Suicide mapping: Case study on Olomouc and Zlín regions in Czech Republic in 2018–2022

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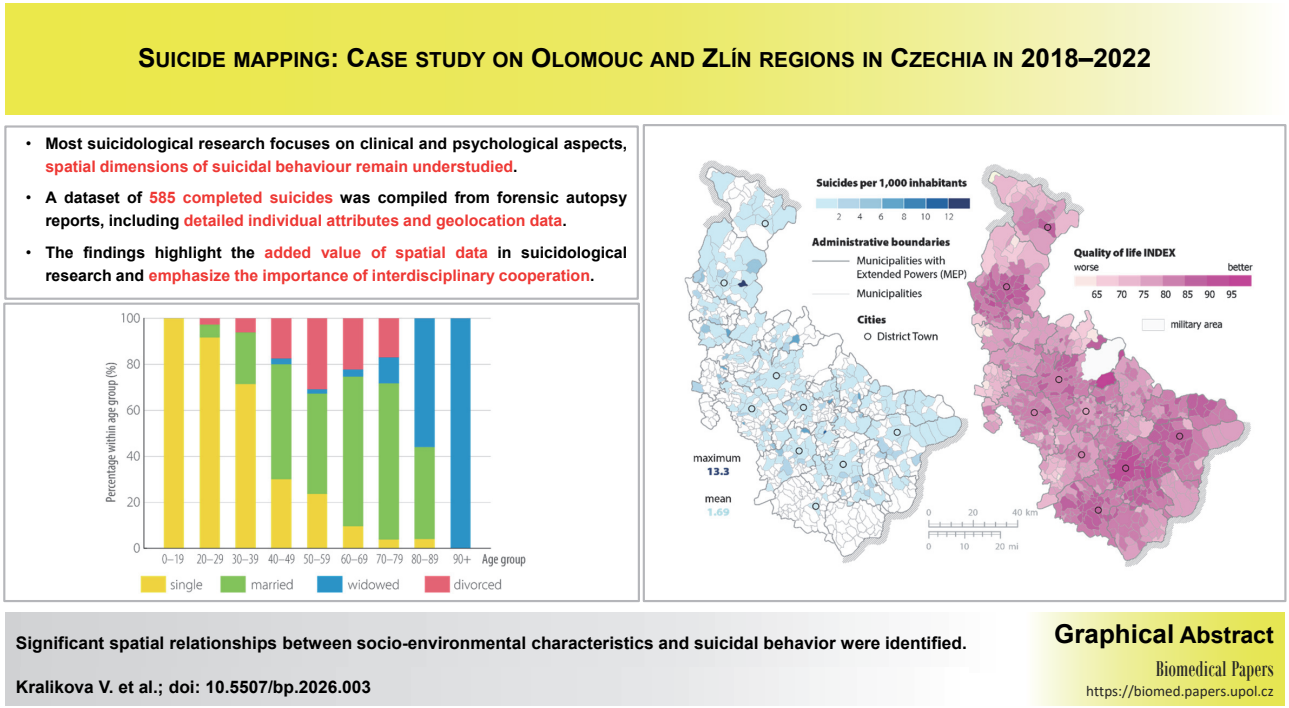
Background and Aims. Suicide represents a major public health issue influenced by a complex interplay of individual, social, and environmental factors. While suicidological research traditionally focuses on psychological and clinical aspects, spatial dimensions of suicidal behavior remain less explored, particularly in Central Europe. This study presents a geospatial analysis of completed suicides in the Olomouc and Zlín Regions of the Czech Republic between 2018 and 2022, using a unique dataset derived from forensic autopsy records. The primary goal was to demonstrate the potential of spatial processing and interdisciplinary collaboration between forensic medicine and geoinformatics in identifying contextual patterns of suicidal behavior.

Methods. A dataset of 585 completed suicides was compiled from forensic autopsy reports, including detailed individual-level characteristics and geolocation data. Spatial analyses were conducted using GIS software, integrating additional layers such as land use, demographic and socioeconomic indicators, and quality of life indices. Both point-level and aggregated data (municipality and administrative district levels) were used to explore correlations and spatial variability.

Results. The study confirmed known trends – such as male predominance and the role of alcohol – and identified new spatial relationships, including a negative correlation between blood alcohol concentration and latitude, and between age and distance from residence to suicide location. Spatial analyses were conducted at multiple levels of aggregation and combined with selected socioeconomic and environmental indicators, including quality of life, urban–rural context, and foreclosure (enforcement) rates. The results demonstrate that spatial patterns and correlations between suicide rates and area-based characteristics vary depending on the spatial scale of analysis.

Conclusion. The findings illustrate the potential of interdisciplinary collaboration between forensic medicine and geoinformatics and provide an exploratory basis for further research and more context-sensitive suicide prevention approaches.



Key words: suicide, database, spatial context, spatial characteristics, GIS, geovisualization, forensic data, Czech Republic

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INTRODUCTION

Suicide as a public health issue

Suicide remains a major public health issue worldwide and represents one of the leading causes of preventable mortality. According to the World Health Organization[1], more than 720,000 people globally die due to intentional self-harm, with many more attempting suicides. According to data from the World Health Organization, suicide is the third leading cause of death among individuals aged 15–29. Approximately 73% of all suicides occur in low- and middle-income countries, and up to 20% of suicides worldwide are carried out through pesticide poisoning, followed by hanging and firearms[1]. However, numbers and statistics can be underestimated. Globally, suicide is a significantly underreported phenomenon. It is not only for religious reasons and societal stigma, in some cases, it may be difficult or even impossible to determine whether a death was a suicide, meaning that suicide data will never be entirely accurate.

Suicide – also referred to as suicidium or self-inflicted death – is the act of consciously and intentionally ending one's own life[2]. Although suicide is commonly understood as an individual act driven by psychological distress, a growing body of research emphasizes that suicidal behavior emerges from a complex interplay of individual, social, environmental, and contextual factors. The WHO states that most suicides occur impulsively during moments of crisis, when individuals experience impaired ability to cope with life stressors such as financial difficulties, relationship conflicts, chronic pain, or illness. Risk groups and risk factors are identified[3], with accurate assessment depending on the detailed recording of data for each suicide case and its subsequent analysis. The WHO's suicide prevention initiative LIVE LIFE highlights multisectoral collaboration as a key strategy[4]. Understanding this complexity requires approaches that go beyond clinical and psychological perspectives alone.

Spatial dimensions of suicidal behavior

An example of interdisciplinary approach is geospatial analysis, which enables us to depict where concentrations of suicide deaths are occurring in local areas, while also allowing for better consideration of factors such as social and economic advantage and disadvantage, availability of services, and specific hotspot locations[4].

In recent decades, increasing attention has been paid to the spatial dimensions of suicidality, recognizing that suicide rates and patterns are not randomly distributed in space. Previous studies have demonstrated spatial clustering of suicides and associations with area-level characteristics such as socioeconomic deprivation, urban–rural context and local socioeconomic conditions, population density, environmental stressors, access to services and others[5–8]. Most studies addressing spatial correlations in suicide data focus on specific regions[6-14], while some approach the issue of spatial analysis in general terms[15,16].

Suicide research in the Czech Republic

In addition to the WHO, national health institutions also address the issue of suicide; in the Czech Republic, this is primarily the National Institute of Mental Health (NIMH) (ref.[17]). Suicide data is presented by NIMH and by the Czech Statistical Office primarily as statistical summaries at national level, without spatial visualization or broader geographical context. This aggregation limits the ability to capture local variability, contextual influences, and fine-scale spatial patterns. Moreover, official statistics are affected by methodological challenges, including regional differences in death classification and underreporting of suicides, which further complicate interpretation[18,19]. In the Czech Republic, underreporting of suicides is estimated to be around 20% (ref.[19]).

According to data from the Czech Statistical Office[20], a total of 6,290 individuals died by suicide in the five-year period from 2018 to 2022, disrupting a previously long-term downward trend in suicide rates (Fig. 1) suicide is more frequently committed by men; during the observed

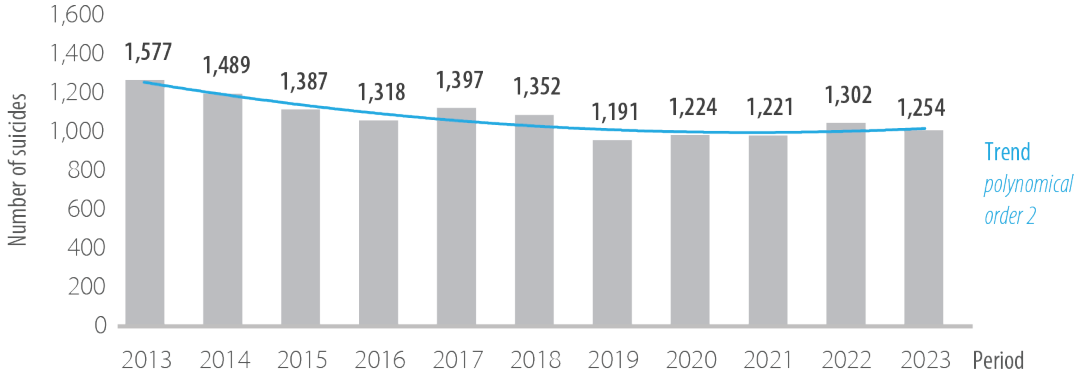

Fig. 1. Suicides in the Czech Republic in the period 2013–2023.
Based on data from the Czech Statistical Office[20].

period, there was an average of 4.1 male suicides for every one female suicide.

