



Original scientific paper

UDC: 314.4(497.11)

<https://doi.org/10.2298/IJGI260618020G>

Received: June 18, 2026

Reviewed: August 5, 2026

Accepted: September 17, 2026



HUMAN CAPITAL AND AVOIDABLE MORTALITY ACROSS SERBIAN MUNICIPALITIES: A SPATIAL-ECOLOGICAL ANALYSIS

Marko Galjak¹ * , Marina Budic² 

¹Institute of Social Sciences, Demographic Research Centre, Belgrade, Serbia; e-mail: galjak@gmail.com

²Institute of Social Sciences, Centre for Philosophy, Belgrade, Serbia; e-mail: mbudic@idn.org.rs

Abstract: There is a strong association between education and mortality. However, the relationship between education and avoidable mortality is understudied in Serbia. In this study, data on education from the 2022 Census and vital statistics covering 2015–2019 are combined to examine whether human capital at the municipality level is associated with avoidable mortality (amenable and preventable) across 162 municipalities. Education was measured by age/sex standardized mean number of years of schooling of persons aged 25+. Mortality was classified with avoidable cause lists and age-standardized. Descriptive mapping was conducted, spatial autocorrelation was tested, mortality was assessed using Moran's I index, and log-mortality models were estimated with ordinary least squares and spatial econometrics techniques. Residuals, Lagrange-multiplier tests, likelihood-ratio tests, information criteria, and parsimony were used in modeling decisions. Amenable and preventable mortalities were studied by estimating a stacked mixed-effects model with municipality-level random intercepts. Education and avoidable mortality have a strong regional component in Serbia, but the cores of both phenomena did not match. Higher standardized mean years of schooling were concentrated near major cities, while avoidable mortality was high in the northern parts of Vojvodina. Once adjusted for region and degree of urbanization, municipal education was significantly negatively associated with mortality. A one-year higher age/sex standardized mean schooling level was associated with an approximately 10% reduction in the rate of avoidable mortality, which was the most pronounced for amenable and the weakest for preventable deaths. For Serbia, higher area-level education is most strongly associated with mortality sensitive to healthcare intervention.

Keywords: avoidable mortality; human capital; education; municipal inequalities; Serbia

1. Introduction

Avoidable deaths, which can be prevented through early treatment and preventive actions, are used as useful benchmarks for judging whether the healthcare needs of a country are met (Kossarova et al., 2009; Nolte & McKee, 2011). The distribution of avoidable deaths is rarely homogenous within a particular state, and educational attainment is consistently associated with premature mortality (Hummer & Lariscy, 2011; Mackenbach et al., 2008). However, when it comes to Serbia, the connection between these two spheres is rarely

*Corresponding author, e-mail: galjak@gmail.com

explored since they are investigated independently: one concerns human capital, and the other one is an indicator of health system efficiency.

1.1. Education, avoidable mortality, and the amenable–preventable distinction

The fact that education is strongly associated with mortality represents one of the oldest and most persistent findings in population health. While the association is substantial in high-income countries, exists independently of the effect of income and occupational class, and experimental analyses indicate that at least some portion of the relationship is causal, and not only selectivity-driven (Hayward et al., 2015; Lleras-Muney, 2005), the functional form is non-linear as it is characterized by higher returns to education around threshold levels of attainment (Montez et al., 2012). However, it persists across nearly all major causes of mortality (Hummer & Lariscy, 2011). The underlying mechanisms of the protective effect of education are less well-understood. There are three primary pathways that have been proposed: material advantages, healthy behavior profiles, literacy and risk assessment skills of the better-educated which allow them to make use of the acquired information (Cleland & van Ginneken, 1988; Rogers et al., 2013; Todd et al., 2016).

The scale of the education–mortality gap is not constant across Europe and changes both spatially and temporally (Mackenbach et al., 2013). In the comparative analyses conducted by Mackenbach and colleagues, it was demonstrated that relative mortality differences were small in some regions of southern Europe and unusually large in the Nordic countries, while being the largest and constantly growing in the post-socialist east (Mackenbach, 2006, 2017; Mackenbach et al., 2008). The transition in the former socialist countries was marked by large inequalities in survival by education, mediated through increased mortality due to circulatory disease and external factors, alcohol consumption and mental stress (Kalediene & Petrauskiene, 2005; Leinsalu et al., 2009; Marmot & Bobak, 2005; Vandenheede et al., 2014; Walters & Suhrcke, 2005). The case of Serbia is situated within this regional context, but is comparatively poorly studied in that context: it is faced with a relatively high premature mortality burden concentrated largely in cardiovascular and neoplastic diseases (Penev, 2003; Santric Milicevic et al., 2009; Vlajinac et al., 2008), worsened by rapidly increasing age structure and pronounced regional differences (Kokotović Kanazir et al., 2026; Marinković & Anđelković, 2026). In comparative terms, life expectancy at birth in Serbia was 76.0 years in 2019, about five years below the European Union average of 81.1 years (Eurostat, 2026).

