., Madhya Pradesh

The urban economy of the Sehore M.C. is mainly dependent upon agriculture and trade of agri-products. Nearly 92% of the workforce belongs to 'other work' according to Industrial Classification of workers in 2011 Census, which testifies for the predominant tertiary sector in Sehore M.C. with an annual urban growth rate of 17.94% (state, 20.30% and national 31.80%); the fact that Sehore M.C. lies in the vicinity of two metros of Bhopal and Indore offers valuable potential in terms of development.

At this note, it is important to highlight that Madhya Pradesh is one of the bottom five states on McKinsey's Femdex (the Indian Female Empowerment Index). Also, as per the country briefings of MPI, 53.71% of the country's population is MPI poor, out of which nearly two-thirds are concentrated in eight states including Madhya

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Pradesh. As per the annual report of RBI (2012), the share of population living below the poverty line (BPL) in Madhya Pradesh is 21% in urban areas (national average 13.7%), amounting to more than half of the population in Sehore M.C. according to the City Development Plan for Sehore (2011).

More than half (58%) of the population in the surveyed area belongs to BPL, of which 12% benefit from Antyodaya Anna Yojana (AAY, scheme for providing subsidized food for the Poorest of the Poor), which is evident from the fact that nearly as much as 84% of the surveyed population belongs to less than Rs 10,000 income category. Within the study area, it has been found that nearly 24% females are working whereas 76% are non-working, with a high dependency ratio of 52%. Yet, although the females are employed, they are working in low-paying petty works, mostly based out of home, which do not amount to any significant change in their lifestyles. The females are clearly working for the mere sustenance of the family and to support their non-working or meagre-earning spouses in running the family.

It has been also found that there are certain areas over the city landscape which amount to a larger proportion of female workers while in other areas their work participation is very low. Most of the area where a high female work participation was registered belongs to the city centre through which the road connecting Bhopal and Indore passes and it thus can be considered the urban-economic lifeline of the city. This is borne out of the fact that poverty carries a multidimensional character and hence it cannot only be judged in terms of economic and working profile of the surveyed population. Several other relevant dimensions are therefore required to be taken into account, such as lack of educational attainment mainly due to the weak economic status and patriarchal mentality, decision-making power which is more evident in a male-dominated upcoming urban society such as Sehore M.C., time constraint due to duality of work which brings about a 'zero-sum game' for women (UN, 1990). All these factors play a significant role in reshaping the health status of women which is again an interplay of the above stated factors.

Thus, keeping under view the small urban size of Sehore M.C. (more than 100,000 population) and the ongoing urban development in the city, along with wide spatial variations in terms of female work participation has prompted to take up the issue of assessment of female-based urban poverty in the city. Therefore, an insight into the determinants and dynamics of female-based urban poverty of Sehore M.C. in spatial perspectives is required to define strategies to close down the gender gap and to promote overall socio-economic development in Sehore M.C. as well as other urbanizing smaller cities in the state of Madhya Pradesh, so that the method of assessment of urban female poverty is applied to similar smaller urban towns in the ambit of larger cities.

Results and Discussion

Female-based Multidimensional Poverty Index in Sehore Municipal Council: Survey Results

The female-based multidimensional poverty index is based on the methodology of Multidimensional Poverty Index given by UNDP (2010). The weighting of indicators for the female-based multidimensional index is done as per the methodology given by the UNDP while each domain has equal weight. The results of the female-based multidimensional poverty index are as follows:

The headcount ratio (H), which is the basic measure of poverty, has recorded a value of 0.96 amongst the surveyed female population, thereby indicating that poverty is wide-spread, covering 96% of the respondents. Concerning the intensity of poverty in terms of weighted indicators selected for the study, 40% of the females are lying within deprivation indices of various dimensions of multidimensional poverty. The final score for measuring MPI is showing a value of 0.39 indicating a severity of female-based MPI amongst 39% of the surveyed female population (Fig. 2).

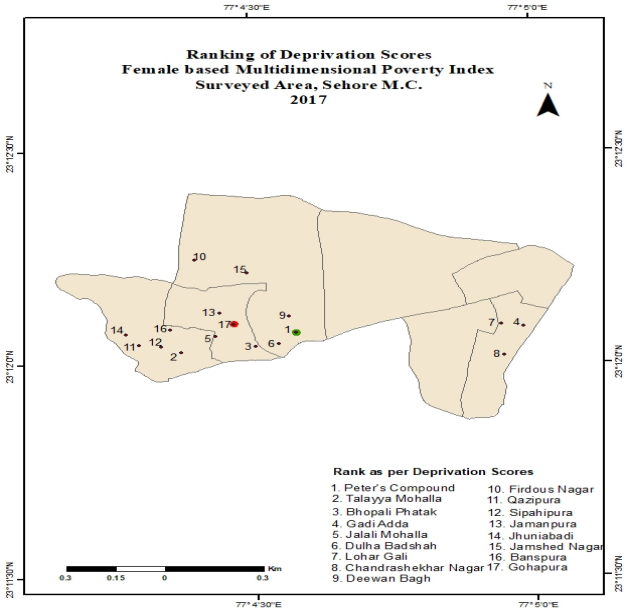

Figure 2: Ranking of Deprivation Scores, Female-based Multidimensional Poverty Index, Surveyed Area, Sehore M.C., 2017

Regarding the deprivation scores, it was observed that localities recording a higher incidence, intensity

and severity of poverty are concentrated towards the western part of the surveyed area (14 localities where both highest and lowest deprivation occur in ward 33 and 31, respectively). The lowest score on female-based MPI is found to be 32% in Peter's Compound thus placing it in a vulnerable category (c(k)<33%), while Gohapura locality scores 51% on the deprivation score, thus belonging to severely poor category (c(k)>50%) of MPI. Thus, 16 localities (96%) of the total localities are suffering from multidimensional poverty. The average score of deprivation of the multidimensional poor (the intensity of the poverty) is 40%. The overall multidimensional score of the female population is 0.39, meaning that the localities are deprived in nearly 39% of the total potential deprivations they experience overall.

Spatial pattern of Female-based Multidimensional Poverty Index for surveyed areas

As per the location map (Fig. 3), certain concentration of deprivation scores dominating localities can be observed. Therefore, spatial interpolation technique through GIS was applied to find out the patterns of concentration or dispersion of female-based urban poverty in terms of deprivation scores as observed below.

Overall, two regions of high and low performing localities are clearly observable as per the interpolation results. The better performing localities lying below the mean deprivation score (<0.40) cover mostly market areas (ward 27), old core areas (ward 31 and 33) in the east of Sehore M.C., while the western portion of the study area lying above the mean deprivation score (> 0.40) is an indicative of poor performing localities covering mostly the city fringe margins merging into the rural hinterland.

The core of the low scoring (better performing) localities is at Peter's Compound, located in the southern portion of ward 31, stretching into ward 32 and 33 in the west and ward 27 towards the east. The core of the high (poor) performing localities lies in Gohapura in ward 33 stretching further west in ward 32.

The worst performing locality (very poor category, 0.51-0.47) of Gohapura (17th, ward 33) is scoring the highest on the female MPI (0.51). The time poverty is significantly prevalent in the locality due to large family size and long work hours involving High Density Polyethylene (HDPE) bag stitching work. The absence of women with education beyond secondary level and lack of exposure to media and awareness, all compound for the worst performance of the locality on female-based MPI.

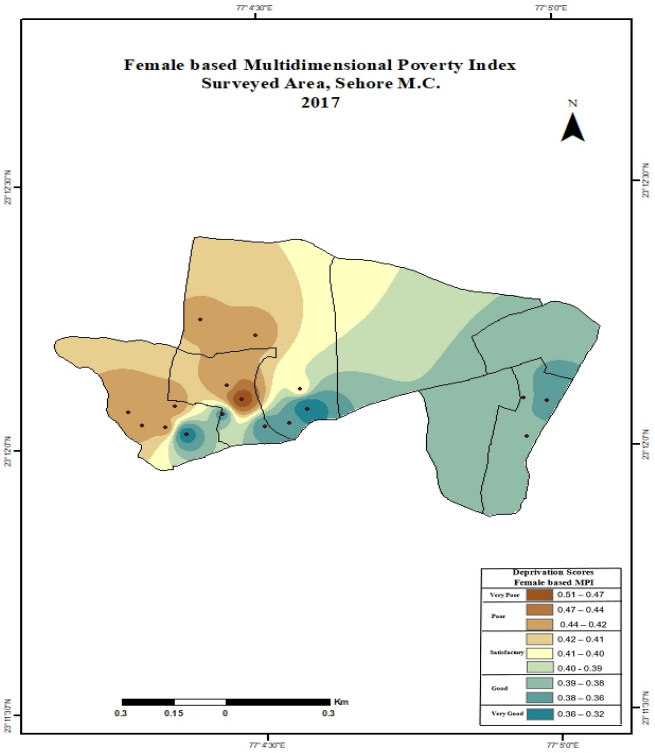

Figure 3: Spatial pattern of Female-based Multidimensional Poverty Index, Sehore M.C., 2017

The poor performing localities (0.47 to 0.42) cover nearly 41% wards of the study area and the behavioural as well as social norms of the households located in the region are being influenced by the proximity to the rural hinterland. Jhuniabadi (16th), Banspura (15th) and Sipahipura (14th) in ward 32 are some of the most economically deprived areas of Sehore M.C., the male domination being visible in nearly all parameters. Though the females are performing fairly on economic domain, due to lack of exposure to media, awareness level and decision-making power, the social status of females is weak within these localities. Jamanpura (12th, ward 33) and Qazipura (11th, ward 32) perform poorly on economic domain due to involvement in low-paying HDPE work while many women suffer from time poverty due to its tedious nature. Firdous Nagar (10th, ward 31) houses most of the neglected migrant population while the high score (poor) on health poverty domain of the female-based MPI is reflected in the lack of access of Anganwadi workers (primary healthcare workers) owing to the interior location of the houses and their nearness to filthy sites.

Satisfactory conditions (0.42-0.39) prevail over Deewan Bagh (9th) in ward 31 which is considered as a posh locality both educationally and economically. Here, women are faring better, but because of the male dominance and the cultural norms which are biased against female work, women mostly work from home or near home, due to restricted mobility.

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The better performing localities (good category, 0.39-0.36) are covering mostly the southern part of ward 33 and 31 and are stretching into the eastern most part of the study area, i.e. ward 27. The vicinity to the market area of Chandrashekhar Nagar (8th), Lohar Gali (7th) and Gadi Adda (4th) of ward 27 provides better access to work opportunities to females as well as social empowerment due to higher degree of awareness and accessibility of educational institutes including Government Colleges. For others, it is the accessibility to basic services and better economic conditions of people such as Dulha Badshah (6th, ward 31), Jalali Mohalla (5th) and Bhopali Phatak (3rd) in ward 33, that females are performing better on female-based MPI.

The best performing localities (very good category, 0.36 to 0.32) are Peter's Compound (1st, ward 31) and Talayya Mohalla (2nd, ward 32) according to the interpolated map results. Peter's Compound is ranking the lowest on the female-based multidimensional poverty index houses, due to better-off economic and educated strata of the society with a better accessibility to both educational and health institutes as well as active Anganwadi workers. Talayya Mohalla is performing better (low poverty) on the female-based multidimensional urban poverty index due to better access to the basic services such as Anganwadis (primary health care centres) and government schools and also due to working females in organized sector.

Decomposition of Female-based Multidimensional Poverty scores by domains

The decomposition of female-based multidimensional poverty scores by domains helps in grasping the meaning of female-based multidimensional poverty in a better and more nuanced way. Through the decomposition, the contribution of each domain has been assessed (Table 3).

Table 3: Domain-wise censored headcount ratio, weight and contribution

Domain	Censored Headcount Ratio (CH)	Weight (w)	Contribution (%)
Housing Poverty	0.53	0.167	23
Health Poverty (15-49 years females)	0.20	0.167	9
Educational Poverty (all females above 7 years)	0.52	0.167	22
Economic Poverty (18-65 years females)	0.29	0.167	13
Lack of Time for Relaxation (all females above 15 years)	0.19	0.167	8
Lack of Women Empowerment and Decision-Making (all females above 18 years)	0.56	0.167	24

The percentage contribution is the highest for lack of women empowerment and decision-making power (24% contribution to female-based MPI) mainly due to the highest censored headcount ratio in the concerned domain supported by the lack of female participation in government (2.8%), closely followed by decision-making deficit amongst females in terms of medical treatment (2.6%). The lack of households having access to smartphones and laptops with internet is causing a high deprivation in terms of housing domain (23% contribution to female MPI).

Educational poverty is significantly prevalent in the study area (22% contribution to female-based MPI), which is evident from the highest deprivation on indicator involving lack of females in technical/vocational education (7%).

Identification of Determinants of Female-based MPI in Sehore M.C.

In order to determine whether the three selected economic indicators (share of BPL households, share of workers in unorganized sector and share of female non-workers) could predict the female MPI, a multiple linear regression analysis was performed.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.669[a]	.447	.319	.036148

a: Predictors: % BPL HH, % of workers in unorganized sector, % of female non-workers

b. Dependent Variable: Female-based MPI

The result shows that there is strong relationship between the three selected independent variables and female MPI and (R=0.669), thus the model is a good predictor of the female MPI.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.014	3	.005	3.504	.047[b]
	Residual	.017	13	.001		
	Total	.031	16			

b. Dependent Variable: Female-based MPI

a: Predictors: (Constant), % BPL HH, % of workers in unorganized sector, % of female non-workers

The result indicated that the model explained 44.7% of the variance (R^2=0.447) in the female MPI and that the model is significant predictor of female MPI, F (3,13)=3.504, p<0.05.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.05519	.124		.445	.664
	% of BPL Households	-.00036	.001	-.140	-.541	.59781
	% of workers in unorganized sector	.00375	.002	.622	2.375	.03365
	% of female non-workers	.00052	.000	.266	1.232	.23973

a. Dependent Variable: Female-based MPI

Thus, the predictors of female MPI is showing the importance of the share of workers in unorganized sectors (0.0037, p<0.05), though the percentage of BPL households is negatively and insignificantly related to female-based MPI (-0.00036, p>0.05); the share of female non-workers was found to be insignificantly related to the female-based MPI (p>0.05). Thus, the choice of mixed population, BPL as well as non-BPL households for the purpose of study is justified. Also, since the share of female non-workers is not significantly contributing as a predictor of female-based MPI, hence, the choice of multidimensional indicators other than only economic indicators is justified for the present prevailing conditions in the context of the study area.