Methodological challenges in spatial suicide research

There is strong evidence that environmental and socioeconomic contexts influence quality of life and health outcomes, including mental health[21–23]. There is significant potential for interdisciplinary research aimed at combining various geographic characteristics with suicide data. Factors such as unemployment, social cohesion, religiosity, urbanization, land use, and access to natural environments have all been discussed as potential modifiers of suicide risk. Are there more suicides due to job loss in regions with higher unemployment? Is the suicide rate higher in mountainous areas or lowlands? Do people die by suicide in their place of residence, or elsewhere? A number of these questions can be addressed using more or less advanced GIS-based analyses, and potentially, by an appropriately designed map. Spatial analysis offers a powerful framework for examining these relationships, particularly when individual-level data can be linked to detailed geographic information.

An important methodological challenge in spatial suicide research is the choice of spatial scale. Relationships observed at aggregated levels may differ substantially from those detected at finer spatial resolutions, a phenomenon commonly referred to as the modifiable areal unit problem (MAUP) and the ecological fallacy. Careful consideration of spatial units and cautious interpretation of area-level correlations are therefore essential.

Aim of the study

The present study seeks to contribute to this gap by introducing a unique dataset of completed suicides compiled from forensic autopsy records in the Olomouc and Zlín Regions of the Czech Republic. Unlike conventional suicide statistics, the dataset includes detailed individual attributes and precise geographic information on both permanent residence and place of suicide. By integrating these data with socioeconomic, demographic, and environmental spatial layers, the study demonstrates the analytical potential of interdisciplinary collaboration between forensic medicine and geoinformatics.

The primary aim of this paper was to explore how spatial analysis can enhance understanding of suicidal behavior in its socio-environmental context. Specifically, the study examines selected non-spatial and spatial patterns of suicide, assesses relationships between suicide rates and area-based characteristics at different levels of spatial aggregation, and illustrates how geospatial visualization can support interpretation of complex datasets. Rather than seeking to establish causal mechanisms, the analyses are intended to be exploratory and hypothesis-generating, providing a foundation for future interdisciplinary research and more targeted suicide prevention strategies.

METHODOLOGY

Study area

The study area – Area of Interest (AOI) – comprises the Olomouc and Zlín Regions located in the eastern part of the Czech Republic. Together, these regions represent approximately 11% of the national population (Czech Republic: 10,827,529 inhabitants; Olomouc and Zlín Regions: 1,212,333 inhabitants) (ref.[24]) and include a diverse mix of urban and rural municipalities.

In the Czech Republic, the smallest administrative unit is the basic settlement unit, of which there are over 23,000. These are followed by municipal parts (over 15,000), municipalities (6,258 as of the end of 2024, including 610 towns), administrative districts of municipalities with extended powers (206), administrative districts of municipalities with authorized municipal office (393), districts (76 and the Capital City of Prague), regions (14), and cohesion regions (8). Fig. 2 locates the area of interest – the Olomouc and Zlín Regions – within the context of Central Europe.

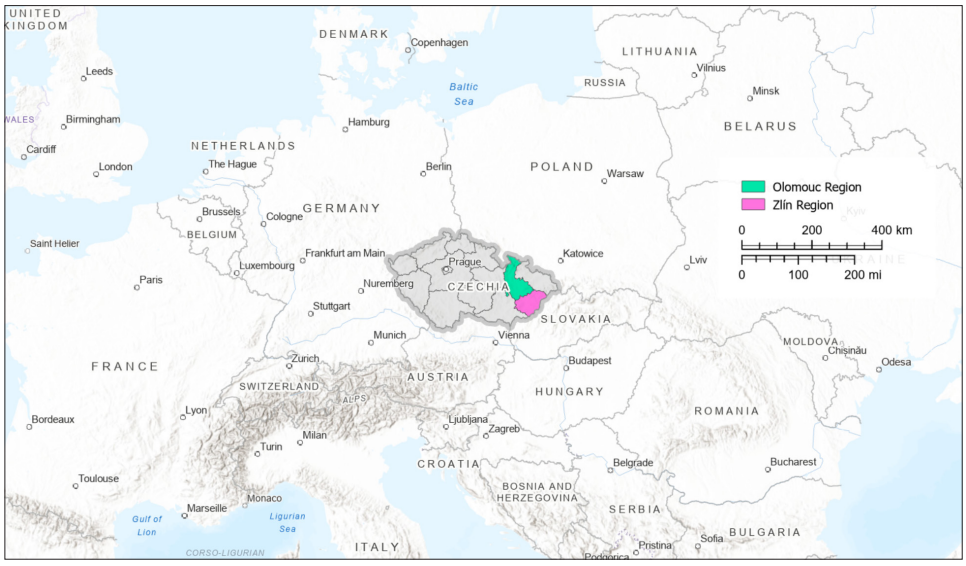

Fig. 2. Area of interest in the context of the Czech Republic and Europe.
Basemap source: © OpenStreetMap contributors, ESRI, USGS.

Data collection

The unique dataset for mapping suicides in the Olomouc and Zlín Regions of the Czech Republic consists of suicide case information collected at the Institute of Forensic Medicine and Medical Law at the University Hospital Olomouc. The dataset includes 585 records from the period between August 27, 2018, and March 30, 2022.

Suicide data in the Olomouc and Zlín Regions were collected by forensic pathologists and recorded in autopsy protocols at the Institute of Forensic Medicine and Medical Law. Although Czech legislation allows for some autopsies to be waived, local practice ensures that all violent deaths are subject to forensic autopsy (as per Act No. 372/2011 Coll., on Health Services).

From the autopsy records, data potentially involving suicide were manually selected. Accidents and deaths by misadventure were excluded through careful review of autopsy reports and information from the Czech Police and family members.

Reasons for underreporting in this dataset include:

- The type of autopsy depends on decisions made by criminal justice authorities, who may order a forensic autopsy (§ 115 of the Criminal Procedure Code) and choose the forensic institute. Most of the Olomouc and Zlín Regions fall under the jurisdiction of the University Hospital Olomouc.
- If no criminal investigation is launched, the body is transported to the nearest contracted autopsy provider under § 39 of the Public Health Insurance Act. As a result, some cases may be handled by other facilities, distorting regional statistics.
- Forensic autopsies may be waived in certain situations, but this did not occur in any case included in this dataset.
- Some suicides – e.g., traffic accidents, falls, and other trauma – may lack evidence of suicidal intent (such as a farewell letter) and are misclassified as accidents.
- Cases without clear suicidal intent were excluded from the dataset – typically poisonings or pedestrian-train collisions.
- Cases with unknown permanent residence or erroneous data (e.g., geocoordinates outside the study area) were excluded.

To improve clarity, the data were categorized more specifically than the standard suicide methods presented earlier, enabling more detailed interpretation:

- poisoning,
- stabbing/cutting,
- burning,
- jumping from a height,
- struck by a train/vehicle,
- electrocution,
- hanging,
- ingestion of acid/alkali,
- suffocation or drowning,
- firearm-related.

Database and individual-level variables

The primary database (PDB) was pre-processed individually in MS Excel and includes dozens of attributes such as: age, gender, marital status, suicide method, primary cause of death, category of cause, secondary causes, date body found, date of autopsy, permanent residence, location of death, psychiatric treatment, diagnosis, comor-

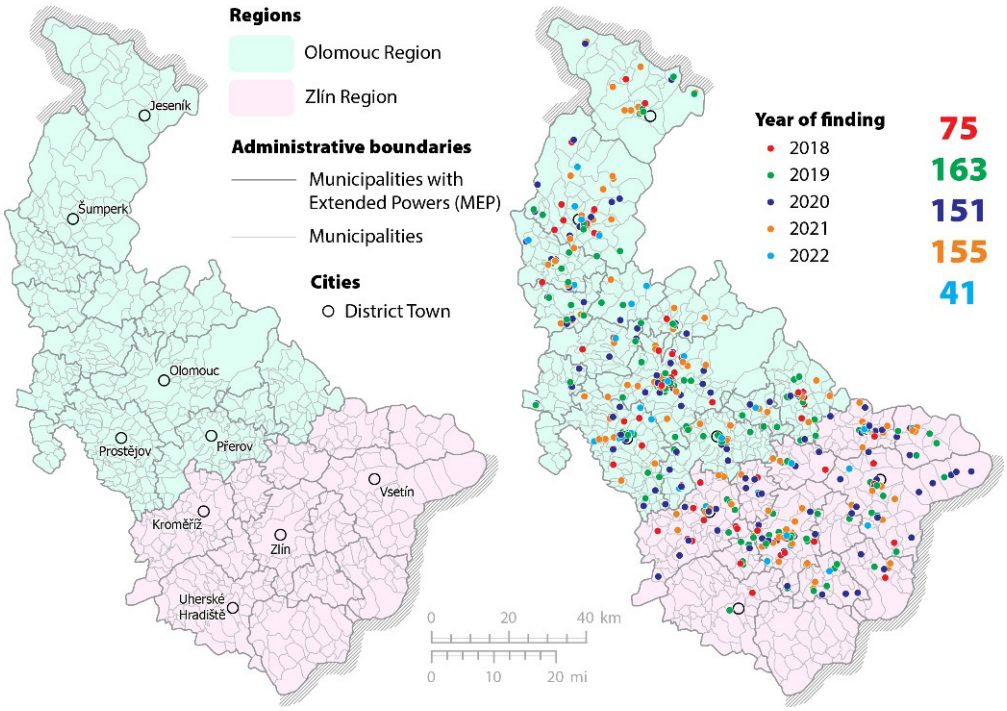

Fig. 3. Administrative units in the area of interest (left); The year the suicide was found between August 2018 and March 2022 (right).