The measure encompasses deaths, below a certain age ceiling, from conditions which are considered avertable given the existing scientific knowledge and technology and includes both treatable (those that can be avoided with timely treatment) and preventable causes (those that can be avoided using non-medical interventions; Kossarova et al., 2009; Nolte & McKee, 2011). When combined, these lists are regarded as a widely used benchmark for the evaluation of the performance of the health-care system (Gavurová & Vagašová, 2017; Gay et al., 2011; Hoffmann et al., 2013), even if the definitions themselves are somewhat arbitrary and open to discussion (Simonato et al., 1998). Avoidable mortality is widely measured in Serbia: in recent years, it comprised the majority of gains in life expectancy, while the total burden remained high compared to western Europe, with preventable causes accounting for larger inequalities than amenable conditions, particularly among men (Marinković, 2022).

According to the fundamental causes theory, negative health outcomes are buffered by socioeconomic status because of its flexible resource basis (knowledge, money, influence, advantageous social networks), which may be applied to any particular problem of an era. As a result, the inequality in health would be expected to be the greatest in situations when effective means of avoidance exist and need to be actively employed (Link & Phelan, 1995; Phelan et al., 2010). The prediction of the theory—that greater inequalities will occur for preventable rather than treatable causes—was confirmed in the US (Phelan et al., 2004) and has been demonstrated for European countries as well (Mackenbach et al., 2015).

A geographical approach is made necessary by autocorrelation between mortality and area-level deprivation, by which the allocation of health care resources is also influenced (Lorant et al., 2001). Pronounced clustering of population and mortality indicators at the municipal level was identified in the geographical analysis conducted in Serbia (Nikitović et al., 2016), while wide variations in education-population outcome associations in different locations were found by spatial regression (Lović Obradović & Vojković, 2021). In general, north-south and center-periphery regional disparities have existed in the country for a long time (Joksimović & Golić, 2017; Miletić, 2006). However, spatial measures of education and avoidable mortality by cause have not been combined in any study conducted in Serbia.

1.2 The present study

All these components are incorporated in this research, in which the 2022 Census is used in combination with aggregate vital statistics data from 2015 to 2019 (pre-pandemic years) to determine the co-location pattern of educational achievement and avoidable mortality in Serbian municipalities. Spatial clustering is examined, and the relationship between the level of human capital at the municipal level and three mortality rates—total avoidable, health-care treatable (amenable), and preventable mortalities—are assessed. Throughout the paper, human capital—a broader construct that also encompasses skills, competences, and health—is operationalized through its most consistently recorded and internationally comparable component at the area level, educational attainment, expressed as the age/sex standardized mean number of years of schooling (Barro & Lee, 2013). To our knowledge, this is the first study for Serbia to examine spatial clustering, municipal educational attainment, and cause-specific avoidable mortality jointly.

2. Data and methods

2.1. Data sources

All datasets used have been provided by the Statistical Office of the Republic of Serbia (SORS, 2022, 2023). The level of educational attainment was based on information about the 2022 Census of Population, Households, and Dwellings, by single years of age, sex, and the highest achieved level of education for every individual residing in a particular municipality. Mortality figures were acquired by linking deaths by municipality of residence, sex, age, and underlying cause of death classified according to the tenth revision of the International Classification of Diseases. Persons under observation were calculated using the data of official annual population estimate by age and sex. Data concerning Kosovo and Metohija are not included in either census or vital statistics.

In the current study, an ecological design is followed, i.e., one in which the units of analysis are populations defined by administrative territories rather than individuals

(Morgenstern, 1995). Since the indicators of interest (education and mortality) were measured at the municipal level, no individual-level inferences can be drawn.

Educational attainment therefore refers to 2022, whereas mortality refers to 2015–2019. Completed education of persons aged 25 and over is largely fixed by early adulthood and is changed at the municipal level only slowly, through cohort replacement and migration; as the 2022 Census is the first one conducted after 2011, it is the closest available measurement of the educational structure that prevailed during the mortality period. The implications of this temporal mismatch are revisited among the limitations.

2.2. Spatial units

The municipality appears to be the proper administrative level at which the two types of data should be disclosed and at which regional policy on health and development can be implemented, and hence its use as the unit of analysis is justified. Six statistical municipalities, operating as subdivisions inside urbanized entities (the inner municipalities of Niš, as well as Vranjska Banja and Sevojno), do not have separate boundaries on the maps and cannot be used as cause-specific rates due to small cell sizes, and therefore are aggregated within their parent municipalities.

The rare occasions when deaths and populations were provided using different administrative levels for the same region, namely, the city of Novi Sad, were harmonized in order to match the numerators and denominators to the same geographic entity. After these aggregations and harmonization, the analytical data set comprised 162 municipalities.

2.3. Measuring human capital

Educational attainment varies across generations, and municipalities with larger proportions of older residents tend to have lower overall attainment in Serbia (Kokotović Kanazir et al., 2024). Family-related barriers to continued schooling are also documented by research in rural Serbia, including attitudes discouraging women's education beyond primary school (Cvejić et al., 2010). That is why unstandardized municipal mean years of schooling may reflect differences in age–sex composition as well as differences in educational attainment within age–sex groups.

In order to disentangle those two variables, each attainment level was converted to years of education it represents (Barro & Lee, 2013). Then an age/sex standardized average number of attained years of education was calculated in relation to the national population, providing comparable municipalities with different age/sex composition. This variable will be used as the main exposure variable. However, as many differences might be masked by one aggregate value, two composition-related exposure variables were kept for sensitivity analyses: percentage of population aged 25 or more with higher education and percentage with primary education at most. Attainment was evaluated among population 25+ years old, since this age corresponds to the common denominator for completed education, and younger people were still enrolled in educational institutions, so that complete information about their attained level of education could not yet be obtained. These and other variables used in the study are listed and described in Table 1.