Conclusion

With a recently urbanizing society having people with patriarchal mindset, the city landscape of Sehore M.C. presents an abysmal picture regarding female workforce participation as female work is mainly discouraged in the tradition bound society living in core of the city or even in parts of posh colonies coming up along Bhopal-Indore State Highway. Since the assessment of female-based urban poverty in Sehore M.C. could not be measured only in monetary terms, therefore, area-specific and socio-cultural dimension of the society is harnessed to assess multidimensional female-based urban poverty in non-monetary terms also, in the upcoming township of Sehore M.C., Madhya Pradesh (India), such as in MPI by UNDP and Women Empowerment Index (WEI) of IFPRI.

The present study has discussed the issue of the multidimensional poverty amongst females and its spatial extent in a recently urbanizing small city of Sehore M.C. which has not been discussed in the previous studies. A widespread female-based multidimensional poverty was observed in the study area and it was validated by a MPI score of 39% covering 96% of the surveyed localities. Except for one locality, the entire surveyed area is experiencing female-based multidimensional poverty, while one locality is facing severe multidimensional poverty in the city area. The western periphery of the study area is experiencing a higher female MPI mainly due

to the lack to basic services and relatively larger distance from the city centre. The study area is suffering from the lack of women empowerment and decision-power deficit amongst women since the contribution of the lack of women empowerment domain is the highest in the female MPI. The lack of women empowerment and decision-power deficit is prevalent in the study area and forms the primary contributor to the female-based multidimensional poverty in the study area.

The choice of some economic indicators has been validated through multiple linear regression analysis from which it is inferred that BPL population is not significantly contributing to the model with female-based MPI as the outcome. Hence, the choice of non-BPL households is justified; the female non-working population is also not significantly contributing, thus pointing towards the fact that female MPI is prevalent in areas with even female work participation, which justifies the choice of non-economic indicators for the study of female MPI.

In order to bring out the women from multidimensional poverty, the schemes that are being run by the government such as training programmes of Centre for Entrepreneurship Development of Madhya Pradesh (CEDMAP), need to be upgraded and applied robustly in the problem areas such as the western portion of the study area covering ward 32 and 33 which is poorer in terms of urban basic services availability as compared to the eastern and southern margin of the study area.

The study is mainly confined to localities with certain socio-economic characteristics like market area, old core city area, and newly urbanizing area and city fringes only in which females work participation is found to be considerable. Therefore, the results of the study highlight the socio-economic conditions of an upcoming township with high female to male gender-ratio but low female work participation rates, a phenomenon common to many developing countries undergoing rapid urbanization.

Therefore, the approach to measure MPI for female to urban poverty is based on both standard as well as area specific indicators derived from survey data of Sehore M.C. (Madhya Pradesh, India) the given selection of indicators can form a basis for addressing similar socio-economic conditions of small towns within the urban sphere of influence of metropolitan cities to assess the multidimensional aspect of female-based urban poverty through MPI in India. This will help in identifying aspects of urban poverty amongst females and promote their economic contribution in an urbanizing society for better economic planning and gender sensitive policy issues.

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An ecological study of vulnerability to COVID-19 in Serbia - using Hotspot Analysis for Evidence-Based Population Health Policy

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Abstract

The risk of severe illness or death from COVID-19 is associated with specific demographic characteristics or composition of the population within geographic areas, and the spatial relationship between these areas. The aim of this paper is to identify areas with a higher concentration of population vulnerable to COVID-19, relying on the concept of spatial dependence. Hence, we focus on the share of vulnerable populations using several salient proxy measures at municipality level data for Serbia. The degree of vulnerability at the municipality level was determined by hotspot analysis, specifically the Getis-Ord Gi* statistics. The results indicate heterogeneity in the spatial patterning and typologies of clusters across Serbia. This spatial heterogeneity reveals potentially differing degrees of risk across municipalities. The results can inform decision-makers in the fight against COVID-19 by helping to identify those areas with vulnerable populations that if exposed may stress the local health care system.

Keywords: *COVID-19, population vulnerability, health care system, hotspot analysis, Serbia*

Rezumat. Studiul ecologic al vulnerabilității la COVID-19 in Serbia – utilizarea analizei hot-spot pentru elaborarea unei politici de sănătate ținând cont de caracteristicile populației

Riscul unei boli severe sau de deces datorat COVID-19 este asociat cu anumite caracteristici și structuri demografice ale populației din anumite zone geografice, precum și relațiile spațiale dintre acestea. Lucrarea își propune să identifice zonele cu o concentrare mai mare a populației vulnerabile la Covid-19, plecând de la conceptul de dependență spațială. Prin urmare, ne-am axat pe ponderea populației vulnerabile utilizând câteva măsuri proxy frapante la nivel de municipalitate în Serbia. Gradul de vulnerabilitate la nivelul municipalităților a fost stabilit cu ajutorul analizei hotspot, mai exact statistica Getis-Ord Gi*. Rezultatele obținute indică eterogenitatea distribuției spațiale și a tipologiei de clustere pe teritoriul Serbiei. Această eterogenitate indică un risc potențial diferențiat în cadrul municipalităților. Rezultatele obținute pot fi utile factorilor de decizie în lupta împotriva Covid-19 întrucât pot conduce la identificarea acelor zone cu populații vulnerabile, care dacă sunt expuse pot cauza o presiune considerabilă asupra sistemului sanitar local.

Cuvinte-cheie: *Covid-10, vulnerabilitatea populației, sistemul medical, analiză hot-spot, Serbia*

Introduction

In December 2019, in Wuhan City (Hubei Province, China), a number of patients were diagnosed with pneumonia, but as reported by the WHO China Country Office, the cause was at that time unknown. On January 9, 2020, the China Center for Disease Control and Prevention reported "a new type of coronavirus as the causative agent of this outbreak, coronavirus disease 2019 or COVID-19" (European Centre for Disease Control and Prevention [ECDC], 2020, p. 5). One of the characteristics of the COVID-19 virus is its rapid spread between individuals and associated with population mobility a rapid transmission between geographic areas.

The first case of COVID-19 was officially recorded in Serbia on March 6, 2020, and nine days later, a state of emergency was declared (March 15). But, according to the newest research, the first documented death associated with COVID-19 in Serbia was on February 5, 2020 (Bogdanović et al., 2021). From mid-March, multiple public health measures and guidelines were introduced to help "flatten the curve" and "reduce the pressure on the health care system". The public health measures included lockdowns, physical distancing policies, closing of catering facilities, kindergartens, schools, and universities, reducing the volume of public transport, and promoting working from home. This period is also characterized by the return of a large number of seasonal workers from abroad who performed temporary or seasonal work (Lukić, Predojević-Despić, Janeska, & Lozanoska, 2021). The spatial dimension of COVID-19 has become an

integral part of health policy management and governmental decision-making, including both place-specific and countrywide mandatory and recommended travel restrictions and social distancing protocols. Šantić and Antić (2020) argued the initial lockdown (from March 15 to May 6, 2020) was not in line with regional and local inequalities in the number of COVID-19 infections and deaths in Serbia.

More formal use of spatial analytical methods can enable researchers and policymakers to study the spatial dynamics of COVID-19, specifically leveraging concepts of and measures for testing both spatial dependency and spatial clustering (Lessler, Salje, Grabowski, & Cummings, 2016). In theory, sub-national ecological data can help identify some of the spatial associations with COVID-19 rates and thus potential implications for local communities, municipalities, and regions, and the health sector that serves these areas (Rosenkrantz, Schuurman, Bell, & Amram, 2020).

The demographic dimension of COVID-19 refers specifically to the population composition, and that different groups of people have a higher risk of contracting and dying from the consequences of COVID-19. In this context, the elderly and groups of people suffering from specific diseases are at the highest risk of disease and death. Researchers can leverage this demographic reality to identify vulnerable populations and vulnerable places, thereby providing important health management guidelines for reducing the burden and/or slowing down the spread of COVID-19.

The importance of paying attention to research and solving health problems is also indicated by the fact that one of the Millennium Development Goals (MDG 6) is dedicated to the suppression of vicious diseases, as well as one of the Sustainable Development Goals (SDG 3). The goal to be achieved by 2030 is to ensure healthy lives and promote well-being for all at all ages. According to the United Nations (2021), the COVID-19 set back the progress of all 17 goals. It is considered that this pandemic could reverse decades of health improvements. Also, this highlighted the additional weaknesses of each national healthcare system, as well as the need to work further on the SDG17, which implies a stronger global partnership for SDG. This paper is also a contribution to accelerate return to the path of sustainable development by 2030.

The paper concentrates on the identification of municipalities in Serbia that are vulnerable to COVID-19, taking into account age and mortality data on respiratory disease, cancer, and deaths associated with the circulatory system. Fundamental to the approach used here is the concept of spatial dependence and the use of hotspot analysis. The main contribution of this paper is to demonstrate the application of hotspot analysis in the identification of vulnerable areas or regions within Serbia that can inform the allocation of resources to combat COVID-19.

Background and literature review

The impacts of place-specific demographic characteristics on population health have attracted the attention of researchers for many years. About 2400 years ago, Hippocrates, in his treatise Airs, Waters, and Places, stated that the place in which people live shapes their constitutions and habits (as cited in Krieger, 2003). Centuries later, the link between space and the health of the population was revealed in maps (e.g., John Snow Cholera map in 1854) and spatial statistical analysis (Auchincloss, Gebreab, Mair, & Diez Roux, 2012; Cromley & McLafferty, 2011; Kamel Boulos, 2004; Lawson, 2013). The development of geospatial health databases and easier access to spatial analytical tools has enabled the detection of the spatial patterns of infectious diseases, their determinants, and planning for their control or amelioration (Kamel Boulos & Geraghty, 2020; Lović Obradović, Krivošejev, & Yamashkin, 2020).

Vulnerable groups of the population are more susceptible to contracting COVID-19. In order to minimize mortality rates, it is necessary to identify where such groups reside, ensure adequate testing, and treat them (e.g., provision of vaccines or ensuring the supply of oxygen therapy and respirators is adequate) without delay (Amram, Amiri, Lutz, Rajan, & Monsivais, 2020; Chen et al., 2020; ECDC, 2020; Popescu, 2020). Here, the protective measures will be targeted at those requiring increased protection, while fewer restrictions will be directed at the general population (Van Bunnik Bram et al., 2021).

Patients with COVID-19 have different demographic characteristics. In countries, regions, and municipalities, where the share of the elderly population is high, and there is a tendency for higher COVID-19 mortality rates (Liu, Chen, Lin, & Han, 2020). Many early studies have shown that the age structure of the population can be an indicator of the spread and intensity of the pandemic (Dowd et al., 2020). Specifically, older persons infected with COVID-19 had the highest mortality rate (Chen et al., 2020), and studies suggest that the 65 plus and especially 80 plus age groups are at the highest risk from the virus (Naqvi, 2020). Onder, Rezza, and Brusaferro (2020) noted that COVID-19 is more lethal in older patients, and they are a particularly high-risk group, in part because a large number live in long-term care facilities where conditions for the rapid spread of COVID-19 are more favorable (Gardner, States, & Bagley, 2020).

COVID-19 is a respiratory and systemic illness, and research has shown that patients with obstructive pulmonary disease are five times more likely to have severe symptoms due to infection, and they must take special precautions regarding protection against the virus and thus reduce contact with people who are infected (Lippi & Michael Henry, 2020). Furthermore, in case of infection with COVID-19, they approximately have two times higher risk for all-cause mortality (Lee, Son, Han, Park, & Jung, 2021). Oh and Song (2021) outlined the importance of prevention and targeted strategies due to their vulnerability.

Patients suffering from various types of tumors are also vulnerable groups of the population. According to the latest research, patients with cancer have impaired immunity, which makes them more susceptible to infection (Sidaway, 2020). Patients who are receiving systemic anticancer treatments have an increased risk of mortality from COVID-19 and stand as a particularly risky subgroup of cancer patients (Lee, Hu, Chen, Huang, & Hsueh, 2020). The underlying malignancy or anticancer therapy affects the impairment of immunity. It is estimated that these patients are twice as likely to contract COVID-19 compared to a healthy population (Al-Shamsi et al., 2020). As such, scientists proposed specific treatment strategies for patients with cancer during this COVID-19 crisis including, the postponement of adjuvant chemotherapy or elective surgery for stable cancer, and the provision of a special type of protection for patients with cancer or cancer survivors. For patients with cancer infected with SARS-CoV-2, enhanced monitoring and treatment are recommended, especially in older patients or those with other comorbidities (Liang et al., 2020). Targeting cancer patients come to the fore in conditions of a limited supply of vaccines when this population group should have priority (Ribas et al., 2021)

Another category of the population that is vulnerable to COVID-19 is the population with cardiovascular diseases. In addition, other patients with underlying cardiovascular diseases (CVDs) might have an increased risk of death (Huang et al., 2020), and as such these patients require a special kind of treatment in case of infection COVID-19 (Zheng, Mha, & Zhang, 2020). Research by authors from Italy and Spain has confirmed dangerous links between COVID-19 and cardiovascular disease, so they suggest several measures to reduce the risk of infection, as well as the mortality of these patients. Some of them are social distancing, self-isolation, healthy lifestyle habits, regular self-monitoring, etc. (Barison et al., 2020)

The number of COVID-19 cases and deaths varies across space as indicators of social vulnerability related to COVID-19 (Amram et al., 2020; De Souza, Machado, & Do Carmo, 2020; Karaye & Horney, 2020; Lawal & Arokoyu, 2020; Macharia, Joseph, & Okiro, 2020; Snyder & Parks, 2020). The importance of identifying the distribution of vulnerable populations related to COVID-19 is driven by the needs of the local health care systems because this is the front-line in the fight to reduce COVID-19 mortality. As seen in Lombardy, Italy, and most recently across India (April–May, 2021), pressure on the health care system can have catastrophic consequences (Armocida, Formenti, Ussai, Palestra, & Missoni, 2020). Indeed, systemic social inequalities highlight the problems related to health care provision during COVID-19 (Dorsett, 2020). Many COVID-19 data dashboards now report not just on cases and deaths but also hospital capacity. In Serbia, the country of interest in this study, the level of health care system preparedness is "medium to high," having approximately 31 physicians, 61 nurses and midwives, and 57 hospital beds for every 10,000 people (The United Nations Development Programme, 2020).