bidities, history of suicide attempts, method of previous attempts, substance abuse (analgesics, alcohol), blood and urine alcohol levels, toxicology (e.g., lithium or clozapine presence), and personal difficulties as reported by doctors, relatives, or police. The analytical potential of this database is extensive, especially with its unique geospatial context. This paper focuses only on selected attributes.

Spatial data and area-based indicators

For conversion into a geodatabase (GDB), two spatial attributes were used: the place of permanent residence and the place of suicide, based on address. These addresses were automatically converted to GPS coordinates and exported to CSV with UTF-8 encoding for secure import into ArcGIS Pro version 3.4.3.

Two-point data layers were created – one based on permanent residence (PR), the other on place of suicide (PS). These spatial layers were further processed in GIS software. Thanks to precise data on the residential address and the location where the body was found, the information can be processed with coordinate-level accuracy (tens of meters) or aggregated into administrative units. For certain types of spatial analyses, exact geolocation of the place of residence and the suicide site is valuable, e.g., for studying the distance between the two. For most other statistically driven analyses, data can be aggregated into administrative units to assess relationships with specific characteristics of those areas. The chosen level of spatial resolution is therefore always justified in the methods section. Fig. 3 shows the administrative units of the area of interest and the most detailed possible localization of data records based on the location where the body was found.

Additional spatial and area-based datasets were incorporated to examine potential contextual associations. These included demographic and socioeconomic indicators, land-use data derived from the CORINE Land Cover database (croplands, grasslands, forest lands, wetlands, etc.), and composite indices developed by the Department of Geoinformatics, Faculty of Science, Palacký University Olomouc. For example, the Quality of Life Index was calculated based on 14 indicators encompassing socioeconomic, environmental, and accessibility-related variables[21-23]; urban–rural classification of municipalities was derived using a fuzzy inference approach[22], etc. Selected area-based characteristics analyzed in relation to suicide rates included unemployment rate, number of foreclosures per capita, proportion of religiously affiliated populations, land-use composition (agricultural and forest land), and net migration balance.

The Quality of Life Index was constructed as a composite indicator reflecting multiple dimensions of living conditions. Although some variables (e.g., unemployment) are more directly linked to suicidality, others were included to capture broader infrastructural and social aspects of quality of life, in line with previous regional quality-of-life studies.

Unless otherwise stated, all analyses are based on a database based on the suicide location.

Statistical analysis

Descriptive statistics were used to summarize individual-level characteristics of suicide cases. Associations between categorical variables (e.g., gender and suicide method) were evaluated using chi-square tests of independence. Non-parametric Spearman's rank correlation coefficients were calculated to assess relationships between suicide rates and selected area-based indicators.

Analyses were conducted separately at the municipality level and at the level of municipalities with extended powers (MEP) to evaluate scale effects. Suicide rates were expressed as the number of suicides per 1,000 inhabitants. Both statistically significant and non-significant results were recorded.

Spearman's rank correlation coefficient was used as a measure of both the direction and magnitude of association. Correlation coefficients below 0.3 were interpreted as weak, values between 0.3 and 0.5 as moderate, and values above 0.5 as strong associations. No additional effect size measures or confidence intervals were calculated, as the study was designed as exploratory.

Methodological limitations

Several methodological limitations must be considered. Spatial analyses relied on address-based geocoding rather than GPS-recorded death locations, which may introduce positional inaccuracies, particularly in relation to land-use classification. Aggregation of point-level data into administrative units is subject to scale effects and the modifiable areal unit problem. Furthermore, area-based indicators cannot capture individual psychosocial factors, and correlations observed at aggregated levels should not be interpreted as evidence of causation.

RESULTS

Descriptive overview: AOI vs. Czech Republic

The study dataset includes records from the period between August 27, 2018, and March 30, 2022. Since the timeframe does not cover full calendar years, the national data used for comparison correspond to the closest available time period evaluated by the Czech Statistical Office – namely, 2018–2022 (ref.[25]).

In the Czech Republic, hanging is the most common method of suicide. During the observed period of 2018–2022, hanging accounted for 51.9% of all suicides, followed by firearm-related deaths (13.5%), jump from a height (11.8%), poisoning (9%), and less frequent methods such as jump in front of a car or train, self-inflicted injury caused by a sharp object, drowning, and others (Fig. 4).

In the observed region of the Olomouc and Zlín Regions, the statistics differ slightly (Fig. 5). While the proportion of hangings is very similar to the national average, the number of firearm-related suicides is lower (8.2% in the study area vs. 16.4% nationally). On the other hand, higher proportions were recorded for suicides involving jumping from a height or stepping in front of a car or train.

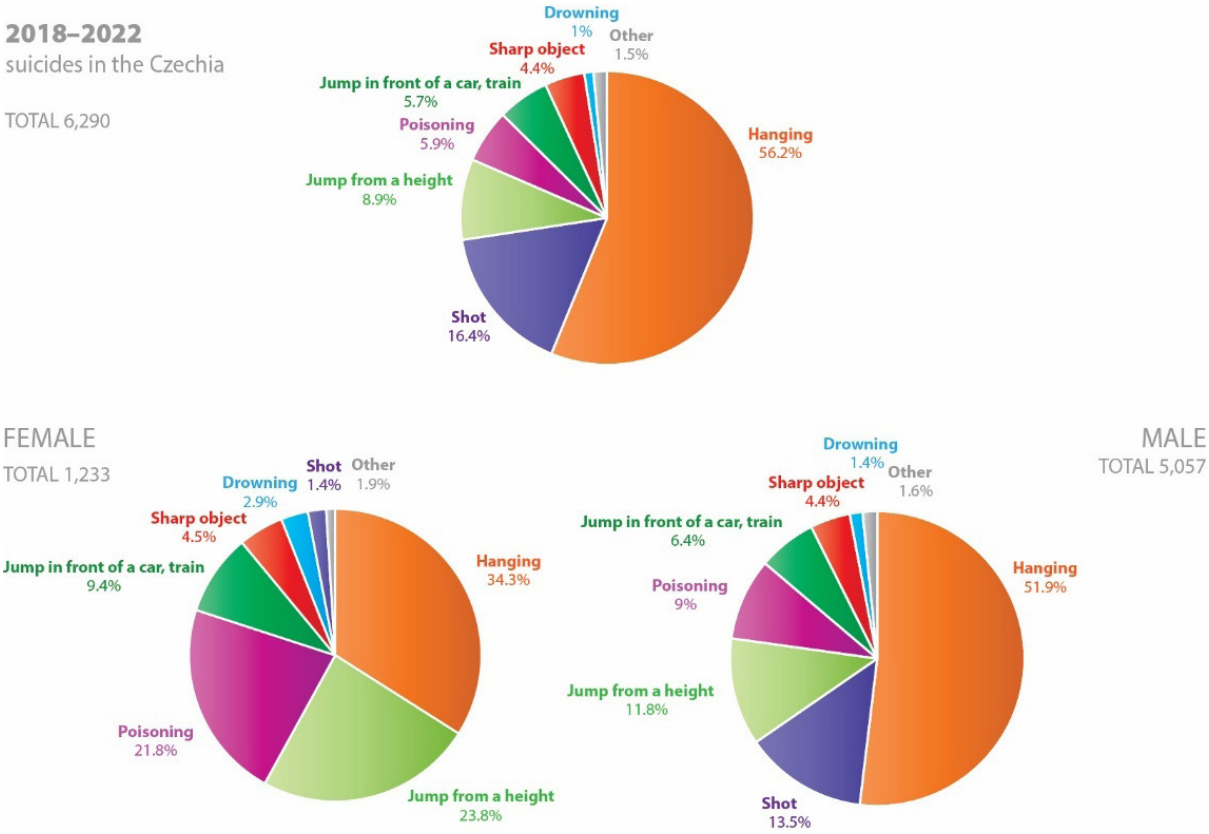

Fig. 4. Suicide methods in the Czech Republic in the period 2018–2022; Based on data from the Czech Statistical Office (ref.[25]).