Table 1. Variables used in the study and how they were calculated or obtained.

Variable	How it is calculated or obtained
Standardized mean years of schooling (years)	Completed education is converted to years of schooling for adults aged 25+ with known education in the 2022 Census. Municipal averages are standardized to the national age–sex distribution.
Tertiary education (%)	Number of adults aged 25+ with tertiary education divided by all adults aged 25+ with known education, multiplied by 100; calculated from the 2022 Census.
Primary education or less (%)	Number of adults aged 25+ with no schooling, incomplete primary or completed primary education divided by all adults aged 25+ with known education, multiplied by 100; 2022 Census.
Age-standardized avoidable mortality	Deaths before age 75 from amenable or preventable causes, counted once, using official death records and annual population estimates for 2015–2019. Age-specific deaths/person-year rates are standardized to the 2013 European Standard Population and expressed per 100,000 person-years.
Age-standardized amenable mortality	Deaths from causes amenable to timely and effective health care, applying cause-specific age limits below 75. Calculated for 2015–2019 using the same age-standardization method; deaths per 100,000 person-years.
Age-standardized preventable mortality	Deaths from causes preventable through public-health action, applying cause-specific age limits below 75. Calculated for 2015–2019 using the same age-standardization method; deaths per 100,000 person-years.
Urban population (%)	Urban-settlement population divided by total population, multiplied by 100, from official 2019 estimates. For merged municipalities, percentages are weighted by the 2022 population aged 25+ with known education.
Distance to primary care (km)	Shortest straight-line distance from an interior point calculated from each municipality’s boundary to the nearest primary-care health center, using geocoded health-facility locations.
Distance to secondary care (km)	Shortest straight-line distance from an interior point calculated from each municipality’s boundary to the nearest general hospital, using geocoded health-facility locations.
Distance to tertiary care (km)	Shortest straight-line distance from an interior point calculated from each municipality’s boundary to the nearest tertiary-care clinical center, using geocoded health-facility locations.

2.4. Avoidable mortality

The avoidable deaths list was based on the established list of avoidable causes (Nolte & McKee, 2011); furthermore, there is another distinction made within the list between avoidable deaths that can be influenced by health care, and those that could have been prevented by broad public health actions or policies. The two lists intersect, meaning that an individual cause could be both amenable and preventable, thus, the definition of avoidable mortality was taken to include all deaths from the two lists without repetition, while deaths amenable and preventable were calculated separately, which resulted in larger numbers of the two than the sum of avoidable deaths. Finally, the three measures were used as separate measures because different processes by which the two types of mortality are influenced should be implied by the distinction between amenable and preventable deaths, whereby

the differences in the educational gradient can be analyzed. Following the rules associated with the classification, the avoidable deaths were calculated only for people under the age of 75, and each cause was limited to the corresponding age group.

The mortality period considered mainly refers to 2015–2019, that is, before the COVID-19 pandemic. Death counts and person-years were summed over these years in order to provide stabilization of municipality-specific cause-specific death rates without taking into account pandemic effects on the primary analysis. However, for sensitivity analysis purposes, a secondary pooled data set referring to 2020–2021, the pandemic period, was created by using the same procedures of harmonization at the municipal level, avoidable deaths classification, age criteria (under 75 years), period-specific denominator, and direct age-standardization approach.

Age adjustment was done directly to the European Standard Population 2013 (European Commission, Statistical Office of the European Union, 2013) for each mortality outcome using the same set of weights regardless of the particular cause. Since only people in the appropriate age brackets are affected by each specific cause, differences in age ranges are accounted for during the classification step, so every rate is then age-adjusted using the common age brackets under 75. All rates were calculated as deaths per 100,000 person-years, and approximate confidence intervals of 95% are provided based on direct standardization variances.

2.5. Statistical analysis

The analysis consisted of three stages. In the first stage, the joint distribution of education and each of the three mortality outcomes was characterized, and pairwise correlation between them was provided on the basis of rank correlation, a non-parametric measure. Next, all variables were checked for global spatial autocorrelation (Moran's I) due to the expected spatial structure in the data. Local spatial patterns were also identified using the local Moran's I statistic, by which High–High, Low–Low, High–Low, and Low–High clusters are identified for each variable in the map using 999 conditional permutations. If the two-sided p-value based on conditional simulations fell below 0.05, a municipality was assigned to the corresponding cluster. For the computation of Moran's I, a first-order queen contiguity matrix was used, row-standardized such that every municipality has at least one neighbor. As a robustness check, the five nearest neighbors method was additionally used. The logarithm of each mortality rate was modeled depending on standardized schooling. In the main specification, urbanization was controlled for (percentage of each municipality's population living in settlements classified as urban) since service supply and local population characteristics are affected by it. Additionally, region was controlled for (four NUTS-2 statistical regions: Belgrade, Vojvodina, Šumadija and Western Serbia, and Southern and Eastern Serbia). Since one of the most likely explanations of the effect under consideration could be the supply of services, on the basis of the geocoded national register of health institutions, distances to primary (health centers), secondary (general hospital), and tertiary (clinical-center) health institution in kilometers were calculated and controlled for in the alternative specification. Note that confounding by age composition is substantially reduced, although not eliminated entirely, as both the dependent and the explanatory variable are standardized by age.