Methodology

Data

Following the principles of ecological study (Morgenstern, 1995), this study focuses on the groups of the population within the spatial units—municipalities. A total of 168 municipalities in the Republic of Serbia (see Fig. 1) were analysed, not including the population of Kosovo and Metohija, the territory under United Nations Security Council Resolution, No. 1244/99.

The municipality is the lowest territorial level for which the measures used in this study are available (Statistical Office of the Republic of Serbia, 2021). We focus on four variables of interest all calibrated for each municipality: the share of the population aged 65 and over, the share of deaths from respiratory diseases, the share of cancer deaths, and the share of deaths from diseases of the circulatory system. All data refer to 2020. The share of the municipalities' population that is older than 65 was chosen as many of the strictest restrictions under the state of emergency identified this group as being of high risk, and subsequently, most complications, hospitalizations, and deaths occurred among this group. Data on the number of infected are obtained from the Open Data Portal (Institute of Public Health of Serbia "Dr Milan Jovanović Batut", 2020a, 2020b).

Analytical strategy

The approach in this paper is to use hotspot analysis to identify statistically significant hotspots and coldspots of municipalities containing specific vulnerable groups. We use a Local Indicators of Spatial Association, known as the Getis-Ord Gi* statistics (Getis & Ord, 1992), implemented within

ArcGIS Pro 2.5 (Esri, 2020). The advantages of Gi* statistics over global indicators of spatial association (Moran I) are higher sensitivity, enabling users to explore the concentration pattern, and identifying and mapping hotspot and coldspot areas within a study area (Gu, Liu, & Shen, 2019). The formula for the Getis-Ord Gi* is:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (1)$$

where: x_j is the value of the municipality j, $w_{i,j}$ is the assigned weight between municipalities i and j, and n is the total of municipalities (Getis & Ord, 1996).

The output of the hotspot analysis tool is *z*-score and *p*-value for each feature or municipality (Prasannakuma, Vijith, Charutha, & Geetha, 2011). The results of the analysis indicate the formation of statistically significant hotspots when the value of a municipality with a high *z*-score value is surrounded by other municipalities with a high *z*-score. The feature is marked as a coldspot when the value of the municipality is statistically significantly lower than the study area (low *p*-value and high *z*-score). We can use a confidence level of 90%, 95%, and 99% conditioned by *z*-score and *p*-value. Non-significant features (municipalities) do not belong to either a hotspot or coldspot and on the maps that follow are left blank.

Fig. 1: The municipalities in Serbia

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Results

By the end of 2021, 1,297,147 cases and 12,688 deaths had been recorded in Serbia. The number of new cases and deaths has varied over time (March, 2020–December, 2021); see Figure 2. The maximum number of new cases (203,380) occurred in October, 2021 and deaths (1,747) in November, 2021.

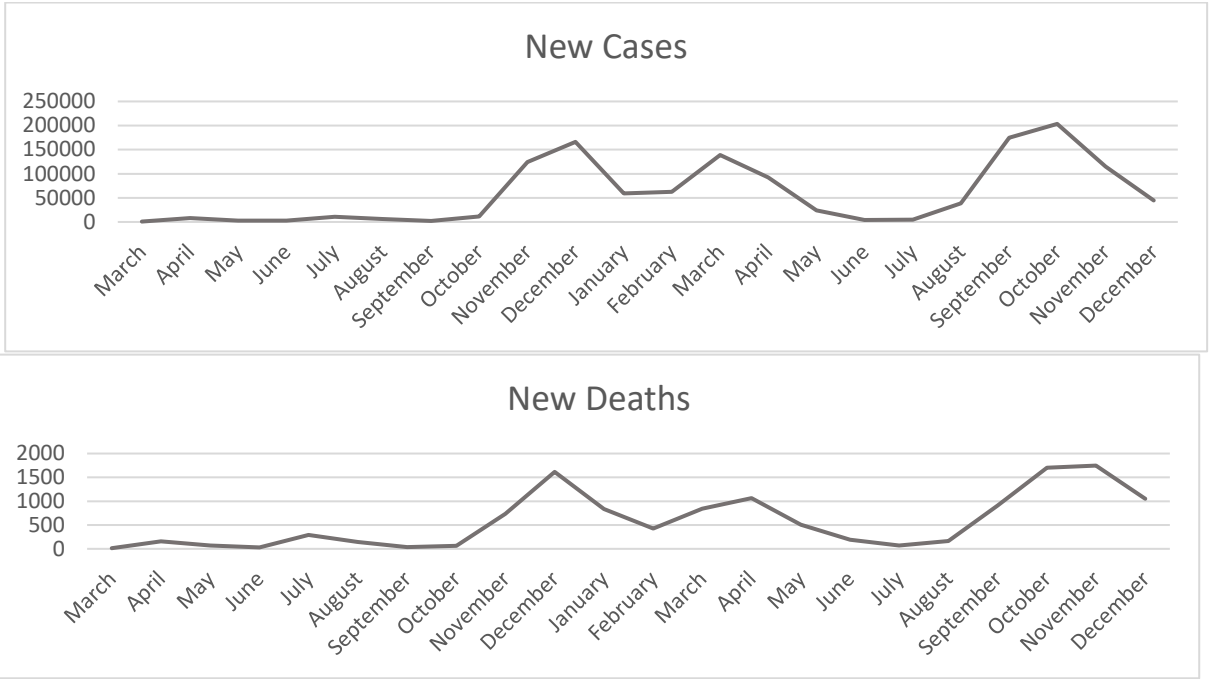


Fig. 2: New COVID-19 cases (top) and new COVID-19 deaths (bottom) by month, March 2020 through December 2021 in Serbia (World Health Organization, 2022)

The share of the population aged 65 and over in a municipality

Figure 3a shows the hotspot analysis of the share of the population aged 65 and over by municipality. The map indicates one strong cluster. A cluster of 38 municipalities is concentrated in the central, eastern, and southern parts of Serbia. In the municipalities in this region, the share of people over 65 is higher than the national average. The northern, southeastern, and southwestern cluster (a total of 41 municipalities), including the Belgrade region, is a coldspot. The maps reveal the stark regional differences in the percent of the population over 65 across the country.

The number of respiratory diseases deaths per 1,000 inhabitants of a municipality

The results of the hotspot analysis for the number of deaths from respiratory diseases (Fig. 3b) indicates a different patterning to the distribution of the percent of the population over 65, with the hotspots found in the central and western parts of Serbia, and one isolated cluster of coldspots in the southeast. More specifically, hotspot analysis identifies a cluster of 19 municipalities with a higher number of deaths from respiratory diseases than average and 21 municipalities with a lower number of deaths from respiratory diseases than average.

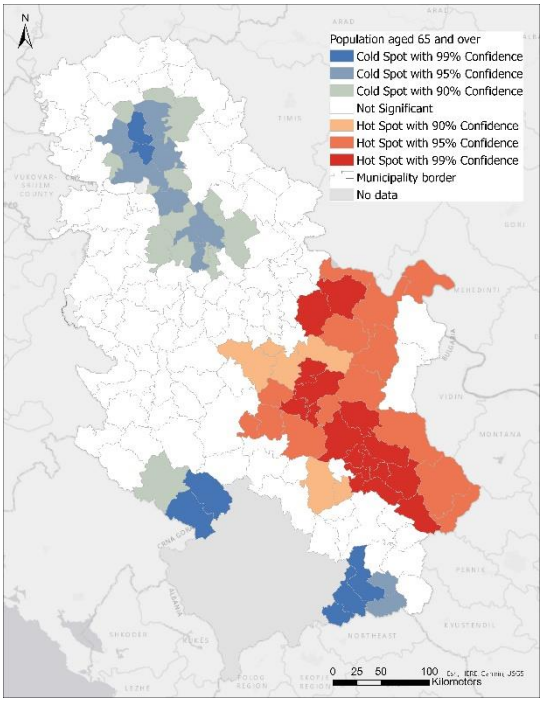
The number of deaths from diseases of the circulatory system per 1,000 inhabitants of a municipality

Figure 3c reveals the concentration of geographic hotspots and coldspots for the number of deaths due to diseases of the circulatory system. In total, 28municipalities for a coldspot in parts of northwestern and central Serbia, occupying a significant part of the Belgrade region. There is an isolated coldspot in the southwest (the municipalities of Tutin and Novi Pazar). The analysis also reveals one strong cluster of high values of deaths from diseases of the circulatory system in the east of the country. Also, two isolated clusters can be noticed (the municipality of Pirot in the southeast and Vrnjačka Banja)

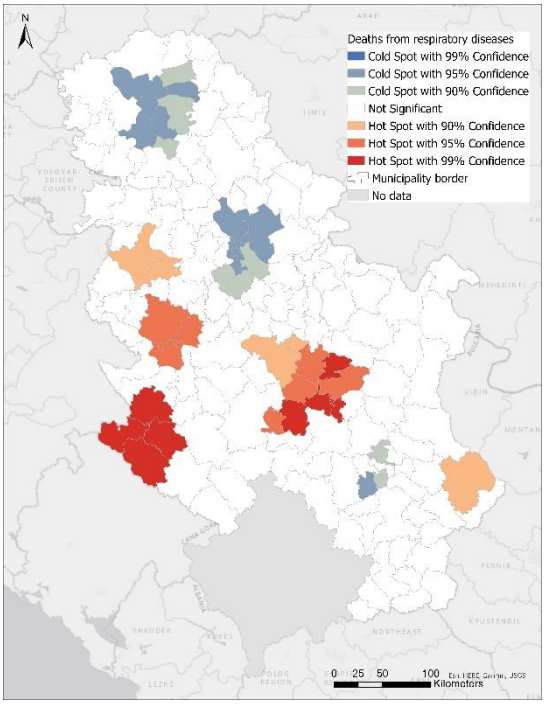
The number of cancer deaths per 1,000 inhabitants of a municipality

The number of deaths from cancer diseases is highest and cluster in the northern and northwestern parts of Vojvodina(Fig. 3d). A few coldspot clusters

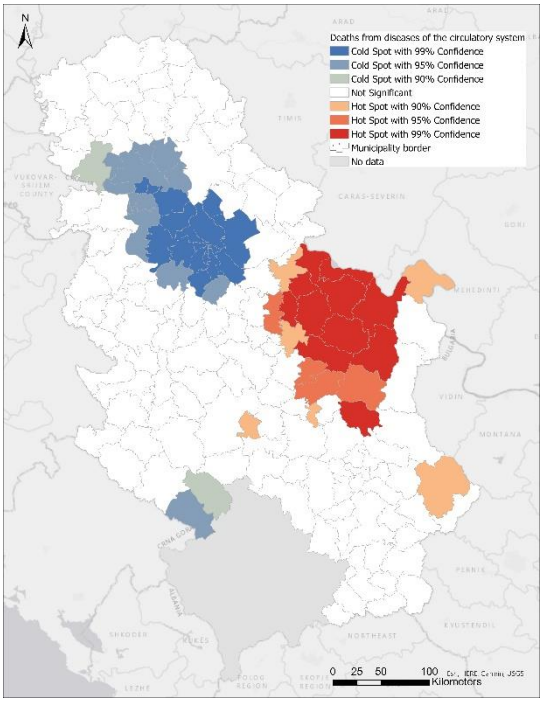
are identified. The first is located in south Serbia, the second is in the southwestern part of the country. Two smaller clusters may be observed in western and eastern part of a country.