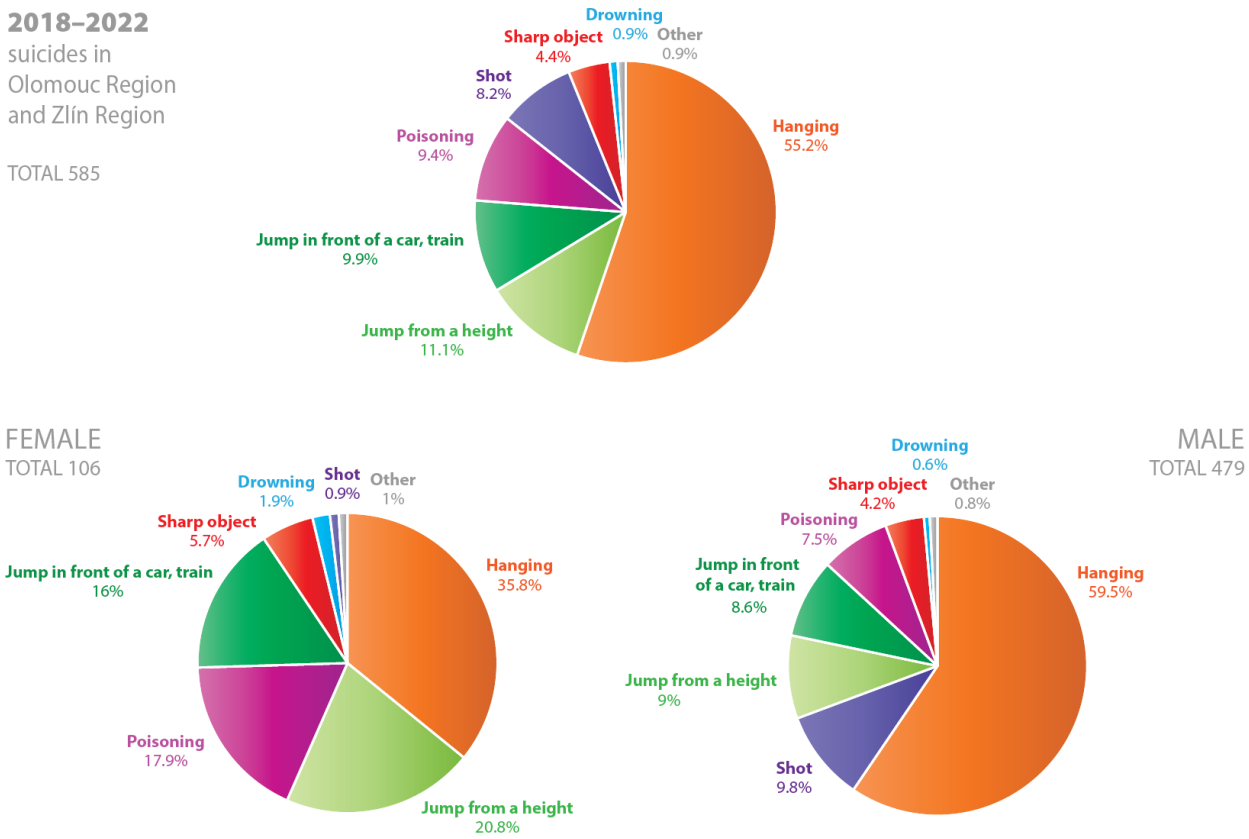

Fig. 5. Suicides in the Olomouc region and the Zlín region in the period 2018–2022. Based on the unique dataset made by Palacký University Olomouc. Pie charts are used to illustrate the composition of suicide methods in the regions under study.

The differences in the proportions of suicide methods between the Czech Republic as a whole and the AOI are not substantial (Fig. 6). This can partly be attributed to the fact that the Olomouc and Zlín Regions are home to over 11% of the Czech population, making the dataset sufficiently representative.

However, different patterns may emerge when comparing values across smaller administrative units, which represents the first step toward geospatial analysis. It is essential to exercise great caution when determining the size of the territorial units used for comparative analysis and how the results will subsequently be interpreted.

Comparison with European or global suicide statistics is of limited relevance in terms of methods of suicide, as this area is highly influenced by regional and cultural factors. However, studies on related topics offer valuable insight (ref.[5-16]).

AOI: Non-spatial analyses

A fundamental WHO-recommended analysis involves dividing total suicides by gender; further statistics are examined in this structure[1]. The first analysis, therefore, explored the relationship between gender and cause of death.

Gender vs. Method of execution: Relative representation by category shows that men most often die by hanging, while women use a more varied range of methods. The correlation is statistically significant (P<0.01), indicating a strong relationship between variables. For example, if the cause of death is firearm-related, it is much more likely to involve a male. Table 1 presents "expected" values (assuming no relationship between variables) compared to actual values and the variance. For instance, fewer women die by hanging than expected, while more women die by poisoning or jumping.

Gender vs. Age: One of the most frequently examined variables is age. The proportion of men and women does not vary significantly with age in the observed territory or time period.

Gender vs. Blood alcohol concentration: The WHO has identified several key risk factors, including alcohol dependence[3]. Analysis of the "blood alcohol concentration" attribute revealed that 65% of individuals who died by suicide had a non-zero blood alcohol level. Although the number of individuals with high blood alcohol content (>1‰) was relatively low, a clear trend emerged: men were more likely than women to have alcohol present in their blood (68% vs. 43%).

Seasonal variation: Another commonly held belief is that suicide is more prevalent in winter, when depressive symptoms are thought to be more common. Seasonal analysis showed some variation in suicide frequency: March, April, May (spring, 23.6%); June, July, August (summer, 23.4%); September, October, November (autumn, 27.7%); and December, January, February (winter, 25.3%). However, these differences were not substantial, and January had the lowest number of suicides (6.3%) throughout the year. Seasonal variation in suicide occurrence was examined using only descriptive frequency distributions. No inferential statistical testing was applied to assess seasonality. A more detailed analysis of additional factors not included in the PDB would be required for a qualified interpretation of this seasonal data.

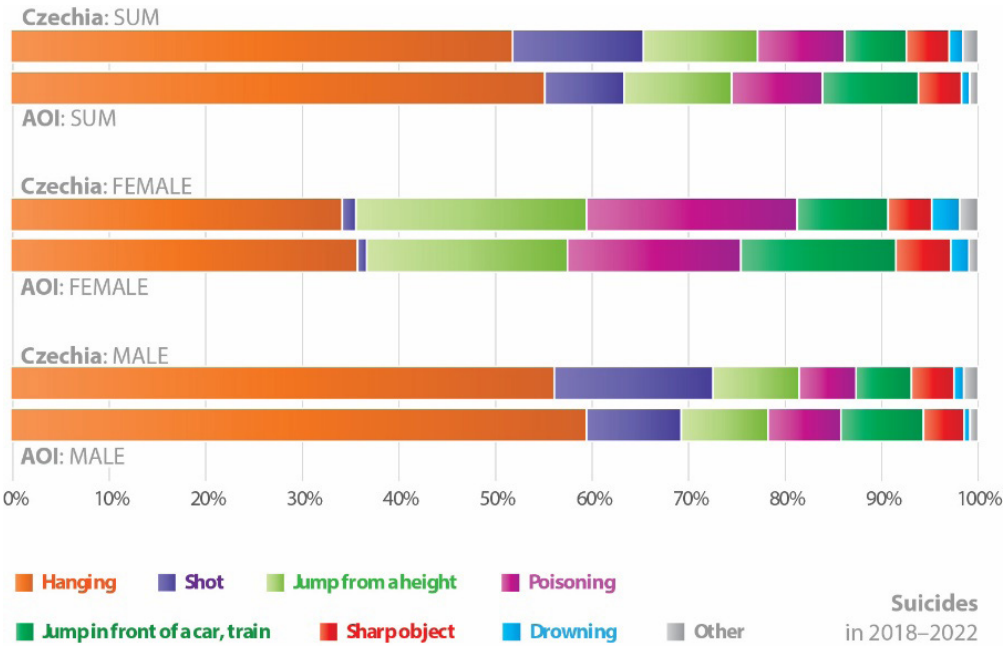

Fig. 6. Structure of suicides by the method of execution in the period 2018–2022; Based on data from Czech Statistical Office[25] and the unique dataset made by Palacký University Olomouc. Presented charts are suitable for comparing the values of individual items across the observed characteristics.

Table 1. Variation in the probability of the method of committing suicide when taking into account the gender aspect (based on the real data) and without taking it into account (expected values).