OLS estimation was performed first, and residuals were examined for spatial dependence using Moran's I and Lagrange-multiplier (Rao score) tests for lag and error dependence (Anselin, 1988a; Anselin et al., 1996). Wherever significant spatial dependence was found,

SAR, SEM, and SDM models were estimated with the help of robust score tests (Anselin, 1988b; Elhorst, 2014). Where necessary, the appropriate model was chosen with the help of a likelihood ratio test of nested models compared to SDM, Akaike information criterion (AIC), and parsimony in case of similar AIC values (Elhorst, 2014; LeSage & Pace, 2009). In the SAR models, a regression coefficient does not represent the marginal effect since a municipality's health outcome is determined by the schooling of the neighboring municipalities as well, due to the spatial lag term. For this reason, estimates for the direct effect, indirect effect, and total impact of education on each outcome are provided with bootstrapped confidence intervals, which are defined as 95% simulation intervals of 1,000 simulated draws and interpreted as the total impact (LeSage & Pace, 2009; Rüttenauer, 2022). To examine directly the relationship between education and amenable vs. preventable mortality, these two variables were stacked in a single equation and the interaction between education and mortality outcome was added. This model is estimated using linear mixed models with municipality random intercept since two correlated observations are provided by each municipality and municipality-clustered standard errors (Bates et al., 2015). It is thereby ensured that the within-cluster correlation of mortality rates is taken into account in the variance of the interaction term. The distribution of municipal death counts was checked, and the effects were recomputed and local clusters re-identified using smoothed rates for sensitivity analysis (Clayton & Kaldor, 1987; Marshall, 1991). To conduct the sensitivity analysis for the period of the pandemic, the ordinary least squares model with log rates was recalibrated using the pooled rates from 2020 and 2021, taking into consideration the same educational risk factor, urbanization, and region fixed effect.

For all the statistical analysis and visualizations, R (Version 4.5.2; R Core Team, 2025) was used. All the data and R code necessary for reproduction of the analysis and figures are included in an open repository: <https://osf.io/7wq86/>

3. Results

3.1. *The two geographies*

There is significant geographical variation in educational attainment across Serbia (Table 2). Standardized years of education range from around 9.0 to 14.9—an interval of more than five years when adjusted for age and gender—with the higher values largely confined to the municipalities around the metropolitan centers of Belgrade and Novi Sad, and the lower to the rural areas of the east and southeast. Similarly, there is considerable variation in avoidable mortality in Serbia, although it tends to be greater, both absolutely and relatively: in the municipality ranked last in the indicator, around 2.8 times as many avoidable deaths are recorded as in the one that fares best (roughly 690 against 250 deaths per 100,000) with comparable contributions from amenable and preventable diseases. While the highest levels of education are found clearly in the cities (Figure 1a), the problem of avoidable mortality is most severe in Vojvodina—not among the less educated rural areas of the east, but rather among those municipalities in the north that score mid-way in terms of educational attainment (Figure 1b). While it is true that the areas with higher educational attainment tend to have fewer avoidable deaths, the areas with high rates of avoidable mortality sit close to the middle of the educational distribution: the highest tercile of avoidable mortality has a median of 10.4 standardized years of schooling, against 10.7 years for all municipalities.

Table 2. Descriptive statistics for the 162 municipalities.

Variable	Mean	<i>SD</i>	Min	Median	Max
Mean years of schooling (age–sex standardized, 25+)	10.85	0.99	9.04	10.70	14.93
Tertiary education (%)	17.14	9.98	5.70	15.05	67.84
At most primary education (%)	31.00	11.43	2.35	32.12	63.96
Urban population (%)	44.04	27.90	0.00	45.33	100.00
Distance to nearest primary facility (km)	7.03	5.69	0.26	6.05	51.44
Distance to nearest secondary facility (km)	19.39	9.67	1.25	20.17	44.50
Distance to nearest tertiary facility (km)	53.85	30.85	1.02	51.00	144.35
Avoidable mortality (ASR)	418.8	77.5	248.6	401.4	691.8
Amenable mortality (ASR)	281.9	58.1	145.6	268.8	469.8
Preventable mortality (ASR)	268.5	51.7	173.1	259.9	457.9

Note. Age-standardized rates (ASR) are per 100,000 person-years (direct method, 2013 European Standard Population, ages <75).