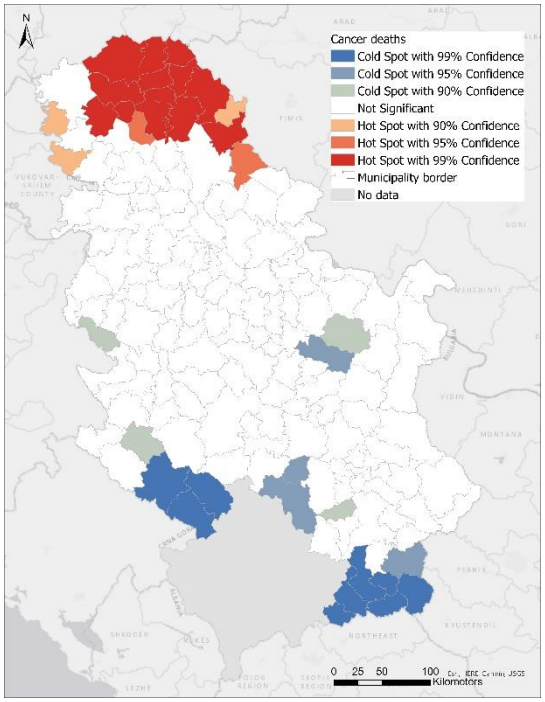
3a



3b



3c



3d

Fig. 3: The hotspot analysis of the studied indicators-the share of the population aged 65 and over in a municipality (3a), the number of deaths from respiratory diseases per 1,000 (3b), the number of deaths from diseases of the circulatory system per 1,000 (3c), and the number of cancer deaths (3d) per 1,000 inhabitants in Serbia, 2020

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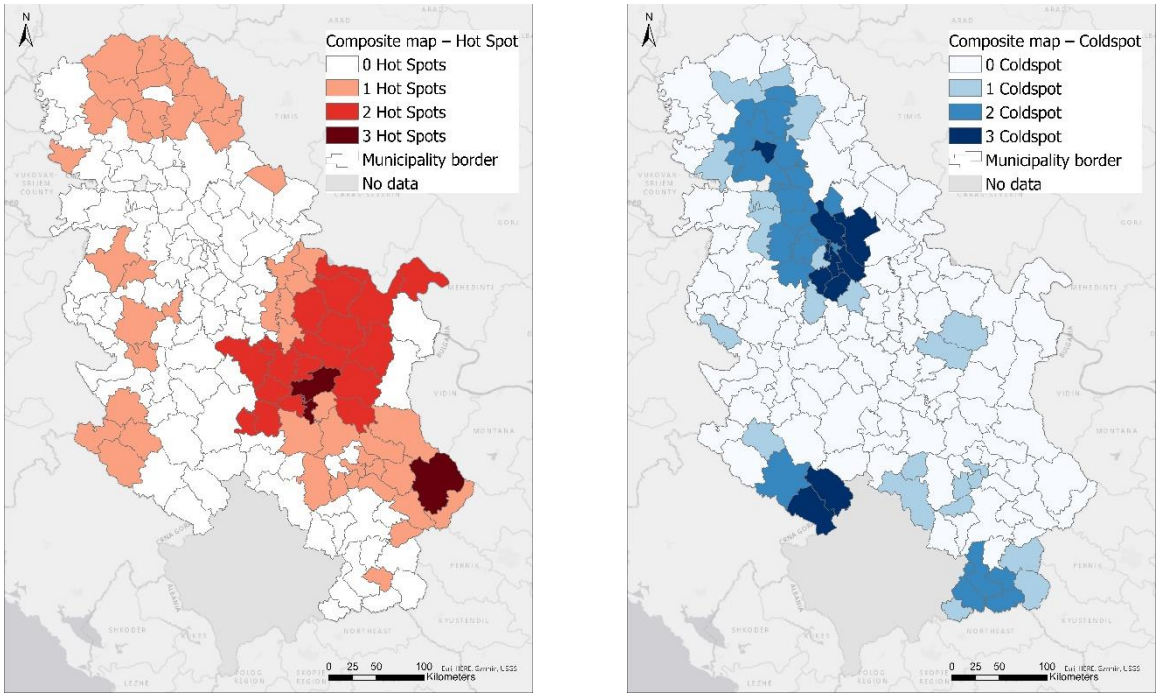
Composite maps of vulnerability to COVID-19

We can use the individual indicator coldspot and hotspot maps to examine the similarity in patterns across Serbia. That is, we can identify municipalities with the most (and least) vulnerable populations, those at risk of contracting or dying from COVID-19 (see Fig. 4). The composite map of vulnerability is derived from the count of hotspots and coldspots across the four indicators reported in each municipality.

Based on this approach, the most vulnerable parts of Serbia are municipalities in the central, eastern, and southeastern parts of the country: Ćićevac, Paraćin, and Pirot. For three of the four indicators, these areas were all health-related hotspots; the indicator that was not significant in these municipalities was cancer deaths per 1,000 inhabitants. This area belongs to the broader area of the region of Southern and Eastern Serbia (NUTS 2). According to Babović, Lović Obradović, and Prigunova (2016), this part of the country has a large elderly population and socioeconomically is one of the poorest regions of the country. Furthermore, unemployment is high, and the share of the population with high and the highest education is the lowest (Matović & Lović Obradović, 2021). Migrations were intensified after World War II, with the largest share of the population from working-age and fertile contingent and one that is characterized by decades of underdevelopment (Miletić, 2022) and known for recent high levels of depopulation (Milošević, Milivojević, & Ćalić, 2010, 2011; Panić, Drobnjaković, Stanojević, Kokotović Kanazir, & Doljak, 2022). The second cluster of municipalities can be seen in the north and northeast of Serbia, the area characterized by a depopulation process caused by long-term negative trends in natural and mechanical population movements (Lukić, 2022). A third hotspot cluster includes three smaller clusters in western Serbia. The current demographic, economic, and health status of areas identified as vulnerable to COVID-19 may deteriorate if targeted measures to protect the population from the current pandemic are not taken. Otherwise, these areas will become even more vulnerable in the future, which will further lead to their devastation.



A B

Fig. 4: Municipalities by the total number of hotspots (a) and (b) coldspots

According to the total number of coldspots, one strong cluster is identified. Includes all municipalities of Belgrade region (most of them are marked as a coldspot according to three parameters). Indeed, the area between Belgrade and Novi Sad, to the north, is a regional coldspot. Belgrade and Novi Sad are the two largest centers of population concentration with a clear example of demographic implosions in certain micro-areas (Lović Obradović, 2019). This axis follows one part of the international Danube corridor. Belgrade and Novi Sad are connected by the international highway (E75), so the daily migrations

of the population are pronounced. The concentration of the population (especially working-age and fertile contingent) is mostly a result of the continuous immigration process that began after the end of World War II. There is evidence of a second coldspot in southwestern Serbia, formed by four municipalities: Tutin, Novi Pazar (three indicators were identified as coldspots), Sjenica (two indicators), and Nova Varoš (one indicator). The main demographic characteristic of these municipalities is the higher share of the younger population, compared to the other parts of Serbia (Penjišević, 2012; Penjišević & Nikolić, 2011), which tend to experience milder COVID-19 symptoms and fewer deaths. The third and fourth clusters of coldspots are found in the southern part of Serbia.

Considering that the number of infected at the municipal level is available only for the early period from March 6 to June 9, 2020, the highest number of infected per 1,000 inhabitants of a municipality that are marked as a hotspot has Kragujevac (16.45) Aleksinac (11.79), and Jagodina (8.22) in Central Serbia, Pančevo (11.87) in the Vojvodina region, followed by municipalities of Vlasotince (11.07) and Leskovac (7.42) in southeastern Serbia. As for the distribution of the number of infected per 1,000 inhabitants in coldspot areas, the highest number is in Novi Sad (21.17) and Belgrade municipalities—Novi Beograd (15.6), Grocka (15.34), and Voždovac (14.35) (Institute of Public Health of Serbia "Dr Milan Jovanović Batut", 2020a, 2020b). It can be seen that municipalities that are vulnerable based on analysed health and demographic metrics had high values of the number of patients in relation to the number of inhabitants in the early phase of the COVID-19 pandemic. This means that at the beginning of the pandemic outbreak, it was necessary to adopt special protection measures and relocate human resources, i.e., health workers in these areas.

Municipalities with the highest degree of vulnerability to COVID-19 have from 14.4 to 32.5 doctors per 10,000 inhabitants in 2020 (Statistical Office of the Republic of Serbia, 2021). The smallest number of doctors per 10,000 inhabitants has Bač (7) and Vladimirci (9.9) in northern Serbia, followed by Rakovica in the region of Belgrade (9.4) and Krupanj in southwestern Serbia (9.4). However, the largest number is in the municipality of Savski venac (908.3) in the region of Belgrade, then in municipalities in southeastern central Serbia: Medijana (146.8), Ćuprija (79), and Kragujevac (48). These higher values are due to the specialized health care facilities found in these municipalities. Of the four mentioned, only the municipality of the Ćuprija is marked as vulnerable based on analysed parameters. A significantly higher number of doctors per thousand inhabitants of the municipality compared to other municipalities, gives this municipality leverage in the fight against COVID-19.

During the COVID-19 pandemic, patients with severe symptoms were transported from the municipalities to which they territorially belong to nearby regional health care centers that have better medical equipment and a larger number of health workers and specialists. The regional health care center for southern and eastern Serbia is district Niš, and for northern major nearby cities Sombor, Subotica, Kikinda, Zrenjanin, or Novi Sad. Patients from the western part of Serbia were transported to Kragujevac (central Serbia). Due to the lack of hospital capacity, two completely new hospitals, specialized only for COVID-19 patients, were built—one in Batajnica (Belgrade), which started operating in early December, 2020. The second COVID-19 hospital was built in Kruševac (southeastern Serbia) and received its first patients in the second half of December, 2020. This hospital is a gravitational center to the population from the southern, eastern, western, and central parts of the country. The construction of the third COVID-19 hospital in Novi Sad began in April, 2021. Thus, new specialized hospital capacities will be able to cope with a larger population of infected COVID-19.

Conclusion

From public health perspective, it is important to identify municipalities with high shares of the population that is likely vulnerable to COVID-19. Further, identifying spatial clusters of municipalities can serve as a basis for local, regional, and national strategies. The increased share of vulnerable groups within municipalities, or clusters of municipalities, also creates increased pressure on the health care systems.

After identifying clusters of vulnerable municipalities (based on the number of deaths from respiratory, circulatory, and cancer deaths and the share of the population aged 65 and over), the highest distribution of COVID-19 cases, and the lowest number of doctors per 10,000 inhabitants (as one segment of provision of health care infrastructure), two municipalities that need targeted population health care policy have been highlighted – Paraćin and Pančevo. Also, municipalities that are marked as a hotspot according to one or two parameters, require a special strategy to combat the spread of the pandemic.

This study contributes to the needs of the Crisis Response team and other decision-makers and seeks to improve preparedness to fight the pandemic in the most vulnerable areas. Determining the spatial clusters of the vulnerable population makes it possible to define measures in advance and thus protect the

population that is more likely to become ill or die from COVID-19. Spatial analysis, more precisely Getis-Ord Gi* statistics, has proven to be a powerful tool in identifying spatial dependence among municipalities vulnerable to COVID-19. Namely, the Government of the Republic of Serbia, on the recommendations of the crisis headquarters, defined specific measures, but only after a period of a sharp increase in the number of the infected.

Limitations and further research

A methodological limitation of this study is the lack of data on the number of confirmed cases, hospitalizations, and deaths from COVID-19 at the municipal level. Aggregating data in the spatial extent and the shape of a municipality can hide local patterns of vulnerabilities at a lower territorial level, so the modifiable areal unit problem can be one more limitation (Openshaw, 1983). The latest available data are for June 9, 2020, and as a result, we can only access the state-level data, which are updated daily (containing the number of new cases daily, as well as the cumulative number of cases and deaths). An open data portal with relevant data on COVID-19 at the lower territorial levels updated daily would enable a more sophisticated approach to a vulnerability problem.

The method used in the paper can be applied at all administrative-territorial levels for which data are available, and future research will focus on the including of as many parameters that may indicate vulnerable groups as possible, so as gender differences and other socioeconomic dimensions of chosen indicators. The use of spatial analysis, in this case, hotspot analysis, has shown that geospatial information can help to fight COVID-19 to reduce the number of infections, hospitalizations, and death.

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Author contribution

Suzana Lović Obradović – Conceptualization, Formal Analysis, Writing - Original Draft

Stefana Matović – Data Curation, Review & Editing

Hamidreza Rabiei-Dastjerdi – Writing - Review & Editing

Stephen A. Matthews – Writing - Review & Editing, Supervision

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Trust in local media and information they share during the Covid-19 pandemic: Belgrade example

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Abstract

The analysis of the relevant literature, especially earlier empirical research of serious pandemics (not including the forces of nature and the processes they create), refers to the assumption that man is (directly or indirectly) guilty of them. Given that the media transmits information related to the intensity of the spread of the pandemic, the death rate of the sick, etc., a survey of citizens' trust in the local media and the information they convey was conducted in order to find out how much the media contribute to the intensity of the spread of the negative effects of the Covid 19 pandemic. Four assumptions were defined as questions to which respondents' answers were requested: *frequency of information through different types of media; assessment of the extent to which different types of media offer the possibility of objective information; the existence of free, independent and impartial media in Serbia, and finding the truth in the media*. The research is of a quantitative type, conducted on a sample of 600 respondents in the city of Belgrade. For the collection and processing of data used the desk method, using interviews and via electronic questionnaires, in which the questions in the first part related to the socio-demographic variables of the respondents, while in the second part the group of dependent variables was operationalized through the statements, which were evaluated on a Likert scale. More sub-questions are offered within the four main questions. Descriptive statistical analysis (percentages, arithmetic mean), T-test, One-factor analysis of variance, Standard deviation, Multiple regression analysis and Pearson's correlation coefficient were used for data analysis. The level of statistical significance was set at $p<0.05$, and all obtained data were processed in the SPSS program, version 23.

Keywords: *information and media, Covid-19 pandemic, state*

Rezumat. Încrederea în mass-media locală și în informațiile pe care le împărtășesc în timpul pandemiei de Covid-19: exemplul Belgradului

Analiza literaturii interne și străine, în special cercetările empirice anterioare referitoare la pandemii (fără a include forțele naturii și procesele pe care le creează), indică ipoteza că oamenii sunt (direct sau indirect) vinovați pentru ele. Având în vedere că mass-media transmite informații legate de intensitatea răspândirii pandemiei, rata mortalității bolnavilor etc., a fost realizat un sondaj privind încrederea cetățenilor în mass-media locală și informațiile pe care le transmit pentru a afla cât de mult contribuie mass-media la intensitatea răspândirii efectelor negative ale pandemiei de Covid 19. Au fost definite patru ipoteze ca întrebări la care au fost solicitate răspunsuri ale respondenților: frecvența informației prin diferite tipuri de media; evaluarea măsurii în care diferitele tipuri de mass-media oferă posibilitatea informării obiective; existența unei mass-media libere, independente și imparțiale în Serbia și găsirea adevărului în mass-media. Cercetarea este de tip cantitativ, realizată pe un eșantion de 600 de respondenți din orașul Belgrad folosind metoda biroului, interviuri și prin chestionare electronice, în care întrebările din prima parte au vizat variabilele socio-demografice ale respondenților, în timp ce în partea a doua grupul de variabile dependente a fost operaționalizat prin enunțuri, care au fost evaluate pe o scară Likert. Au fost oferite mai multe subîntrebări în cadrul celor patru întrebări principale. Analiza statistică descriptivă (procente, medie aritmetică), testul T, analiza variației cu un singur factor, abaterea standard, analiza regresiei multiple și coeficientul de corelație Pearson au fost utilizate pentru analiza datelor. Nivelul de semnificație statistică a fost stabilit la $p<0,05$, iar toate datele obținute au fost procesate în programul SPSS, versiunea 23.