Method of execution	Male		Female		Expected values
	Variability	Real values	Variability	Real values	
Hanging	3.5%	48.7%	45.2%	−3.5%	6.5%
Shot	1.3%	8.0%	6.7%	−1.3%	0.2%
Jump from a height	−1.7%	7.4%	9.1%	1.7%	3.8%
Poisoning	−1.5%	6.2%	7.7%	1.5%	3.2%
Jump in front of a car/train	−1.1%	7.0%	8.1%	1.1%	2.9%
Sharp object	−0.2%	3.4%	3.6%	0.2%	1.0%
Drowning	0.1%	0.5%	0.4%	0.1%	0.3%
Other	−0.0%	0.7%	0.7%	0.0%	0.2%

Age vs. Marital status: A chi-square test of independence examining the association between age group and marital status (categories single, married, widowed, and divorced) yielded a highly significant result (χ^2=311.59, df=24, P<0.001). Row percentages showed that younger decedents (under 40) were overwhelmingly classified as single (over 70%, peaking at 100% in the 0–19 group), while middle-aged groups (40–69) had the highest shares of married individuals (43–68%). The share of widowed cases increased sharply in the oldest groups, dominating in the 80–89 (56%) and 90+ (100%) cohorts. Standardized residuals indicated that single was markedly over-represented in younger age groups (e.g., +5.94 in 20–29), married in the 60–79 groups (+2.65 and +2.74), and widowed in the 80+ groups (+8.75 and +6.69), with corresponding under-representation patterns in other age–status combinations. The correlation between the number of suicides and age has been addressed at the international level by Bachmann[26]. Fig. 7 illustrates the marital status distribution by age group.

AOI: Spatial analyses

As previously mentioned, each recorded suicide is associated with two spatial attributes: the individual's place of permanent residence and the location where the body was found. These allow for further analyses that track the spatial variability of selected attributes using either location as a point of reference. The aim is to identify spatial relationships that could enhance understanding of how the surrounding environment influences both the incidence and specific patterns of suicidal behavior.

Additional spatial layers were added to the geodatabase. The selection and processing of these data types were guided by intensive interdisciplinary collaboration involving both medical and geoinformatics/cartography experts.

The **Quality of Life Index** was calculated according to the methods described by Rypl O. et al.[23]. The authors used 14 indicators to compute the index: Unemployment rate, Foreclosures, Employment in industry, Crime index, Emissions, Accessibility of centers, Accessibility of kinder-

Fig. 7. Marital status distribution by age group.

gartens, Accessibility of secondary schools, Accessibility of health care facilities, Unavailability of high-speed internet, Life expectancy of men, Population growth, Divorce rate index, and Religiously affiliated population.

The **Urban–rural classification of municipalities** was computed based on the approach described by Pászto V. et al.[22]. Input socioeconomic indicators included: Total population, Population per built-up area, Share of family houses among all permanently occupied dwellings, number of completed dwellings per 1,000 inhabitants, Population change (in %), Driving distance to the county seat (normalized in meters), and Urbanized area share (%).

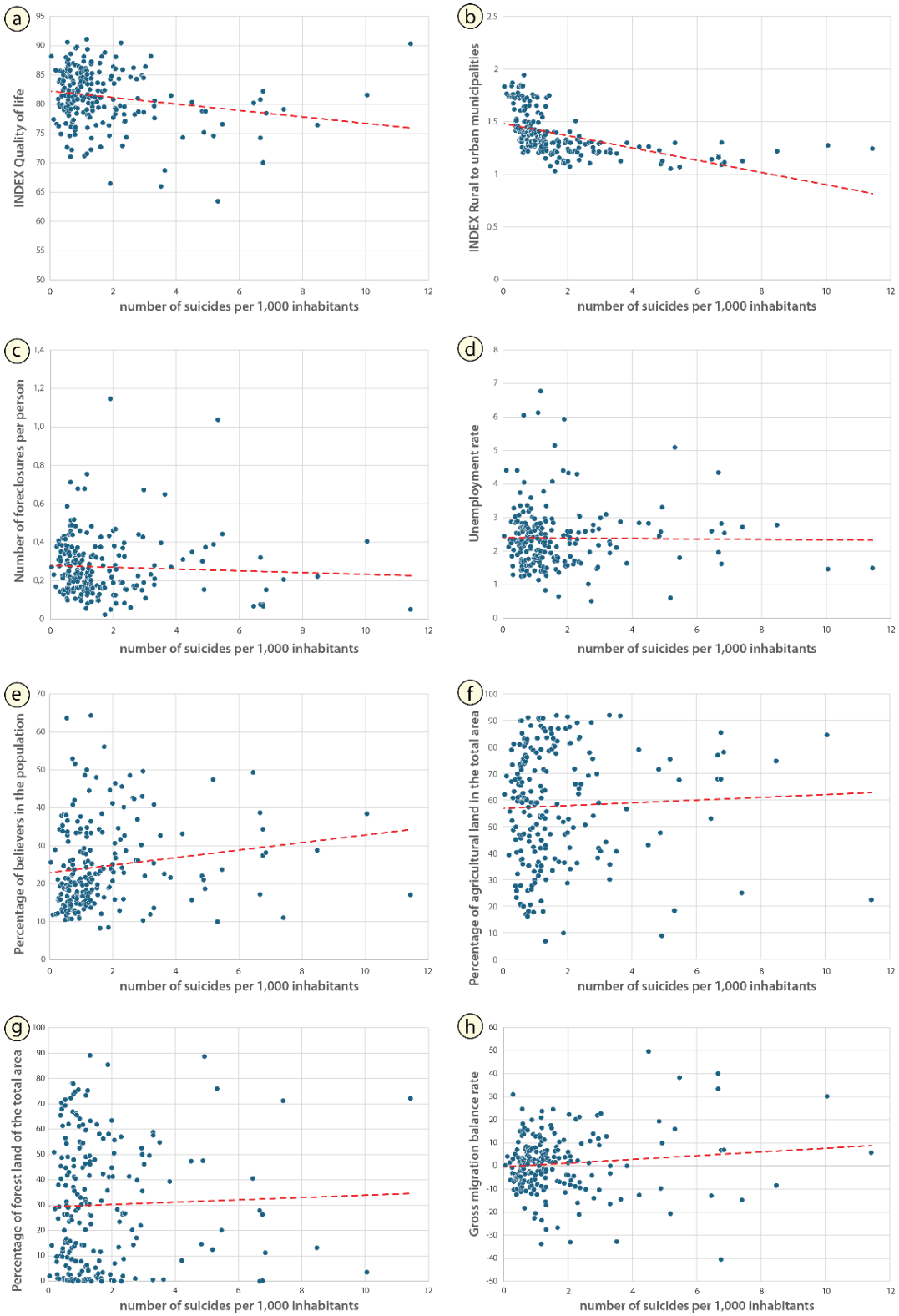

Fig. 8. Selected graphs calculating correlations between various phenomena and the number of suicides per 1,000 inhabitants.

Other **area-based characteristics** were of a simpler nature and included: number of foreclosures, unemployment rate, percentage of religious population, proportion of agricultural land, proportion of forest land, and net migration balance. The selection of these topics was based on expert consultations with geodemographers.

Spatial results: Municipality level

The initial set of spatial analyses was conducted at the municipality level. Suicide counts were converted to relative indicators (suicides per 1,000 inhabitants). Where appropriate, other datasets were normalized as well. Figure 8 presents selected themes examined for correlation with suicide counts per municipality during the study period:
(a) Correlation with the Quality of Life Index;
(b) Urban–rural classification of municipalities (lower values = rural, higher = urban);
(c) Number of foreclosures per capita;
(d) Unemployment rate;
(e) Percentage of religious individuals in the population;
(f) Share of agricultural land within total municipal area;
(g) Share of forest land within total municipal area;
(h) Net migration balance.

The topics were selected based on widely accepted assumptions that suicide rates may be influenced by factors such as quality of life, availability of natural recreational spaces (e.g., forests), or urban stress exposure.

Statistical correlations and the importance of spatial unit selection

Among the themes presented in Figure 8, statistically significant correlations were observed for the following:
(a) Quality of Life Index (Spearman's correlation coefficient = –0.171; P=0.012)
(b) Rural–urban index of municipality type (Spearman's correlation coefficient = –0.723; P<0.001)
(c) Number of foreclosures per capita (Spearman's correlation coefficient = –0.173; P=0.011)
(e) Percentage of religious individuals in the population (Spearman's correlation coefficient = 0.263; P<0.001)

Quality of Life Index: Fig. 9 presents a comparison of the Quality of Life Index and the number of suicides per 1,000 inhabitants. The correlation between these two variables is presented in numbers above; here, a map-based comparison is provided.