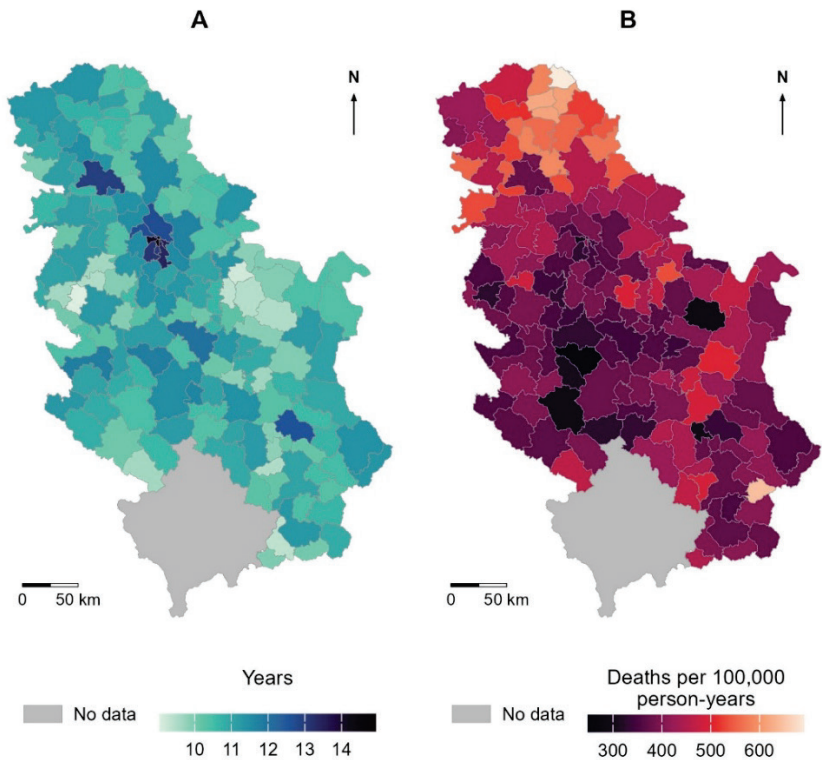


Figure 1. Standardized mean years of schooling (A) and age-standardized avoidable mortality, 2015–2019 (B), by municipality.

As could be expected, the “double advantaged” combination, which includes higher educational levels and low mortality, dominates in the Belgrade core while the “double disadvantaged” combination, with low educational level and high mortality, represents an easily recognizable pattern of municipalities in eastern parts and certain areas of the center (Figure 2). The above-mentioned distribution of patterns is in line with recent municipality-level analysis of human capital in Serbia, in which strong differences between various regions with regard to human capital have been highlighted, where a significant concentration of people with higher education has been shown for Belgrade and Novi Sad while Southern and Eastern parts of Serbia are significantly behind (Kokotović Kanazir et al., 2024).

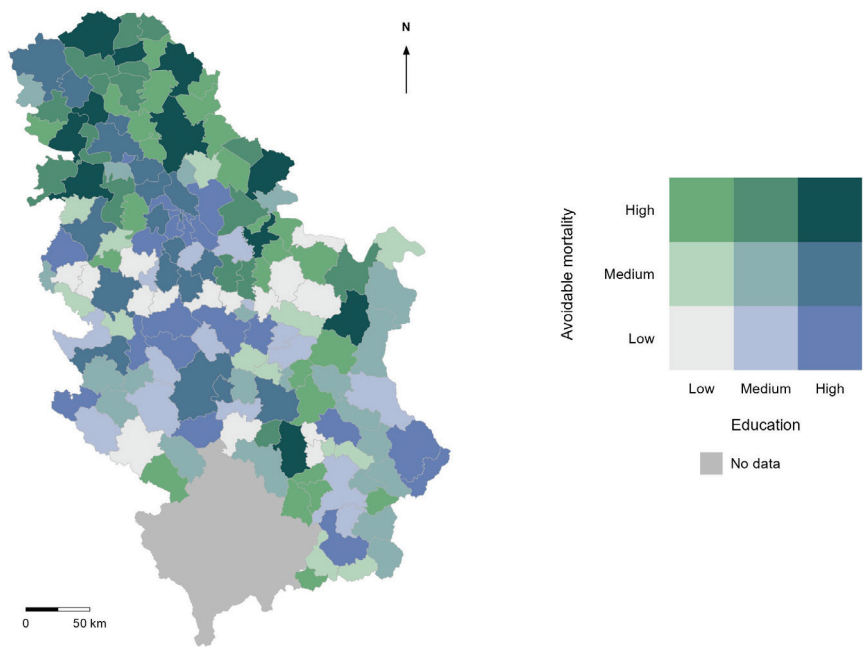


Figure 2. Bivariate classification of municipalities by education (terciles) and avoidable mortality (terciles).

3.2. Spatial structure

The global spatial autocorrelation values are highly significant for each variable (Moran's I varies between 0.49 and 0.59, with all p values < 0.001), meaning that both education and mortality are neither evenly spread across Serbia nor randomly distributed but form regional clusters. With 999 local permutations, and $p < 0.05$ significance level, high levels of education correspond to the region around Belgrade, while the high mortality cluster can be found in the northern part of Vojvodina (Figure 3). The two cluster geographies therefore overlap only partially, and the regression analysis that follows is motivated by this mismatch, since the education gradient cannot be separated from the regional structure shared by the two variables on the basis of the maps alone.