Cuvinte-cheie: *informație și mass-media, pandemie de Covid-19, stat*

Introduction

Since the outburst of the coronavirus, the following burning issues: occurrence of the virus (where, how and when), spread of the virus (manner and speed), prevention and treatment of the coronavirus, and especially knowledge about the death toll, have been conditioned by the media and information they share (https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200121-sitrep-1-2019-ncov.pdf?sfvrsn=20a99c10_4). Some religious leaders consider the epidemic to be God's message to the people (Tervanotko, 2020).

In addition to all the doubts and fears caused by the Covid-19 pandemic (Batool et. al, 2020), special attention has been paid to the incompetence of developed countries. The mass media is the main source of information about the virus (Anwar et.al, 2020; Zhao et.al, 2020). Hundreds of thousands of people in the United States are dying from the coronavirus! What is the problem (Besser, 2021)? Is it possible that the United States cannot produce an adequate vaccine? Is it possible that the most powerful force in the world does not have an

adequate health care system (Vinelli et al., 2020)? Is it about the culmination of the liberal/neoliberal model of organizing society and the state (Dusanic, 2021)? Is the Keynesian approach to solving economic problems unavoidable (Alan and Mark, 2010)? Interventions of governments of developed countries in crises are inevitable (Draskovic, 2021). Part of the answer to the previous questions may be found in the "theory of long cycles of capitalist economic systems" by N. Kondratyev - whether the time has come to change the economic cycle (Papageorgiou & Tsoulfidis, 2006).

In retrospect, the globalization process, generated by neoliberal principles, has undoubtedly contributed to an increasing flow of goods and services at the planetary level, and faster movement of financial, especially corporate capital (Podra et. al, 2021) but also a number of social, economic and social problems (Vujović & Reljic, 2016) thanks to the media to a great extent (Pérez-Gaxiola & Amelsvoort, 2020). By researching and analyzing worldwide political and economic trends in-both developed and underdeveloped countries and economies, the conclusion may be drawn that all crises and major social problems in the world are related to the economy (Vujović and Vukosavljević, 2013). It would be an epochal endeavor to define the guidelines of economic development that could serve as a model for overcoming the economic problems of society, with the indispensable role of the media and information.

Accelerated development of techniques and technologies under the control of large corporations with the help of media houses (Vujović and Miletić, 2016; Nemethy, 2021), with Covid-19 raises the question of further control of new technological breakthroughs. Does anyone control Covid-19 (https://www.epi-win.com/)? "The Covid-19 pandemic will likely leave us with an economy in which larger companies play an expanded role, representing a higher share of both employment and revenue" (Orszag, 2020). Is Covid-19 a planned action for settling undiscovered China and the United States? Is Covid-19 an accidental mistake of the curious (Kesikli & Gökalp, 2021; Wang et. al, 2015)? All these questions demand an urgent answer. It should be emphasized here that the urgency of the response is under the scrutiny of media houses as much as under the scrutiny of the economy and the fact that the population is dying.

Research methodology

The research was done using the desk method, direct interview and using questionnaire tests in the city of Belgrade in the period of May and June 2021. Field research, as well as data collection, processing and analysis, were done by the authors. Respondents were selected using a random sample method from among employees in the public and private sector, to whom the questionnaires were prepared electronically via available email addresses, but part of the questionnaire was also conducted by direct interview with randomly selected respondents on the street filling out the questionnaire. The questionnaire is structured in the form of four basic questions with sub-questions within each of them: 1) frequency of information through different types of media (electronic editions of newspapers and magazines, information through TV, WEB portals, printed editions of newspapers and magazines and other places on the Internet); 2) assessment of the extent to which different types of media offer the possibility of objective information (here the possibilities of objective information through each of the mentioned six media were assessed - from "not at all" to "completely"); 3) the existence of free, independent and impartial media in Serbia (five options are offered here - "no", "not at all", "not sure", "yes", "yes of course") and 4) finding the truth in to the media (here, of the fourteen options for answers, four were selected - see the dependent variable under "d").

A total of 600 respondents of different ages and from different institutions were included, and on the basis of the processed tests, 432 tests or answers were accepted for further processing, of which 267 respondents were male and 165 female. A large number of tests (186) were not accepted due to not meeting the criteria of the answers themselves, not understanding the questions.

The level of education of the respondents was divided into categories: secondary education (46.5%), college (11.1%), university (31.3%), master's or doctorate (11.1%), with no respondents in the sample only primary school education or have not acquired full primary school education.

According to age, respondents were divided into the following categories: up to 29 years (22.9%), from 30 to 39 (21.5%), from 40 to 49 (34.0%) and over 50 years (19.4%), while 2.1% of respondents did not provide information about age.

Employment status by income shows that 72.9% of respondents an income, while 27.1% do not earn any income.

Work experience was expressed through the following categories: up to 10 years of service (31.9%), between 11 and 20 years (34.0%), between 21 and 30 years (21.0%) and over 30 years of service (11.8%). 6.3% of respondents did not have this information.

Personal income was expressed through four categories: lack of personal income (18.1%), up to EUR 500 per month (45.8%), from EUR 501 to EUR 1,000 per month (28.5%) and over EUR 1,000 per month (7.6%).

Household income was divided into the following five categories: lack of familiarity with household income (8.3%), up to € 500 per month income (18.1%), € 501 to € 1,000 (41.7%), € 1001 to € 1,500 (18.8%) and over 1500 euros per month (13.2%).

The number of household members is expressed in five categories: independent living (8.3%), two-member household (15.3%), three-member household (29.9%), four-member household (31.9%) and households with five or more members (14.6%).

When it comes to the number of household members who earn income, respondents are divided into four categories: households in which none of the members earn income (2.1%), households in which only one person earns income (20.8%), households in which two members generate income (51.4%) and households in which three or more members earn income (25.7%).

Research results

The following four variables are defined as dependent:

a) frequency of information through different types of media;

b) assessment of the extent to which different types of media offer the possibility of objective information;

c) the existence of free, independent and impartial media in Serbia, and

d) finding the truth in the media.

a) Frequency of information through different types of media

Respondents on a five-point Likert - type scale (very rare - very common) assessed how often they were informed through each of these six media. The results showed that the respondents estimate that they are most often informed through electronic editions of newspapers and magazines, where the arithmetic mean for the estimates of this type of media is 3.45, and the standard deviation is 1.33. Also, information on TV was frequent, with an arithmetic mean of 3.28 and a standard deviation of 1.23. The arithmetic mean of the estimates for the frequency of information via the WEB portal is 3.09 with a standard deviation of 1.30, while the arithmetic mean for other places on the Internet is 2.99 with an arithmetic mean of 1.33. Finally, the arithmetic mean of the estimates for printed editions of newspapers and magazines is 2.97 with an arithmetic mean of 1.37, while for radio the arithmetic mean is 2.84 with a standard deviation of 1.33. These results indicate that respondents are most often informed through electronic editions of newspapers and magazines and through TV, while they are least often informed through radio.

b) Assessment of the extent to which different types of media offer the possibility of objective information

Respondents assessed the possibility of objective information through each of the six media on a five-point Likert-type scale (not at all - completely). The results show that respondents have the most confidence in the objectivity of information that can be found on "other places on the Internet" (M=2.98, SD= 0.90), followed by information from the WEB portal (M=2.95, SD=0.90). The arithmetic mean for assessing the objectivity of electronic editions of newspapers and magazines is 2.86 (SD=0.90), for radio it is 2.69 (SD=0.87), while for TV it is 2.67 (SD=0.99). The lowest assessment of objectivity is for printed editions of newspapers and magazines (M=2.63, SD=0.91). From these results, it can be concluded that the respondents trust "other places on the Internet" and WEB portals the most, while they trust the printed editions of newspapers and magazines the least. However, it can be noticed that overall there is no great confidence in the objectivity of information from the media.

c) Existence of free, independent and impartial media in Serbia

By circling one of the five offered options, the respondents answered the question of whether they think that there are free, independent and impartial media in Serbia. The option "no, not at all" was chosen by 28.5% of respondents, while the option "no" was chosen by 41.0% of respondents. The "I'm not sure" option was chosen by 18.8% of respondents. On the other hand, the option "yes" was chosen by 7.6% of respondents, while the option "yes of course" was chosen by only 1.4% of respondents. These results indicate that a very small number of respondents believe that there are free, independent and impartial media in Serbia.

d) Finding the truth in the media

Respondents assessed the extent to which they agreed with fourteen claims about coming to the truth in the media. For each of the claims, they assessed the extent to which they agreed with it on a five - point Likert-type scale (I do not agree at all - I agree completely). The results were processed by analysis of the main components with Varimax rotation. This analysis singled out four factors that together explain 63.67% of the variance. The first factor is called "concealing the truth" and explains 29.84% of the variance. This factor is saturated with claims that the media serve to cover up the truth, as well as that even those who create information for the media do not know the truth. The second factor explains 16.01% of the variance and is called "alternative sources of truth". This factor refers to claims that the truth can only be revealed by NGOs or foreign media. The third factor is called "spiritual truth" and explains 10.59% of the variance. This factor refers to claims that the

truth can be provided by the Church or prophecies. The last factor explains 7.24% of the variance and is called "multi-media tracking". This factor refers to the claims that the truth can be reached by following more media, comparing information, critical thinking, as well as avoiding bad taste and lack of culture in the media. *This structure of the results shows that a very large part of the variance of attitudes about the truth in the media can be explained by four factors. Also, the results show that the respondents cultivate distrust towards the information coming from the media, as well as that they tend to turn to other sources of information that are separate from the media*.

Crossing of dependent and independent variables

Frequency of information through different types of media depending on demographic variables.

One-factor analysis of variance examined the differences in the frequency of information through different types of media depending on the number of household members. This analysis showed that significant differences exist when it comes to radio, $F(4, 421)=4.03$, $p<.01$ and other places on the Internet, $F(4, 418)=2.46$, $p<.05$. Also, it has been shown that with the increase in the number of household members, the frequency of information via radio increases, while the frequency of information via other places on the Internet decreases. This result suggests that there are significant differences in the frequency of informing respondents via radio and other places on the Internet depending on the number of household members in which they live.

Also, a one-factor analysis of variance examined the differences in the frequency of information through different types of media depending on the number of household members with income. Significant differences were found in printed editions of newspapers and magazines, $F(3, 428)=4.09$, $p<.01$, electronic editions of newspapers and magazines, $F(3, 425)=7.09$, $p<.01$ and in TV, $F(3, 428)= 6.70$, $p<.01$. In addition, it has been shown that with the increase in the number of household members who earn income, the frequency of information through printed and electronic editions of newspapers and magazines increases, while the frequency of information through TV decreases. The obtained results show that the frequency with which respondents are informed through printed and electronic editions of newspapers and magazines and through TV differs significantly depending on the number of members who earn income in their household.

One-factor analysis of variance examined the differences in the frequency of information through different types of media depending on the personal income of the respondents. It has been shown that statistically significant differences exist when it comes to the frequency of information through printed editions of newspapers and magazines, $F(3,428)=3.32$, $p<.05$, electronic editions of newspapers and magazines, $F(3,425)=5.58$, $p<.01$, radio, $F(3, 422)= 2.95$, $p<.05$ and WEB portals, $F(3, 419)=4.63$, $p<.01$. This analysis showed that with the increase of personal income of the respondents, the frequency of information through printed and electronic editions of newspapers and magazines and through WEB portals increases, while the frequency of information through radio decreases. The obtained results speak in favor of the fact that the frequency of informing respondents through printed and electronic editions of newspapers and magazines, as well as through radio and WEB portals differs depending on the amount of their personal income.

The T-test for independent measurements examined the differences in the frequency of information through different types of media depending on gender. Significant differences were obtained for the frequency of information through printed editions of newspapers and magazines, $t(430)= -2.87$, $p<.01$, through the WEB portal, $t(421)= -3.12$, $p<.01$ and through other places on the Internet, $t(421)= -2.58$, $p<.05$. It has also been shown that women use all three sources of information more often than men. These results show that men and women differ in the frequency with which they are informed through printed publications of newspapers and magazines, WEB portals and other places on the Internet.

One-factor analysis of variance compared the differences in the frequency of information through different types of media depending on household income. This analysis showed that there are significant differences in the frequency of information through printed publications of newspapers and magazines, $F(4, 427)=2.99$, $p<.05$, radio, $F(4, 421)=2.52$, $p<.05$ and WEB portals , $F(4, 418)=2.62$, $p<.05$. In addition, this analysis showed that with the increase in household income, the frequency of information through printed publications of newspapers and magazines and through WEB portals increases, while the frequency of information through radio decreases. The obtained results show that the respondents are informed with different frequencies through printed editions of newspapers and magazines, radio and WEB portals, depending on the income of the household in which they live.

T-tests for independent measurements compared the differences in the frequency of information through different types of media, depending on whether the respondents earn income or not. Statistically significant differences existed in printed editions of newspapers and magazines, $t (430) = 3.99$, $p <.01$, electronic editions of newspapers and magazines, $t (427) = 3.83$, $p <.01$ and in TV, $t (430)$

= 2.07, p <.05. It has been shown that people who earn income use printed and electronic editions of newspapers and magazines, as well as TV, more often as a source of information than people who do not earn income. This structure of the results shows that, depending on whether the respondents earn income, they differ in the frequency of obtaining information through printed and electronic editions of newspapers and magazines, as well as through TV.