Spatial results: MEP Level

An alternative would be to aggregate data into larger spatial units. However, when analyzed at the level of administrative districts of municipalities with extended powers (MEP), the data are smoothed out to a degree that often obscures relevant patterns. For example, calculating correlation coefficients for variables such as the Quality of Life Index or the rural–urban classification is not mean-

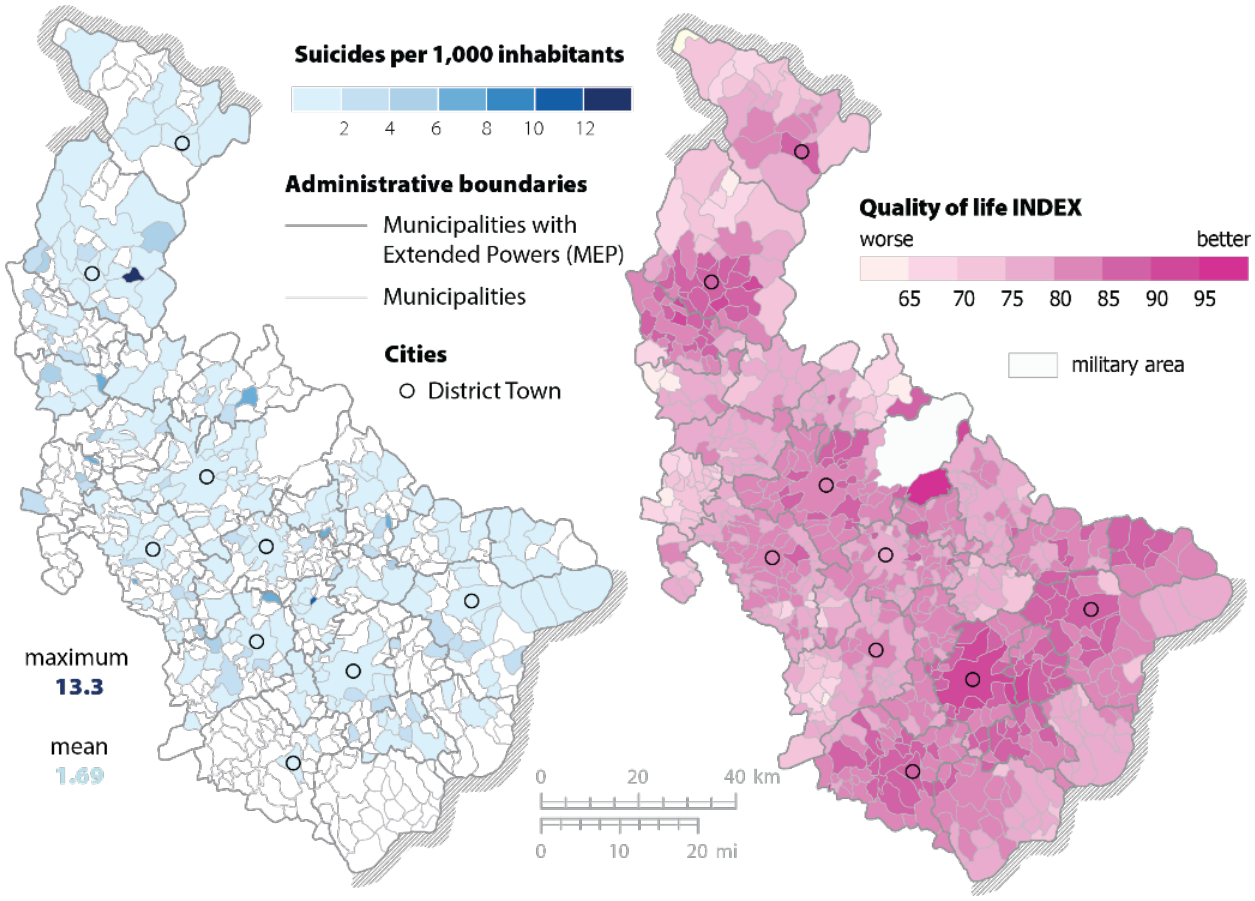

Fig. 9. Maps can be used to visually compare two different indicators; in the sample maps suicides per 1,000 population and a Quality of Life Index.

ingful at the MEP level, since significant differences in these indicators exist primarily between individual municipalities. At the same time, variability between MEP is much smaller.

On the other hand, using MEP-level aggregation may still be meaningful for indicators such as the number of foreclosures or religious affiliation, as these variables show meaningful differences even at higher administrative levels.

Suicides per 1,000 inhabitants: Fig. 10 illustrates how the choice of spatial unit is critically important for spatial variability analysis. There are large differences between value ranges (min/max), and it is the reason why different color scales were chosen: if a single uniform scale were applied, all MEPs would fall into the first category of the scale used for municipalities. As visualization largely influence user perception and the cognitive aspects of data interpretation, it is needed to follow the cartographic principles[27]. These maps are provided for illustrative and exploratory purposes only and do not serve as a basis for statistical inference.

Average Blood Alcohol Concentration: Fig. 11 shows the average blood alcohol concentration (BAC) among suicide cases where alcohol was detected (i.e., average of non-zero values). While no clear spatial pattern is observable at the municipality level, a more noticeable trend emerges at the level of administrative districts of municipalities with extended powers (MEP). Here, average BAC tends to increase toward the south, which corresponds to media reports[28].

A statistically significant negative monotonic relationship was found between latitude and average BAC: in northern MEPs, the average BAC is lower than in southern MEPs. *(Authors' note: This may be consistent with a general assumption that alcohol consumption is higher in southern Moravia, an area known for viticulture and fruit brandy production)*

The Spearman correlation between latitude and average BAC at the MEP level was –0.417 (P=0.038), indicating a statistically moderate association.

Comparison between indicators: In some cases, it makes sense to compare multiple indicators, as combining them can yield additional (interpretationally more complex) results. Fig. 12 presents two comparative maps created using a technique known as bivariate mapping. Two variables are shown, each divided into three quantitative categories, with each category combination assigned a distinct color. The left-hand map illustrates the relationship between blood alcohol concentration and the number of suicides per 1,000 inhabitants. A bright yellow color indicates a low suicide rate and high blood alcohol concentration; conversely, a cyan color indicates a low alcohol concentration and a high suicide rate. The top of the legend represents the highest quantitative values for both variables. The right-hand map shows a combination with the Quality of Life Index. In addition to statistical evaluation, spatial geovisualization can also be beneficial for experts, as it allows for visual comparison, which can reveal interesting spatial relationships.

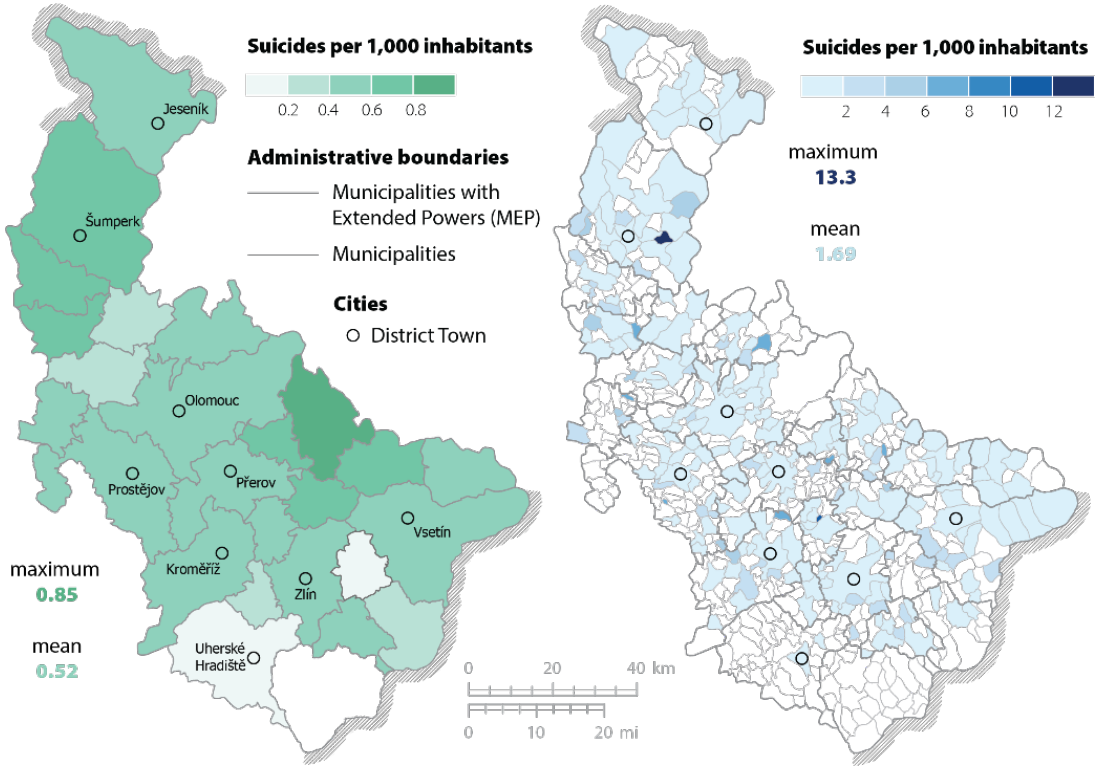

Fig. 10. Example of spatial variability of the phenomenon Suicides per 1,000 inhabitants in MEP (left) and in municipalities (right).