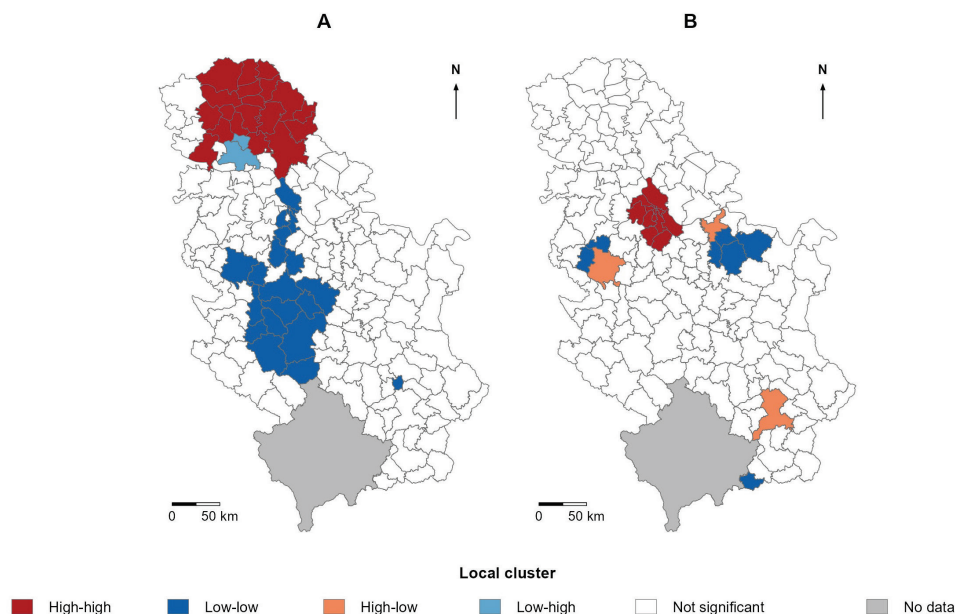


Figure 3. Local Moran's I clusters of avoidable mortality (A) and educational attainment (B).

3.3. *The education gradient and the amenable–preventable contrast*

As a measure of bivariate association, it is indicated by the rank correlation coefficient that the link between the two variables is negative ($\rho \approx -0.28$) and moderately strong. The relationship between education and amenable mortality is stronger ($\rho \approx -0.34$) than that between education and preventable mortality ($\rho \approx -0.10$) which, by itself, lacks statistical significance. Once urbanization and regional dummies are accounted for, however, there is a clear, significant negative gradient in each outcome (Table 3). In the ordinary residuals, spatial autocorrelation persists (Moran's $I \approx 0.15$, $p < 0.001$), and according to Lagrange-multiplier tests, the preferred choice is a lag structure instead of the more complex spatial-error structure (no substantive improvement over the SAR model was provided by the SDM; likelihood-ratio $p \geq 0.08$), so the spatial-lag model was used to fit the data instead (spatial autoregressive parameter in the range $\rho \approx 0.40$ – 0.43 ; Table 3).

Table 3. Education coefficients and model diagnostics, by outcome and specification

Coefficients and fit							
Outcome	Spec.	β	SE	p	ρ/λ	AIC	Pseudo- R^2
Avoidable	OLS	−0.081	0.020	< 0.001	—	−201.1	0.50
	SAR	−0.060	0.018	0.001	0.415	−215.1	0.56
	SEM	−0.065	0.019	< 0.001	0.389	−209.1	0.55
	SDM	−0.050	0.021	0.015	0.364	−215.8	0.57

Table 3. Education coefficients and model diagnostics, by outcome and specification (*continued*)

<i>Coefficients and fit</i>							
Outcome	Spec.	β	SE	p	ρ/λ	AIC	Pseudo- R^2
Amenable	OLS	−0.090	0.023	< 0.001	—	−143.8	0.45
	SAR	−0.067	0.022	0.002	0.399	−156.0	0.52
	SEM	−0.073	0.023	0.001	0.390	−152.1	0.51
	SDM	−0.055	0.025	0.026	0.336	−157.0	0.53
Preventable	OLS	−0.069	0.022	0.002	—	−162.8	0.42
	SAR	−0.052	0.020	0.011	0.427	−177.3	0.50
	SEM	−0.052	0.022	0.017	0.438	−173.1	0.49
	SDM	−0.041	0.023	0.076	0.398	−175.1	0.50

Spatial diagnostics (OLS residuals) and test-down (entries are p-values unless noted)

Outcome	Residual Moran's I	LM-lag	LM-error	Robust LM- lag	Robust LM- error	LR: SDM vs SAR
Avoidable	0.152	< 0.001	0.002	0.002	0.138	0.096
Amenable	0.155	< 0.001	0.002	0.019	0.340	0.083
Preventable	0.164	< 0.001	0.001	0.003	0.109	0.392

Note. β is the coefficient on standardized schooling for log mortality; in SAR/SDM it is *not* the marginal effect (see Table 4); ρ/λ is the spatial autoregressive (SAR, SDM) or error (SEM) parameter.

A one-year increase in age-sex-adjusted average years of schooling was linked to a decrease in avoidable mortality by about 9.7% (see Table 4). In the joint mixed model, the effect of education on preventable mortality is found to be statistically significantly weaker than the effect on amenable mortality (interaction $p < 0.001$).