One-factor analysis of variance compared the differences in the frequency of information through different types of media depending on the length of service (of total work experience at work) of the respondents. Statistically significant differences were not found only when it comes to the frequency of information via radio, while for all other types of media significant differences were found depending on the length of service. It has been shown that with the increase in length of service, the frequency of information through printed editions of newspapers and magazines and on TV increases, while the frequency of information through electronic editions of newspapers and magazines, WEB portals and other places on the Internet decreases. Thus the results show that depending on the length of service of the respondents, the degree of frequency in which they are informed through all media except radio differs.

One-factor analysis of variance compared the differences in the frequency of information through different types of media depending on the acquired education of the respondents. Statistically significant differences were found in the frequency of information through printed editions of newspapers and magazines, F(3, 428)=5.21, p<.01, electronic editions of newspapers and magazines, F(3, 425)=3.79, p<.05 and over WEB portal, F(3, 419)=6.58, p<.01. Also, the results showed that with the increase in the professional qualifications of the respondents, the frequency of information through printed and electronic editions of newspapers and magazines, as well as through the WEB portal, increased. The obtained results show that the respondents differ significantly in the frequency of information through printed and electronic editions of newspapers and magazines, as well as through the WEB portal, depending on their education.

Finally, a one-factor analysis of variance compared the differences in the frequency of information through different media depending on the age of the respondents. Statistically significant differences were obtained for all types of media except for electronic editions of newspapers and magazines. Also, it has been shown that with the increasing age of respondents, the frequency of information through printed newspapers and magazines and TV increases, while the frequency of information through radio, WEB portals and other places on the Internet decreases. These results show that, depending on their age, the respondents differ in the frequency of information through all media except electronic editions of newspapers and magazines.

Attitude about the possibility of objective information through different types of media depending on demographic variables

One-factor analysis of variance examined differences in attitudes towards the possibility of objective information through different types of media depending on the number of household members. This analysis showed that significant differences exist when it comes to WEB portals, F(4, 421)=2.62, p<.05 and other places on the Internet, F(4, 418)=2.61, p<.05. Also, this analysis showed that with the increase in the number of household members, there is a decline in agreement with the statement that it is possible to be objectively informed through WEB portals and other places on the Internet. The obtained results show that the level of trust in WEB portals and other places on the Internet differs significantly depending on the number of household members.

One-factor analysis of variance examined differences in attitudes towards the possibility of objective information through different types of media depending on the number of household members with income. Significant differences were found in printed editions of newspapers and magazines, F(3, 428)=3.56, p<.05, TV, F(3, 428)=3.90, p<.01 and in other places on the Internet, F(3, 422)=2.66, p<.05. At the same time, it has been shown that with the increase in the number of household members who earn income, the belief in the objectivity of information from printed editions of newspapers and magazines, TV and other places on the Internet decreases. These results show that the degree of trust of respondents in printed publications such as newspapers and magazines, TV and other places on the Internet differs significantly depending on the number of household members with income within the household in which the respondent lives.

One-factor analysis of variance examined differences in attitudes towards the possibility of objective information through different types of media depending on the personal income of respondents. It has been shown that statistically significant differences exist when it comes to radio, F(3, 422)=3.15, p<.05, WEB portals, F(3, 422)=4.17, p<.01 and other places on the Internet, F(3, 422)=13.57, p<.01. This analysis showed that with the increase in personal income of respondents, trust in radio, WEB portals and other places on the Internet decreases. This structure of results speaks for itself that the level of trust in radio, WEB portals and other places on the Internet differs significantly depending on the level of personal income of respondents.

The T-test for independent measurements examined differences in attitudes towards the possibility of objective information through different types of media depending on gender. Significant differences were found only when it comes to WEB portals, t (386) = - 2.33, p <.05, where it was shown that women have a higher degree of trust in WEB portals than men. The obtained result shows that there is a significant difference in the trust of information from the WEB portal between women and men.

One-factor analysis of variance compared differences in attitudes towards the possibility of objective information through different types of media depending on household income. It has been shown that significant differences exist when it comes to printed editions of newspapers and magazines, F(4, 427)=2.86, p<.05, electronic editions of newspapers and magazines, F(4, 427) = 5.03, p<.01, WEB portals, F(4, 421) = 5.92, p <.01 and other places on the Internet, F (4, 421) = 4.50, p <.01. In addition, it has been shown that with the increase in household income, trust in printed and electronic editions of newspapers and magazines grows, as well as in WEB portals and other places on the Internet. This result shows a significant difference in trust in information from printed and electronic editions of newspapers and magazines, as well as from WEB portals and other places on the Internet, depending on the income of the household in which the respondent lives.

T-tests for independent measurements compared differences in attitudes towards the possibility of objective information through different types of media, depending on whether respondents earn income or not. Statistically significant differences were found only when it comes to radio, t(424)= -2.30, p<.05, where it was found that respondents who do not earn income have more confidence in the objectivity of radio than respondents who earn income. The obtained result shows that the trust in the information from the radio varies significantly depending on whether the respondents earn income or not.

One-factor analysis of variance compared the differences in attitude towards the possibility of objective information through different types of media depending on the length of service of respondents. Significant differences occurred when it comes to printed editions of newspapers and magazines, F(3, 401)=5.51, p<.01, TV, F (3, 401) = 6.22, p <.01 and WEB portals, F 3, 398) = 4.02, p <.01. Also, this analysis showed that with the increase in the length of service, the degree of trust in the objectivity of printed editions of newspapers and magazines and TV grows, while the trust in WEB portals decreases. These results suggest that there are differences in trust in information from print newspapers and magazines, TV and WEB portals depending on the length of service of respondents.

One-factor analysis of variance compared the differences in attitude towards the possibility of objective information through different types of media, depending on the level of education of the respondents. Statistically significant differences were found in all types of media except electronic editions of newspapers and magazines. Also, it has been shown that with the increase in the level of education, the level of trust in the objectivity of all types of media in which significant differences have been found decreases. These results indicate significant differences in the degree of trust in all types of media, except for electronic editions of newspapers and magazines, depending on the level of education of the respondents.

Finally, a one-factor analysis of variance identified differences in attitudes toward the possibility of objective information through different types of media depending on the age of the respondents. A statistically significant difference was obtained only when it comes to TV, F (3, 419) = 2.69, p <.05, where it was shown that with increasing age of respondents increases the degree of confidence in the objectivity of information from TV. The obtained result shows that there is a difference in trust in information from TV depending on the age of the respondents.

Predicting attitudes about reaching the truth in the media based on demographic variables

Multiple regression analysis predicted average degrees of agreement with the claims made up of each of the four factors singled out by analyzing the main components of the questionnaire relating to attitudes about ways of reaching the truth in the media.

This analysis shows that the degree of agreement with the first factor, called "truth concealment", cannot be successfully predicted based on a set of demographic variables. This result suggests that there is no direct link between demographic variables and the extent to which respondents believe that the truth is deliberately concealed in the media.

Multiple regression analysis showed that the degree of agreement with the factor called "alternative sources of truth" can be successfully predicted based on a set of demographic variables, R2 = .32, F(9, 383) = 4.92, p <.01. Also, it has been shown that the variables gender, β= .21, t=4.22, p <.01 and the acquired degree, β = -.31, t = - have a significant independent contribution to predicting the degree of agreement with the statements on this factor. 5.20, p <.01.

Multiple regression analysis showed that the degree of agreement with the factor called "spiritual truth" can be successfully predicted based on a set of demographic variables, R2 = .22, F (9, 383) = 2.25, p<.05. In addition, this analysis showed that a

significant independent contribution to this prediction is made by the variables gender, β= .12, t = 2.20, p<.05, degree, β= -.13, t = -2.16, p <.05 and the amount of personal income, β= .27, t = 3.18, p<.01.

Finally, multiple regression analysis showed that based on demographic variables, the degree of agreement with the factor called "multi-media monitoring" can be successfully predicted, R2= .33, F (9, 383) = 5.09, p <.01. This analysis also showed that the following variables have a significant independent contribution to this prediction: gender, β= .14, t = 2.78, p <.01, degree, β= .14, t = 2.33, p <. 05, employment status by income, β = .19, t= 2.84, p <.05, number of household members, β= -.13, t = -2.25, p<.05 and number of household members earning income β= .12, t = 2.12, p<.05.

These results show that there is a connection between demographic variables and agreement with the existence of alternative sources of truth, spiritual truths, as well as agreement with the importance of following more media in order to reach the truth. Also, these analyzes indicate the lack of connection between demographic variables and agreement with claims about concealing the truth in the media. In addition, it was confirmed that certain demographic variables have a significant independent contribution in predicting the degree of agreement with the factors: alternative sources of truth, spiritual truth and monitoring of several media.

Conclusions

The results of the research confirm that there is a relationship between socio demographic variables (gender, age, level of professional education, work status, monthly personal income of the respondent and monthly personal income of the respondent's household, number of members in the household and number of household members who earn income) and their agreement with the existence of alternative sources of truth, spiritual truths, as well as agreeing with the importance of following multiple media in order to reach the truth. Also, these analyzes indicate the absence of a connection between demographic variables and agreement with claims about the concealment of the truth in the media. In addition, it has been shown that certain demographic variables have a significant independent contribution in predicting the degree of agreement with the factors alternative sources of truth, spiritual truth and following multiple media. The results undoubtedly confirm that respondents are most commonly being informed via electronic editions of news and magazines as well as via TV programs, while they rarely adopt information broadcasted via radio channels. Furthermore, the results reveals that respondents are prone to trust "other places on the internet" and web portals the most, while there is a noticeable luck of trust when it comes to printed editions of newspapers and magazines. However, it may be noticed, generally, that there is no great confidence in the objectivity of information published in media. The established results indicate that very few respondents believe that free, independent and impartial media exist in Serbia.

The structure of the results confirms that a substantial part of the variance of attitudes about the trust in media may be explained by four extracted factors. In addition, the results reveal that respondents cultivate distrust towards the information coming from the media, and they tend to turn to other sources of information separated from the media.

One-factor analysis of variance revealed differences in the frequency of collecting information through different media, which depends on the age of respondents. Statistically, significant differences were obtained for all types of media except for electronic editions of newspapers and magazines. Furthermore, it has been determined the frequency of adopting information through printed newspapers and magazines and TV increases with the age of respondents, while the frequency of collecting information through radio, web portals and other places on the Internet decreases. It appears from these results that respondents, depending on their age, differ in the frequency of collecting the information through all media except electronic editions of newspapers and magazines.

Lastly, it has been determined by means of the one-factor analysis of variance that there are differences in the attitude towards the possibility of objective information sharing through various types of media depending on the age of the respondents. A statistically significant difference was obtained only when it comes to TV, F (3, 419) = 2.69, p <.05, where it was presented that degree of confidence in the objectivity of information from TV grows with the age of respondents. The obtained result confirms that there is a difference in trust in information from TV depending on the age of respondents.

Author contribution

Slavoljub Vujović made the greatest contribution to the research presented in the paper, starting from defining the concept and structure of the research, pointing out the very interesting connection between the media and the Corona virus, emphasizing the spread of fear and panic of the population through the information broadcast and thus the intensity of the virus. In addition to doubting the veracity of the information, there is doubt about the connection between pharmaceutical and media companies. Zeljko Bjeljac contributed to the work from the socio-geographical aspect, pointing to the planetary coverage of the Corona virus and media, in the sense that the Corona virus is present on all continents and in all nations, thus pointing to the planetary importance of research. Nenad Vujić contributed to the field data collection through interviews and tests, while Jovan Spajić contributed to the research through statistical data processing.

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Transformations of the Ukrainian-Polish border regions: experience of Ukraine

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Abstract

The paper addresses the issue of the state border. It emphasizes the fact that the state border is a multi-component and multifunctional phenomenon. It was proved that a legally established and internationally recognized border acquires a sign of politicality. The political boundary is a holistic and dynamic phenomenon, inherent in the internal logic of development. The issues of functioning and institutional support of state borders were generalized. The influence of state borders on the development of border territories was revealed. A scheme for the development and integration of contact border areas has been developed. The factors of contact border regions development were studied, as well as the process of various types of regional socio-economic systems formation under the condition of the predominance of state border certain functions. The importance of the functioning of state borders and the development of border regions for the formation of various types of ties, the level of stability of the border and the formation of a political environment have been clarified.

Keywords: *state border, contact-making border areas, the USSR, Poland, Ukraine*

Rezumat. Transformarea regiunilor de la granița ucraineano-poloneză: experiența Ucrainei

Lucrarea abodează chestiunea granițelor statale, subliniind faptul că granița este un fenomen multifunctional, ce cuprinde mai multe componente. S-a dovedit că o graniță recunoscută la nivel internațional și stabilită legal capătă în timp un statut politic. Granița politică este un fenomen dinamic și holistic, inalienabil în logica internă a dezvoltării. Chestiunea funcționări și suportul instituțional pentru granițele statale au fost generalizate. Influența granițelor asupra dezvoltării regiunilor din zona de graniță a fost dezvăluită si s-a propus o schemă pentru dezvoltarea și integrarea zonelor de graniță. Au fost analizați factorii care condiționează dezvoltarea zonelor de la graniță, precum și procesul pentru formarea diferitelor sisteme socio-economice ținând cont de condițiile predominante și funcționalitatea acestora. S-au adus clarificări cu privire la importanța funcționării granițelor, dezvoltarea regiunilor de graniță și formarea anumitor tipuri de legături, precum și gradul de stabilitate al granițelor și formarea unui mediu politic corespunzător.