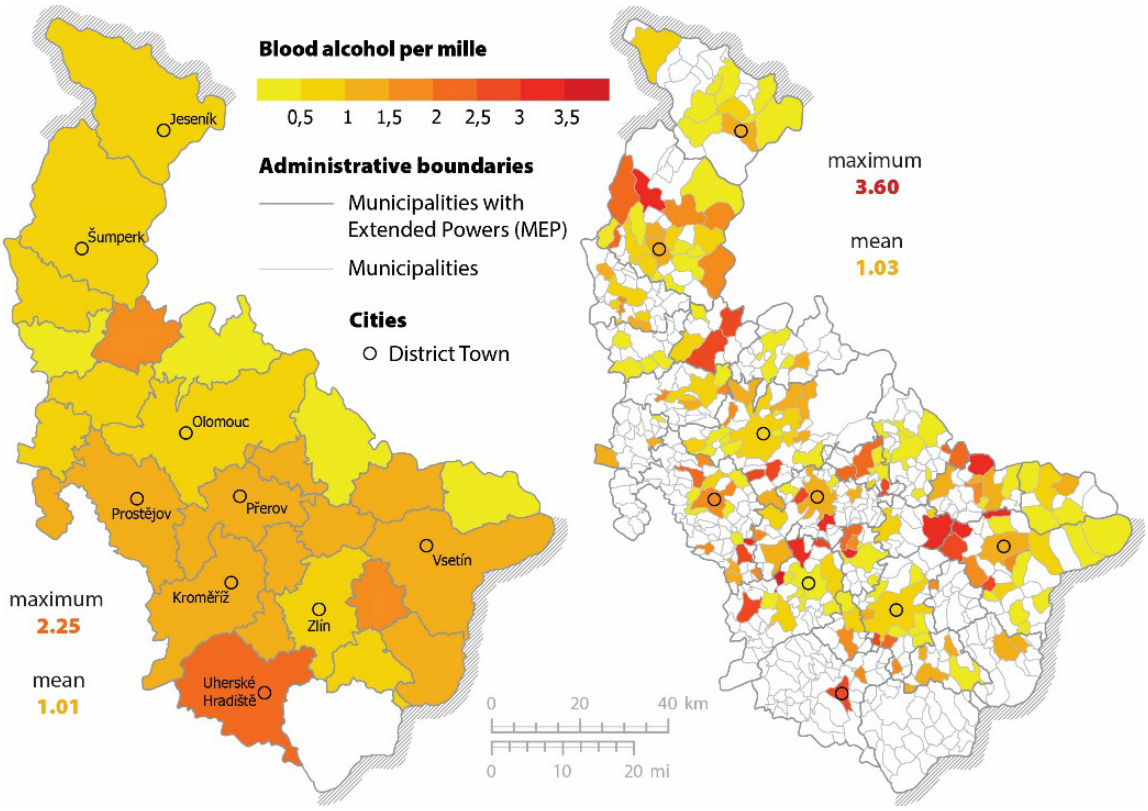

Fig. 11. Visible dependence of mean blood alcohol level and latitude in detail on MEP.

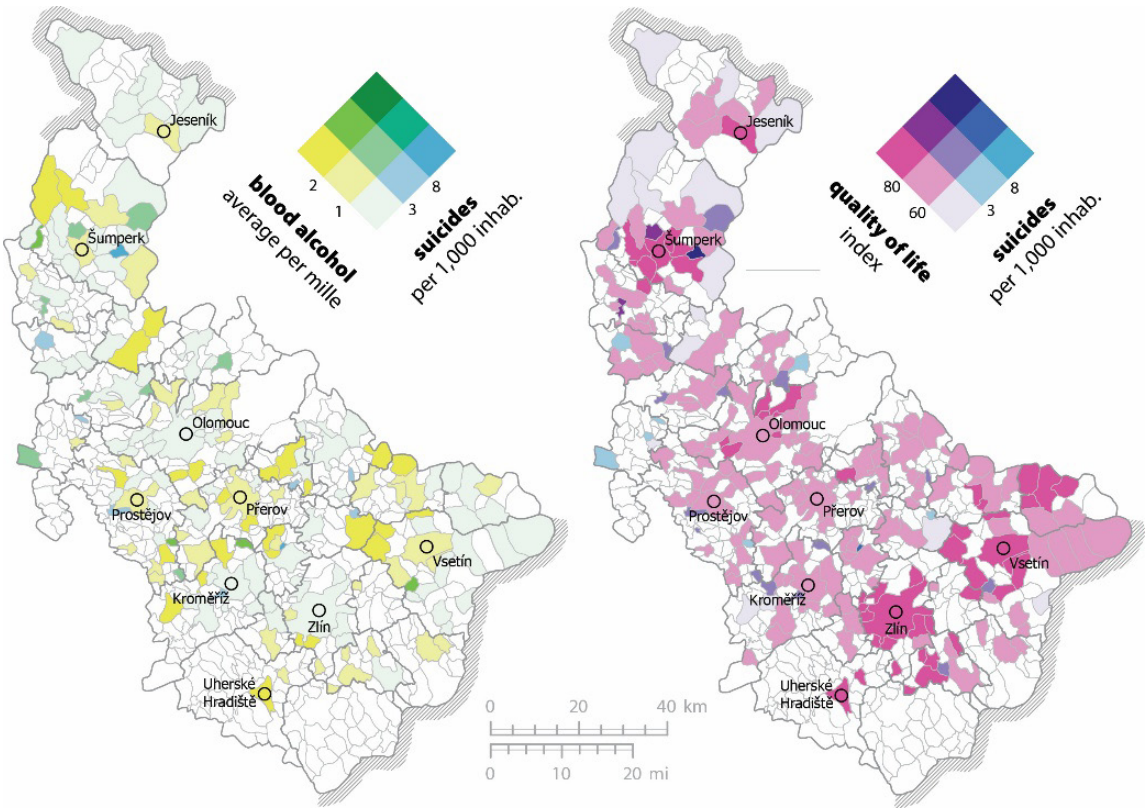

Fig. 12. Bivariate mapping presenting two different phenomena together in one legend; combination suicides per 1,000 inhabitants with blood alcohol average per mille (left) and quality of life index (right).

Residence vs. Suicide location: As previously noted, two spatial datasets were created at the beginning of the project: one based on permanent residence (PR) and the other on the location of suicide (PS). The place of suicide represents an interesting spatial variable in its own right.

Any individual could have been living long-term somewhere other than their registered permanent residence, though this cannot be determined from the records. According to the 2021 population census by the Czech Statistical Office, about 8.5% of the Czech population lives outside their place of official residence. Primary reasons include education, employment, family matters, or avoidance of administrative complications related to updating permanent residency. However, this phenomenon is prevalent in Prague and the neighboring Central Bohemian Region. In contrast, in the Olomouc and Zlín Regions, this mismatch is far less common: the number of people with a usual residence is only slightly lower than those with permanent residence. The ratio is 99.3% in Olomouc and 98.5% in Zlín. Thus, the likelihood that an individual does not actually live at their registered address is significantly lower than in other regions of the Czech Republic and is therefore considered statistically negligible in the context of this analysis.

This issue was studied in more detail because, if a suicide did not occur at home (i.e., the address of death differs from the address of permanent residence), the straight-line distance between the two locations was calculated. In cases where the individual did not truly reside at their registered address, this distance could introduce false-positive results. However, the degree of this distortion cannot be realistically quantified and is therefore considered insignificant.

In approximately 41% of records, the distance between residence and location of death is zero, meaning the two locations coincide. Among the non-zero records, the average distance is 32 km, the median distance is 6.5 km, and the maximum distance recorded is 1,005 km (Fig. 13).

Distance between residence and Suicide location vs. Age: Spatial analysis of the dataset revealed a weak but statistically significant negative correlation with age (ρ= –0.259; P<0.001). This suggests that the younger the individual, the greater the distance between their permanent residence and the location where the body was found. This may reflect greater mobility among younger people or the fact that younger individuals are more likely to reside long-term outside their officially registered place of residence.

Distance between residence and Suicide location vs. Land use: A weak correlation was also found with land use type at the location of the body (ρ=0.12; P=0.0018). Land use types were The longest distances between residence and place of suicide occurred in urban areas, near water bodies, and in natural or agricultural landscapes. However, proper interpretation of this finding requires additional context, e.g., whether the person had previously lived in the area, possibly returning to a former place of residence.

Land use vs. Method of execution: No statistically strong correlation was found between land use type and method of suicide execution (P=0.376). It should be noted, however, that the land use data (from the CORINE Land Cover database) are highly dependent on the precision of the location data for where the body was found (croplands, grasslands, forest lands, wetlands, etc.). These locations are not yet routinely collected as geographic coordinates, but rather as postal addresses. For example, a suicide may occur at the edge of a forest, but the ambulance might have been parked on a road, and the death is recorded as occurring at the nearest address point – mapped in a different land use category. This limitation could be addressed in the future if data collection protocols are updated to include GPS-based field localization of death sites.

DISCUSSION

Summary of key findings

This study introduced a unique dataset of completed suicides from 2018 to 2022, where the body was found within the Olomouc or Zlín Regions. The main objective was to demonstrate the possibilities of spatial data processing and the analytical potential of interdisciplinary collaboration between medical and geoinformatics experts. The analyses conducted revealed statistically significant relationships between socio-environmental

Fig. 13. The link between the permanent residence and where the suicide was found.
Basemap source: © OpenStreetMap contributors, ESRI, USGS.

characteristics and suicidal behavior – important findings given that suicide is generally considered a deeply personal act.