Table 4. Impacts of standardized schooling and the amenable–preventable gradient contrast

<i>SAR impacts of +1 year of schooling on log mortality</i>						
Outcome	Direct (95% SI)	Indirect (95% SI)	Total (95% SI)	Total % change (95% SI)	p (total)	
Avoidable	−0.062 [−0.098, −0.024]	−0.040 [−0.081, −0.013]	−0.102 [−0.172, −0.041]	−9.7% [−15.8%, −4.0%]	0.002	
Amenable	−0.070 [−0.113, −0.027]	−0.042 [−0.093, −0.014]	−0.112 [−0.192, −0.044]	−10.6% [−17.4%, −4.3%]		
Preventable	−0.054 [−0.095, −0.011]	−0.036 [−0.090, −0.007]	−0.090 [−0.177, −0.022]	−8.6% [−16.2%, −2.1%]		

Amenable vs preventable gradient (stacked linear mixed model, random intercept by municipality, REML)

Term	Estimate	SE	p
Education slope, amenable (reference)	−0.104	0.022	3.9×10^{-6}
Education $\times$ preventable (difference)	+0.048	0.009	3.4×10^{-7}

Note. Values in brackets are 95% simulation intervals from 1,000 draws; % = $100 \cdot (\exp(\text{total}) - 1)$. The interaction (a weaker gradient for preventable than for amenable mortality) is robust to municipality-clustered standard errors ($p \approx 10^{-9}$).

The effect size is reduced by a mere 12–24% when the distance to the closest primary, secondary, and tertiary health-care center is included while the distance terms are insignificant. The gradient between years of schooling and avoidable and amenable mortality is essentially equal across men and women, although the same cannot be said for preventable mortality, for which a gradient is exhibited among men (–7.7% per year, $p = 0.002$) and to a lesser degree among women (–4.8%, $p = 0.08$). In the descriptive pandemic-period sensitivity check, the adjusted schooling coefficient was more negative in 2020–2021 than in 2015–2019 for avoidable mortality ($\beta = -0.104$ vs. -0.081) and especially for amenable mortality ($\beta = -0.125$ vs. -0.090), while the preventable-mortality coefficient was essentially unchanged ($\beta = -0.070$ vs. -0.069). Consistent with the above results, the same conclusions are yielded when tertiary-education share and/or primary-education share are used as exposure, as they are when a spatial-error model with five nearest neighbors is used. Cause-specific deaths are not few in number—the lowest municipality has 27 preventable and 34 amenable deaths over five years, with no empty cells—and the ordering of gradient magnitudes and most of the local clusters are preserved under empirical-Bayes smoothing (although more uncertainty around the gradient estimates is introduced: the classification as local clusters is maintained for approximately 81–85% of municipalities).

4. Discussion

Both education levels and avoidable mortality in Serbia are strongly regionalized (Miletić, 2006; Nikitović et al., 2016), but their regional cores do not overlap. Human capital is concentrated in metropolitan Belgrade, while the burden of avoidable mortality is highest on the northern plain. Educational and mortality maps are related, but separate, and the former should not be used as a stand-in for the latter without losing information, which is consistent with the non-perfect concordance between deprivation and mortality found in previous research (Joksimović & Golić, 2017; Lorant et al., 2001).

After accounting for regionalization, urbanization, and service structure, there is an inverse association between education and avoidable mortality. The estimated effect corresponds to a gradient-like relationship previously observed between human capital and life expectancy (Lleras-Muney, 2005; Mackenbach et al., 2008).

Cardiovascular and neoplastic mortality has been above normal on the northern plain for decades, and, as already noted, cardiovascular mortality is particularly socially graded (Mackenbach et al., 2000). A high-salt diet (reported for Novi Sad and Serbia as a whole; Milešević et al., 2023; Trajković-Pavlović et al., 2015), along with alcoholism and smoking and the demography of an aging, depopulating rural hinterland, could contribute to this phenomenon—a complex mix of environmental and demographic risks not easily captured by education alone. These patterns suggest that the excess mortality observed in Vojvodina may partly reflect localized risk environments (rather than solely a deficit in human capital) though this interpretation remains tentative, as the present analysis did not directly measure environmental or behavioral exposures.

The education–amenable mortality association is steeper than the education–preventable mortality association. Such a pattern is at variance with straightforward expectations based on fundamental cause theory according to which socio-economic advantage is more protective against preventable diseases because in cases like these knowledge matters most (Mackenbach et al., 2015; Phelan et al., 2004). A stronger link with preventable causes would be expected if the effects of area-level human capital on avoidable mortality operated primarily

via behavior (smoking, alcohol consumption, dietary choices, etc.). There appears to be an emphasis on curative services, where health literacy and social capital are required for them to be used correctly (Baker, 1999; Jansen et al., 2018; Miller, 2016). Interpreting the finding as an area-level association and not one involving individuals, it is concluded that better survival outcomes are achieved in more-educated municipalities in the context of a similar health-care system. This hypothesis aligns with the persistence of educational gradients in cancer stage at diagnosis and survival despite universal access to healthcare services (Al-Ramamahy et al., 2024; Booth et al., 2010; Gornick et al., 2004; Hussain et al., 2008). As cancer currently constitutes the leading contributor to avoidable mortality in Serbia (Ilić & Ilić, 2018), any disparities in amenable mortality rates are taken to reflect inequalities in curative service utilization rather than poor health-system performance. Amenable mortality is, in fact, determined by disease incidence, accumulated exposure to risk factors, screening prevalence, diagnostic and certification procedures, and, finally, the sociodemographic composition of the area. Thus, the steeper amenable mortality gradient is consistent with, but does not prove, disparities in curative services use. The contrast is also informative in the Serbian context, where at the national level the larger inequalities have been reported for preventable rather than amenable causes (Marinković, 2022); area-level and individual-level gradients need not coincide, and contextual features of service use may be captured at the municipal scale that are not captured in individual-level comparisons. Departures from the straightforward fundamental-cause prediction are not unusual in Europe, as the relation between education and cause-specific mortality varies considerably across populations, and in the post-socialist east, a heavy burden of behavioral risk is combined with health systems in which effective, rather than nominal, access still differs across social groups (Gavurová & Vagašová, 2017; Leinsalu et al., 2009; Mackenbach et al., 2015). That the gradient is barely attenuated by distance to health-care facilities points in the same direction: what appears to matter is not the physical availability of services but their timely and appropriate use (early presentation, participation in screening, referral, and adherence) all of which are conditioned by health literacy and social resources (Baker, 1999; Jansen et al., 2018; Miller, 2016).