Cuvinte-cheie: *granițe de stat, zone de la contactul cu granița, URSS, Polonia, Ucraina*

Introduction

The state border defines the spatial boundaries of the state territories and the scope of its sovereignty. Authors would like to draw the attention on some differences in the definition of state borders that exist in Ukrainian and Western scientific thought. Ukrainian scientists understand the state border as a legally and actually established artificial line (on land and water) and a vertical surface passing along this line in the subsoil, waters and airspace. Such a definition of the border is established by the Ukrainian law. Western scholars like Anderson and O'Dowd (1999, p. 595) argue that boundaries are "constitute imprisonment; a kind of gate with the "outside world" and perform the functions of: protection and areas of opportunity and / or danger; areas of contact and / or conflict; cooperation and / or competition". The theory of international relations states that state borders must be properly guarded, the territory must be indivisible, and the state must have full control over its delimited territory. However, in practice the boundaries are not always well-defined and coherent. Nowadays, due to globalization and regionalization, borders are often being changed and transformed. All this affects the development of contact border regions (territories). And they, in turn, affect the level of political stability, economic security, civil liberty, form stable types of ties, affect the level of socio-economic development. A comparison of the development and transformation of contact border regions in different historical periods can be of specific scientific interest. This question is addressed in the study, focusing on the example of Ukraine and Poland, as two adjacent states, and in different time periods and under different political regimes.

Analysis of scientific research and publications about the studied topic

The analysis of research and publications on the subject regarding the state border functioning and development of the cross-border areas demonstrates high interest from various fields, involving political science, history and geography. Alaev (1983), Bielienkyi et al. (2002), Bohorad, Teveliev, Padalka, Pidmohylnyi (2004), Baklanov&Hanzei (2008), Dolhov (2013), Hranberh (2000), Kolosov (1985; 2003), Kolosov&Myronenko (2001), Mochernyi et al. (2002),

Vermenych (2003), Yaromenko (2009) and many other scholars demonstrate a great interest in the subject within their works. Current situation about functioning of state border and possible ways of cross-border areas development, especially in the field of cross-border cooperation was deeply studied in works of such scholars as Antoniuk&Papish (2019), Barthel (2021), Gryzenko (2010), Krasnikova, Filatov &Krasnikov (2016), Kravtsova et al (2009), Stokłosa (2012), Varnaliia (2007), Wolczuk (2008). Moreover, Kotsan (2017a; 2017b; 2017c) raised some issues on the state border functioning and development of the cross-border areas between Poland and Ukraine. In this area foreign investigations are also quite significant. Newman (2006, p.146), in his work "Lines That Continue to Divide Us: Borders in Our World Without Borders", describes the Renaissance of a scientific interest in the study of border problems: "The study of borders has revived in the last decade. This is reflected in a large list of conferences, seminars and scientific publications". A similar view was expressed by Hagen (2021): "At the turn of the XX century, the study of borders experiences a period of revival," and added that, ironically, this "renaissance" coincided with the flowering of theories of "world without borders". Moreover, "reflecting the growing scientific interest in frontier research, a number of research centres and associations have been set up to disseminate information, encourage research and organize conferences on border issues." Ukrainian scholar Kotsan (2021, p.31) says that "In nowadays Ukraine, research institutes, organizations and institutions, independent scientific centers are systematically engaged in border research, among which the National Institute of Strategic Studies (which studies security issues), the Institute of World Economy and International Relations, the Center for Peace, Conversion and Foreign Affairs of Ukraine (Kyiv), Institute of Regional and European Integration Studies "EuroRegionUkraine" should be singled out". However, the issues of dynamics, development and transformation of border areas, specifics of contact border space, factors of its formation, peculiarities of state borders functioning and significance of this process for neighbouring states in general and for Ukraine in particular need further clarification and deep analysis what became the main reason for the researched topic studied in the article.

Methods of research

The following methods have become important in the study of Ukrainian-Polish border regions and the processes associated with their transformation: chronological, periodization, retrospective and perspective method, comparative-historical method. Thus, regularities, contradictions and connections of certain events and processes in chronological order were revealed on the basis of research of their appearance, formation and development. In addition, they allowed to identify the primary information that provides a basis for further theoretical reflection and construction.

Obviously, all real-world objects change, have certain phases and stages of development. The chronological method allowed to carry out a thorough analysis on the formation of the border under certain domestic political conditions and external factors, to study the dynamics of its functions changes. This method, together with the diachronic method, became the basis for highlighting specific stages and political features of the border areas of Ukraine and Poland. In the research, periods and stages of development and transformation of the Ukrainian-Polish border regions were selected on the basis of the following criteria: branching of the institutional and legal framework; political features of the border functioning; functional component of the border. For each period and stage of border regions development, the name of the border type and the type of border area was proposed. The influence of the political system on the functioning of the border was taken into account; the impact of border functions on the development of border areas, the degree of stability of the political, economic and social situation in the region, etc. The names of the periods are closely related to a certain historical period (for example, "Interwar", "Military") and have a clear definition within the years. The names of border types reflect the predominant functions and their effect on borders accordingly. The names of the types of border regions show the degree of interaction of different states' neighbouring territories; the level of states' relations, regulated by their governments and determined by their national interests; the degree of integration of the border with adjacent territories of the neighbouring country.

Such methods as analysis, synthesis, induction and deduction, retrospectives and perspectives were also used, which allowed us to get a comprehensive picture of the nature, features and patterns of transformation of the Ukrainian-Polish border areas in historical retrospect and perspective.

Theoretical foundations of the border regions study

The established state border obtains political features and legally determines cross-border regime. Moreover, border area rules affect the process of defining and consolidating certain norms, rules, status and roles as well as developing them into the system that will operate in order to ensure state interests. The institutionalisation of borders takes place. The border becomes a multifaceted and multifunctional phenomenon and in broader sense a

systemic one. The political border is a multifunctional phenomenon, it performs not only principal functions, but also specific functions, such as political, social, cultural, economic and identifiable (psychological) ones, which can be also called boundary-communication functions.

The main functions of the state border include barrier, joining and filtering; secondary ones are separation, regulation and comparison. Depending on the geopolitical situation in the system of international affairs, either one of these functions prevails, or all of them are performed simultaneously (Malynovska, 2001).

A particular state provides relationships with the international world system through border's execution of the main and secondary functions. The state border acts as a barrier, a common zone as well as a filter of interstate interaction including the political, economic, cultural and other fields.

One of the principal functions of the border is a barrier one. It is significant as each country has a full and exclusive supremacy in its state territory (Malynovska, 2001).

As a linear form, the border limits the growth of socio-economic phenomena that characterise neighbouring states. As a result, these aspects develop in different political, economic, historical and cultural contexts, which were formed in different sides of the border. Therefore, a barrier function of the border involves creating a specific barrier between the states that is exhibited by various restrictions on its crossing as well as restrictions on activities in the states' border areas.

A barrier function of the border is expressed by the ability to reduce or even suspend cooperation between neighbouring states. A property of the border to promote the interaction indicates its joining function. The correlation of state border properties directly depends on the model of management of foreign economic relations and the political regime.

The state and its authorized state bodies are exclusive subjects in the centralised model. In this case, border allows external cooperation only in the context of interstate and international agreements and programmes. Border does not make any contacts within all other interactions. In terms of a decentralised model, the situation alters radically. Primary economic elements, such as enterprises, cooperatives, associations, research institutions, etc., are the subjects of foreign economic activity. Thus, barrier qualities are not represented by fundamental impossibility of foreign relations of the main economic elements, but are in the form of administrative, economic, border and customs restrictions on direct exporters and importers. These restrictions perform as a set of measures in order to ensure national economic interests. The barrier may be shown through limitations on both sides, the conditions for the emergence of flows between countries and the conditions under which they operate.

In the first case, the barrier is reduced to reflection, filtering of flows and setting a threshold for flows that cross the border. In the second case, the barrier is reduced to the outlay for the border crossing.

The reflection is exhibited in the creating of unfavourable conditions in order to spread any phenomenon or process in the border area. Border filtering is demonstrated in the selective capacity of flows (goods, services, passengers) across the border. It is carried out through various governmental, administrative and economic methods of control over external relations: licensing, tariff and non-tariff restrictions, visa and passport regime, exchange rate, currency turnover, etc.

The threshold is shown in the fact that to cross the border it is necessary to overcome the difference in the potential of neighbouring countries. In economics, overcoming such a threshold can be expressed in cost form: if the cost of overcoming is too high, the border will be impenetrable.

The implementation of the barrier function requires significant infrastructure costs, that is, building border constructions, maintaining border and customs services. Being a barrier, the state border plays a separation role. However, this fact is influenced by the level of economic and political "merger" of the neighbouring countries.

There are two cases within the barrier function: a restricted or an open border. A case of the restricted border is represented by non-friendly countries or it is applied by the state that wants to preserve its people from the external impact. At the border, a required minimum of crossing points remains; border frontiers are reinforced and defence capability of the strategically vulnerable parts is strengthened (Kolosov, 2003).

The open border demonstrates friendly and neighbourly relationships between the countries. Various communications cross the border, ethnic groups at both sides of the border have access to communicate freely.

Even the case of the open border remains a hurdle, i.e. performs a filtering function, and is aimed at protecting national interests of the state, especially economic ones. This objective is implemented by the work of border and customs services. The border filters flow of people, goods, investments and information. Control over the flow of people involves using different visa types, such as for tourists, government officials, business people, migrant workers etc. Ideally, states can sign bilateral or multilateral agreements or visa-free border crossings. Transportation of goods across the border is regulated by setting of tariffs on different product categories or by applying of various licences and

quotas. Since the flow of capital must be transparent, international banking systems are responsible for the movement of non-cash funds, the movement of cash, gold and other valuables can be normalized and declared. Quarantine, environmental and other restrictions are also imposed.

In modern context, there is an increasing tendency to intensify the joining function of the borders. It reflects objective processes of internationalization of the economic life, the development of multilateral relations among the states, the establishment of interstate and cross-border cooperation. The effect of the joining function is vividly exhibited within the cross-border regions.

We should note that there are many interpretations of the category "region" in terminology (Karymova, 2006, Bezverkhniuk, 2007, Symonenko, 1997). The term "cross-border region" implies a region that is characterised most significantly by the presence of the state border as well as by wide opportunities for interregional and cross-border cooperation with neighbouring regions and states (Yaromenko, 2009).

In the monograph "Theoretical and methodological issues of historical regional science in Ukraine", Vermenych (2003, p.66-67) addressing the essence of the notion "cross-border region" states that: "Nowadays, there continues the process of determining the place of cross-border regional science within both economics and regional research or regional science as a field of scholar work based on the interdisciplinary approach that is aimed at studying the patterns of regionalization of the country taking into account natural, geographical, historical, ethno-cultural, economic, socio-demographic factors, as well as the study of regional development of border zone in its relationship with the principles of public administration and the main courses of state building".

The term "cross-border region" is used both for the geographical content and for the economic characteristics of the region. Quite often, the term "border area" is used instead, as it is considered to be more flexible and appropriate in the case of developing projects, programmes, models and concepts of borderland development.

In addition, scholars define the cross-border region as an administrative unit that is on the next level after state and it is located directly along the state border. This definition is based on the definition of the term "region" proposed by the Assembly of European Regions. "A region is a territorial unit-subject of public law, formed at a level that is immediately lower than the state, and endowed with the right of political self-government. The region will be recognized as a national constitution or legislation that guarantees its autonomy, identity, power and organizational structure" (Assembly of European Regions, 1996).

Although this definition is not official, it became a part of the terminology of the Council of Europe and the European Commission. Some authors summarised the definitions above and they consider that "cross-border region is a part of the economic zone of an independent state which borders with one or more countries and it is characterised by geographical integrity, specific natural, climatic, economic and social conditions, location and development of productive forces, participation in cross-border cooperation and international division of labour " (Milashovska, 2010).

Nowadays, cross-border regions can independently solve their issues, establish interregional relations or ties with foreign states within the framework of national legislation. Each region, including the cross-border region, has its own approaches to using natural resources, peculiarities of its location, national and historic features, specific structure of the economy, level of economic development, specialisation (Zakony Ykrainy, 2001). Their harmonised socio-economic growth enhances economic independence of the country as well as increases its competitiveness among other states.

The principal features of harmonised socio-economic growth of cross-border regions are:

- optimal, economically and environmentally justified use of the region's resources;
- rational sectoral and territorial structure of the economy which must meet social and environmental requirements;
- close relationship with adjacent areas of the neighbouring states and the need to coordinate their socio-economic development programmes (Milashovska, 2010).

The concept of "cross-border region" implies that an area belonging to it is under the influence of the state border. Moreover, cross-border region is a territory that covers one or more administrative units of a state and adjoins the state border (Mikula, 2004).

Functioning of the border affects the development of the adjacent border region, therefore, quite often scholars argue the establishment of the so-called "contact-making border area". The concept of "contact-making border area" serves as a special historical and spatial category as it studies two objects, the processes of interaction and functioning between contacting groups and centres over a certain time frame, and the processes of presentation of the "border image". Furthermore, interpretations of the political and economic contexts within contact-making border areas are not limited only by peculiarities of the borders. So, the study of "contact-making border areas" is relevant and significant.

Contact-making border areas, including frontier and interstate areas, have been performing important

functions within the past and modern development of the state. They are a sort of "membranes" that regulate exchange (economic, political, cultural, demographic, etc.) and decrease the impact of the "external factor" on the state. Contacting space in these zones is inhomogeneous and multi-vector. Depending on the political and economic situation it can transform either in a "barrier" or a "filter". In general, there are three types of objects that influence the formation of contact-making border areas. They are: area (territory), boundaries (outlines) and capital centres. It is an important fact that within these zones, infrastructure develops intensively, enterprises are created and designed to use raw materials, labour, materials from the neighbouring regions and countries as well as they are export-oriented. However, they depend on external sources of raw materials as well, so they are vulnerable to military or isolationist influences from abroad. Hence, the main tasks of "contact-making border areas" are the stabilization of the supranational geopolitical system, the accumulation of integration, historical experience of compromises and exchange of achievements. In order to attain these objectives, the border must implement the joining function.

Formation of contact-making border areas depends chiefly on the influence of political, historical, natural and geographical factors and in particular on the events of political history, ethno-cultural features, social and religious relationships in the region. Moreover, the political regime of the state, administrative policy, socio-economic and demographic capacity of the region, ethno-cultural integrity impact on the progress of contact-making border areas. Intensity of the socio-political processes in contact-making border areas hinges on the geopolitical development and strategies of cross-border interaction. In one case, an "isolated borderland" is formed, in another one an "integrated border zone" of neighbouring states can be created (Kotsan, 2018).