Socioeconomic context and environmental factors

Some known assumptions were confirmed, such as the higher incidence of suicides among men and the association with alcohol. At the same time, new spatial relationships were identified – for instance, a negative correlation between average blood alcohol concentration and geographic latitude, or the influence of land use type on the distance between place of residence and place of suicide.

We find that the socioeconomic characteristics of an area (e.g., number of people in foreclosure proceedings, religiosity, quality of life index) may play a role in shaping the risk environment for suicidal behavior. However, these conclusions require further verification and enrichment through deeper sociological and psychological data. The study also highlights the need for interdisciplinary collaboration, standardization, and improvement in the collection of geographically precise death records.

Ecological fallacy and spatial unit effects

Surprisingly different interpretations and conclusions may emerge depending on the spatial level of analysis. In an administrative district with a high number of suicides, one municipality may be severely affected while the rest are not, and aggregation may conceal this disparity. Relationships observed at the aggregated level (MEP, administrative districts of municipalities with extended powers,) may not reflect those present at the level of smaller units (individual municipalities). This is a well-known statistical phenomenon referred to as ecological fallacy.

This also occurs within our dataset. When analyzing the relationship between the number of foreclosures and suicides at the MEP level, Spearman's correlation coefficient is 0.443 (P=0.023). For the proportion of religious individuals in the population, Spearman's ρ=–0.461 (P=0.018). Both relationships are statistically significant but point in the opposite direction compared to municipality-level data: the higher the number of foreclosures per capita, the higher the suicide rate; and the higher the proportion of religious individuals, the lower the suicide rate. This reversal provides a cultural and historically plausible interpretation, but the validity of such conclusions must be grounded in deeper socioeconomic understanding. These opposite trends do not necessarily indicate an error – they may simply reflect a different analytical context. Understanding the true significance of these relationships would require further investigation into psychology or sociology.

This principle applies equally when exploring correlations between environmental indicators and individual suicide cases (i.e., using non-aggregated data). The strongest relationship observed was between foreclosure rate and religious affiliation: a strong negative correlation was found (ρ= –0.697; P<0.001), suggesting that more religious municipalities tend to have fewer residents in foreclosure proceedings. This finding may be consistent with the general hypothesis that stronger social cohesion and normative frameworks may serve as protective factors against socioeconomic decline. Notably, foreclosure is often cited as a significant factor influencing individual decisions to die by suicide.

A weaker but still statistically significant correlation was also found between the proportion of people in foreclosure and the suicide method category (ρ= –0.108; P=0.009).

These findings illustrate how effect sizes and even the direction of correlations may change depending on spatial aggregation, underscoring the importance of cautious interpretation rather than causal inference. The study demonstrated that the choice of spatial aggregation level has a substantial impact on result interpretation – relationships observable at the municipal level may differ at the MEP level.

All the spatial analyses presented above were based on the PR dataset – i.e., locations based on the deceased persons' permanent residence. Although the place of permanent residence does not always reflect where the individual actually lived long-term, the results may be consistent with the theory that the socioeconomic context of a person's living environment may, to some extent, influence the nature and trajectory of suicidal behavior.

Methodological considerations and limitations

Research based on such detailed suicide data as found in the presented PDB introduces new challenges. Advancing technology has brought about the possibility of sharing information between medical professionals (e.g., patient records, medication data), and in the future, potentially more effective data integration with other entities such as police departments and national population registries.

Although the research team, led by the primary author, also recorded information from the Czech Police, such as whether a farewell letter was present and the presumed reasons for suicide, the number of well-documented records remains too low to support comprehensive statistical analyses. This is expected to improve in the future.

In addition to seeking a broader context from personal data, it is also essential to explore spatial relationships. Spatial analyses can, for example, reveal inconsistencies in the classification of cause of death (as discussed in the introduction) and may include more detailed demographic, economic, and physical geographic characteristics of the location where the individual lived or died. These insights can enrich our understanding of how environmental conditions influence both the qualitative and quantitative aspects of suicidal behavior.

Caution must be exercised in interpreting correlations between suicide data and any spatial indicator. For example, Spurious Correlations[29] illustrates how random high correlations can occur between unrelated variables. However, in the present study, all spatial and non-spatial relationships explored were based on logically justifiable topics chosen before statistical testing.

In interpreting correlation analyses, the spatial aggre-

gation level plays a crucial role. In our case, we found that Spearman correlations between suicide rates and selected indicators may differ in direction when analyzed at the municipality level versus the MEP level. This discrepancy is partly due to the effect of aggregation: municipalities capture finer spatial detail and are more sensitive to outliers in small populations, whereas MEP-level data smooth out these local variations, potentially reversing the apparent relationship. This can be further compounded by the ecological fallacy, where patterns observed in aggregated data (e.g., at the MEP level) may not hold for individuals or smaller spatial units (e.g., municipalities). It is therefore essential to consider the nature of the data, the size of spatial units, and the influence of spatial configuration when comparing results across different levels.

Practical example of such situation is, that – given the nature of the data and its limitations – the following preliminary conclusions may be suggested from the statistical analyses: the more urban the municipality, the lower the suicide rate; a higher number of foreclosures per capita is associated with a lower suicide rate; a higher proportion of religious individuals is associated with a higher suicide rate. These patterns may be caused by the improper size of the spatial units used in the analysis. As mentioned, in small municipalities, the instability of ratio-based data (rate volatility) becomes a problem. This occurs when indicators are calculated as ratios based on a small denominator (i.e., small population). As a result, even a minimal number of suicides can create the impression of a critical situation (in one municipality the suicide rate is reported as 13.3 per 1,000 inhabitants, which is caused by two suicides in a population of 150). Other possible approaches to address rate instability include temporal aggregation or weighted correlations; however, these were beyond the scope of the present exploratory analysis.

Although the study period overlaps with the COVID-19 pandemic, the aim of this study was not to assess temporal trends or pandemic-related effects, but to explore spatial patterns across the study area. Moreover, the use of forensic autopsy records mitigates some of the distortions observed in aggregate mortality statistics during the pandemic period.

Ethical aspects of spatial suicide research

A final and essential theme in the discussion is ethics. Suicide research inevitably raises ethical questions. All data used in this study were anonymized, and no identifiable individuals were tracked. Nevertheless, the nature of the data – death, cause, mental health, etc. – is highly sensitive, and care must be taken to ensure that results are presented only in aggregated form (e.g., by municipality) to avoid enabling local residents to identify specific individuals. A key ethical principle is thus the protection of the dignity of the deceased and their families.

Detailed spatial analyses may also lead to stigmatization of certain communities or regions, so it is critical that results are always interpreted within an appropriate context.

Implications for future research and practice

If the PDB continues to be expanded, it will be possible to conduct much more detailed analyses in the future. In the Czech Republic, for instance, a patient's medication record system is now accessible to registered physicians and pharmacists. This allows for the identification of medications used by the deceased and the healthcare providers involved. A comprehensive electronic health record system is also planned, which will enable researchers to explore the links between psychiatric illness and the method of suicide.

A key question for the future is whether a sufficiently large and detailed dataset could support predictive modeling to inform early warning systems and targeted suicide prevention. This could also lead to the identification of high-risk areas for focused intervention.

CONCLUSIONS

This study demonstrates the potential of spatial analysis to enhance suicidological research by integrating forensic, medical, and geoinformatics data. Using a unique dataset of completed suicides from the Olomouc and Zlín Regions, the analyses identified several spatial and non-spatial patterns that provide insight into the socio-environmental context of suicidal behavior.

The findings highlight that relationships between suicide rates and area-based characteristics depend strongly on the spatial scale of analysis. Associations observed at the municipality level differed from those identified at the level of administrative districts of municipalities with extended powers, underscoring the importance of multi-scale analysis and cautious interpretation of aggregated data. This scale dependency represents a key methodological insight with implications for future spatial suicide studies.

Rather than establishing causal mechanisms, the results should be understood as exploratory and hypothesis-generating. They suggest that socioeconomic context, environmental characteristics, and geographic patterns of risk behavior may contribute to shaping suicide-related outcomes and merit further investigation using interdisciplinary approaches.

Future research should focus on expanding spatially precise suicide datasets, improving the accuracy of death location recording, and integrating geospatial analyses with richer psychosocial and healthcare data. Such efforts may support the development of more context-sensitive suicide prevention strategies while maintaining strict ethical standards and respect for the dignity of affected individuals and communities.

The study has yielded findings that form a foundation for further research.

ABBREVIATIONS

AOI, Area of Interest; BAC, Blood Alcohol Concentration; GDB, GeoDataBase; MEP, Administrative districts of Municipalities with Extended Powers; NIMH, National Institute of Mental Health; NUTS Nomenclature of Territorial Units for Statistics; PDB Primary DataBase; PR, Permanent Residence; PS, Place of Suicide; WHO, World Health Organization.

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