If barrier or filtering border functions dominate in contact-making border areas of the neighbouring states, "isolated" border areas are formed. Therefore, they are influenced by national political and economic system and have weak ties with foreign countries. A certain "image" of the border as well as the attitude to one's own territory with a specific level of socio-economic development, to border policy in particular and policies in general, to the political regime, etc. are formed within these regional socio-economic systems. Historical events, misapprehension and conflicts with neighbouring territories on the other side of the border, ethnic peculiarities, social, religious and other types of relations are accumulated on these realties. All mentioned above affects the establishment of loyalty or disloyalty to the border. Most often, within the "isolated" border areas performance of the specific (boundary-communication) functions leads to formation of an unstable socio-political environment which is exhibited by violation of cross-border regime and border area rules.

In these cases, border areas create solid relations (political, economic, cultural, etc.) with the adjacent territorial entities of the same level, which enhances their role in the state, increases the level of socio-economic development and forms a stable political environment.

Development and transformation of Ukrainian-Polish border regions

Ukrainian-Polish border regions are parts of the economic territory of Ukraine and Poland, which are separated by a border, but are characterized by geographical integrity, similar natural and climatic conditions, specific socio-economic potential, location and development of productive forces. In addition, these are the border administrative parts of Ukraine (regions) and Poland (provinces), which take an active part in the international division of labor, border and cross-border cooperation. The Ukrainian-Polish border regions have a common history, ethno-cultural origins, social and religious relations. Therefore, it is quite interesting to consider their transformation, as well as the influence of the border on this process not only at the current stage, but also in retrospect. After the First World War in 1921, a boundary was established between the Ukrainian Soviet Socialist Republic (the Ukrainian SSR) and the Russian Soviet Federative Socialist Republic (the RSFSR) on the one hand, and with the Republic of Poland (the RP) on the other side. Thus, the interwar period of frontier formation and development of Ukrainian and Polish border regions began (Table 1).

This period is divided into two stages based on a number of criteria, such as institutional and legal framework, political features, functional component of the border. At the first stage of "establishment and institutionalization" (1921-1924), the border was established with successive phases of allocation, delimitation, demarcation. The artificially marked Soviet-Polish frontier had a low level of stability, socio-political loyalty of the population to it, which affected the instability of socio-political relations in the cross-border regions. It was also superimposed on the political regimes of both states, their efforts to control and dominate in the region. This fact impacted the features of the border functioning with the predominance of sabotage, provocative and investigative work. Under these conditions, both sides were forced to strengthen the borders, create institutions for border security, execute operational, counter-sabotage activities and form a legal basis for

them. The boundary was a filter, while the border areas were semi-isolated.

During the 1925-1939 period, the Soviet-Polish boundary blocked increasingly and became a barrier in the interstate interaction. The stage of "centralisation and closure" is known for the expansion of regulatory and legal framework for the functioning of the border; reorganization of institutions for its protection, tightening forms and methods of their work; creating specialized units within border security institutions (especially with regard to intelligence and counterintelligence activities). Barrier and filtering functions became predominant. Although specific functions lost their primacy, they did not disappear. In 1925–1939, among the prevailing activities on the Soviet-Polish border were: intelligence, counterintelligence, operational, law enforcement and other. The border became a barrier, and the border area was isolated.

Table 1: Stages of formation and development of cross-border regions of Ukraine and Poland

Period	Stage	Time frame	Type of border	Type of border socio-economic systems
Interwar	Establishment and institutionalization	1921–1924	Filter	Semi-isolated
	Centralisation and closure	1925–1939	Barrier	Isolated
War		1939–1945	**	Occupied
Socialist	Centralised functioning	1945–1989	Barrier	Isolated
Modern	Democratisation	1989–1994	Filter	Semi-isolated
	Constructive stage	1995–now	Filter	Semi-isolated with the elements of integration
Progressive	Integrated	After Ukraine's accession to the EU	Open	Integrated

*** The WW2 terminated the functioning of the border*
Source: compiled by the authors

The Second World War terminated the functioning of the border. The war period began for the border areas that became occupied.

After the Second World War the boundary between the Ukrainian SSR as a part of the USSR and the Polish People's Republic (the PRL) was established on the new basis. This basis became the Soviet-Polish treaty on friendship and the border. Acording to this agreement, the border between the USSR and Poland was established along the so-called "Curzon line" with a deviation from it in some places from 5 to 8 km in favor of Poland. The Soviet side ceded in favor of Poland the territory north of Rava Ruska to the Bug and Solokia rivers with a depth of up to 30 km (modern Ukrainian territories). Ukrainian ethnic lands remained within the borders of Poland - Kholmshchyna, Pidlyaschya, Posyannia, Lemkivshchyna. However, in 1945, the border was not completely formed. Its clarification took place through a long-term negotiation process. Until 1948, the governments of the USSR and Poland concluded interstate agreements. For the residents of the border, this turned into significant problems: they were subject to "displacement", lost their farms, and in result their families were separated. At that time, the border served as a barrier. In 1945 started the so-called socialist period of the development of the Ukrainian and Polish border areas, which continued till the end of the 1980s. A distinctive feature of this period was the centralised functioning of the border that was completely subordinated to the political regimes of neighbouring states. However, within this time frame, the USSR (thus, the Ukrainian SSR as its part) and the Polish People's Republic were socialist countries, so their political leaders allowed the Ukrainian border areas to establish certain forms of relationships with the Polish border regions. The forms of cross-border relations were meetings and correspondence between the representatives of party bodies, government agencies, mutual tours of art groups, 10-day meetings, art festivals, movie rentals, exhibitions, plain air works, exchange of work experience among the specialists, student exchanges, exchange of new technologies, development of cross-border trade. But these opportunities for mutual contacts were limited by strict regulations of party bodies. At that time, the border was a barrier (with a predominance of barrier and filtering functions), while

border regions of Ukraine (the Ukrainian SSR) and Poland were isolated.

The modern period of the development of the cross-border regions and the functioning of the Ukrainian-Polish boundary is a qualitatively new step in the legal and institutional maintenance of the border, democratisation of its functioning, development of all areas of cooperation, including cross-border cooperation, which was implemented in a democratic Poland and independent Ukraine. The modern period is structured in two stages: "democratisation" and "constructive stage". The first one was characterized by rapid forming of legal maintenance as well as determining of principles, mechanisms and tools of cooperation. During this period about 50 interstate documents were signed on legal and substantive issues of establishing regional, border and cross-border cooperation (CBC). At this stage, the border became a filter (with a predominance of filtering and the development of the joining functions), as the result border areas were semi-isolated.

At the next "constructive" stage (from the middle of the 1990s till now), there was cooperation in different fields; the two countries created Euroregions as the most effective forms of cross-border cooperation, designed and implemented mutual projects and programmes at regional and local levels, which helped to solve the issues of the border areas. Thus, it increased the level of their socio-economic development and their role in the state.

When the state-members of the Carpathian and Bug Euroregions accessed the EU in 2007, the eastern border of this authoritative institution coincided with the western border of Ukraine. This fact influenced significantly the role and place of the mentioned Euroregions in the framework of Ukraine's cooperation with Poland and the EU. By that time, Euroregions with the participation of Ukrainian and Polish border areas performed a local function of cross-border integration. Now Euroregions began to play a fundamentally new role of the highest organizational form of CBC on the new eastern borders of the EU. It gave hope to Ukraine to get involved in European integration processes. The cross-border regions of Ukraine and Poland transformed into those that have elements of integration (see Table 1), while the Ukrainian-Polish boundary fulfills both joining and filtering functions. All these processes had a positive impact on establishing a stable political environment.

In our opinion, it would be legitimate to single out the "integration" stage of development of the Ukrainian and Polish cross-border regions, since the integration programmes of regional growth exist even now. Ukrainian regions require a new prospect and new tools in order to attain competitiveness. There is a determined and attractive possibility, that is the integration to the EU as well as the implementation of the concept of regionalization, while tools are clear from the analysis of the success of individual industries in the world market. In this context, the cross-border regions that border the EU countries play an important role in accumulating the best European experience, testing of European practices in the legislative field of Ukraine with the subsequent assurance of a multiplier effect in other regions of Ukraine (Nosa-Pylypenko 2015). At the same time, the Ukrainian-Polish frontier will be open and transparent. The opening of borders can be implemented in stages. At the first stage, the economic component of the border is transformed. Border and customs control can be abolished. Visas are cancelled for crossing the border. Goods, capital, services, persons move freely. The next stage is the country's entry into the Schengen area, as a result of which passport control at the border is abolished.

The analysed open borders are possible for the section of the Ukrainian border with the EU states in general, and the Ukrainian-Polish border in particular. According to many scholars and practitioners, an important step towards open and transparent borders within Europe is the legal provisions for the development of relations within the framework of the Eastern Partnership. The European Community understands the Eastern Partnership as part of the European Neighbourhood Policy. And it, in turn, is the EU's framework policy towards neighbouring countries.

In May 2008, the Eastern Partnership initiative was presented to the EU Council by Poland with the support of Sweden. The Eastern Partnership project was launched at a special summit in Prague (May 7, 2009). For Ukraine, it became "relevant only after an unsuccessful attempt to join the NATO Membership Action Plan, with Ukraine's absolute political certainty, strong US support, criticism from Germany and France, and unfounded protests by the Russian Federation. This project is a specific Eastern dimension of the European Neighbourhood Policy, based on the desire to create a favourable climate for the development of various forms of regional and subregional cooperation. This is primarily due to the desire of the EU to create a zone of stability on the new borders" (Holdun, 2009, p. 77). The EU member states, as well as Moldova, Ukraine, Belarus (the participation of which will depend on the development of its relations with the EU), and the countries of the Caucasus (Azerbaijan, Armenia, Georgia) are the participants of the program.

The main objectives of this project for Ukraine became the following: further liberalization of the visa regime; creation of a free trade zone; supporting the process of adapting the legal and regulatory framework, strengthening the institutions of partner countries; cooperation in the field of energy security;

creation of an integrated border management system (Shejko, 2020).

The complex and dynamic security environment towards Ukraine requires changes in approaches to border management. In recent years, the state has taken a number of steps to implement a modern, coordinated border management system - integrated border management (IBM). The main problems on the way to the introduction of IBM in the modern period are the following: new threats, in particular the aggression of the Russian Federation in certain regions of Donetsk and Luhansk regions, the occupation of the Autonomous Republic of Crimea and the city of Sevastopol; exacerbation of the migration crisis in the EU countries bordering Ukraine; incompleteness of measures on contractual and legal establishment of the state border; the need to introduce European standards for various types of control at the state border (border, customs and others); the need to improve international, interstate and interdepartmental cooperation on the control and passage of citizens, goods and vehicles at checkpoints.

Moreover, the Concept of IBM has already been developed and approved in Ukraine by the Cabinet of Ministers with the Decree №83 on October 27, 2010. Implementation of the IBM Concept will allow: "to introduce European standards of integrated border management; to improve international, border and interdepartmental cooperation; to coordinate the efforts of authorized state bodies of comprehensively and flexibly respond to current threats of state border security, and to ensure its openness».

The EUBAM mission is assisting Ukraine to make progress in terms of IBM. Thus, open and transparent borders of Ukraine will promote full integration of Ukrainian border regions with Polish ones and will promote the implementation of the concept of regionalization. This will help to increase the status and role of Ukraine not only in Europe but also in the world.

Conclusions and further research prospects

Ukrainian-Polish border regions have come a long way of development and transformation. Demarcated in 1921, legally delimitated and internationally recognized, the border acquired signs of politics. The political border developed under the influence of many external and internal factors and was transformed. The main and secondary functions of the border were performed by state institutions, whose activities were highly politicized. The functioning of the border influenced the development of contact border areas. During the interwar period, barrier and filtering functions prevailed among the functions of the border, and "isolated" territories were formed in the border contact territories of neighbouring states. The action of specific functions here has led to the formation of an unstable socio-political environment. Instability was indicated by violations of the border regime, which were observed throughout the interwar period, although with varying intensity. Illegal population migrations (in both directions) were significant in the first years of the border's operation and in the early 1930s. This created tensions at the border, and migrants fell victim to political repression in both countries. The political components of the border activity influenced the manifestations of specific (boundary-communication) functions: political, economic, social, cultural, psychological (identification). Therefore, the improvement of institutions (creation of special units of intelligence, counterintelligence), tightening of forms and methods of their work (in both states) influenced the "closing" of the border with the predominance of barrier and filtering functions. The border barrier existed until 1989 (but with some changes in activities and functioning), when Poland started the path of democratic development, and later Ukraine declared independence.

The current stage of development of the Ukrainian-Polish border regions can be characterized by the strengthening of cooperation, the definition of principles, tools and mechanisms of cooperation. During this period the work of institutions on border protection and functioning has changed: they have begun to act exclusively on legal grounds and in the interests of states. The attitude of border residents to the "image" of the border has changed also. From now state border opened up new opportunities for them: contacts, trade, finding new jobs, visiting neighbouring areas on the other side of the border for recreation and recreation. At this stage, the border became a filter (with a predominance of filtering and the development of contact functions), and as the result border regions became semi-isolated with elements of integration.

Implementation of the EU Council Eastern Partnership Project, visa-free regime for crossing the border with the EU, Ukraine's integration intentions open new opportunities for Ukrainian-Polish regions and their inhabitants. In our opinion, they will become more and more integrated and will become the "locomotives" that will help to integrate into the EU and show the results of the concept of regionalization. We consider that the main objective of contact-making border areas is to stabilise the supranational geopolitical system, accumulate integration, historical experience of compromises and exchange the achievements. The implementation of these objectives took place in the cross-border areas of Ukraine and Poland. As the historical background has shown, however, Ukrainian and Polish borderlands were intertwined, superimposed and had not only a

positive experience of mutual contacts, but also a negative one.

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