The problem of double-disadvantaged regions of the east (with high mortality rates due to educational deprivation) and high mortality northern regions of Vojvodina (where education is not low) represent two separate challenges by which two separate solutions are required. Since there is no effect of proximity to healthcare facilities on mortality rates and the presence of the amenability-dominance gradient in this region, it is assumed that there must be another important variable affecting this outcome. No support for the expansion of the facility network as a remedy is given by our results, since facility proximity was unrelated to mortality; they are more consistent with demand-side measures, such as patient recall initiatives and outreach programs aiming to increase awareness and educate citizens. A plausible strategy for amenable diseases would be cancer screening in regions characterized by lower levels of education, targeting cancers which can be effectively cured (such as breast, cervix, colon). These are, however, hypotheses that follow from area-level associations and would have to be tested directly, rather than conclusions established by the present design.

Excess mortality in northern Vojvodina may be better addressed through population-wide preventive programs, given the lifestyle and behavior patterns characteristic of this region, including excessive consumption of salt in diet, alcohol consumption, smoking and a generally aging depopulated area. It is suggested by the male-specific gradient that particular attention be paid to sex-specific prevention of injury and alcohol abuse disorders.

Municipal associations are no guarantees of personal ones (Schwartz, 1994; Wakefield & Lyons, 2010). In turn, individual-level associations may be obscured or exaggerated by area-level indicators of SES status (Lokar et al., 2019; Shih et al., 2023). The associations themselves might be biased by some area characteristics, for example, service delivery, income levels, and selection of individuals into Belgrade's metropolitan area. This process is well-known and documented in the case of Belgrade (Filipović et al., 2022). Education is measured in the 2022 census, while deaths occur in 2015–2019, but as schooling levels are largely formed in early adulthood, mostly past education levels are captured by the 2022 measure for persons over the age of 25. Also, associations are specific to a particular zoning and might be changed under alternative zoning strategies (modifiable areal unit problem; Parenteau & Sawada, 2011).

Mortality and education have been standardized to different reference populations (European Standard Population of 2013 and national age-sex distribution, respectively). The risk of small number bias and distortions caused by the age structure is reduced by pre-pandemic five-year aggregation and direct standardization, yet area-level associations are thereby not equated with individual-level causal relations.

5. Conclusion

Two distinct geographies are described by education and avoidable mortality in Serbia: educational attainment clusters around Belgrade and Novi Sad, whereas avoidable mortality clusters in the north of the country, in Vojvodina. Neither map can be substituted for the other, which matters for the way regional health inequalities in Serbia are described and monitored. Net of region and urbanization, one additional standardized year of schooling was associated with roughly a 10% lower rate of avoidable mortality, and the gradient was steepest for amenable and weakest for preventable deaths. This ordering runs contrary to what the fundamental cause theory would lead one to expect and is, in our view, the main contribution of the study, since it is thereby suggested that in Serbia, area-level human capital is linked most closely to the deaths that can be averted by timely health care. These are associations between areas rather than between individuals, and causation is not established by them. Individual-level linkage of education and cause of death, decomposition by specific causes, and direct measurement of screening and treatment use are the natural next steps for testing the mechanisms that can only be hypothesized in this study.

The ecological design and the temporal mismatch between the 2022 education measure and 2015–2019 mortality data remain important limitations and individual-level or causal interpretation is thereby precluded. In future research, individual educational attainment should be linked with cause-specific mortality, and screening, treatment use, and other mechanisms of effective access to care should be directly examined. From a practical perspective, the distinct spatial patterns of educational disadvantage and avoidable mortality suggest that educational indicators alone should not be relied on in regional health and development policies, but that both local human-capital conditions and area-specific mortality profiles should be considered.

References

- Al-Rammahy, A., Fadum, E. A., Nilssen, Y., Larsen, I. K., Hem, E., & Bringedal, B. H. (2024). Educational disparities in cancer incidence, stage, and survival in Oslo. *Research in Health Services & Regions*, 3(1), Article 1. <https://doi.org/10.1007/s43999-024-00037-x>

- Anselin, L. (1988a). Lagrange multiplier test diagnostics for spatial dependence and spatial heterogeneity. *Geographical Analysis*, 20(1), 1–17. <https://doi.org/10.1111/j.1538-4632.1988.tb00159.x>
- Anselin, L. (1988b). *Spatial Econometrics: Methods and Models*. Kluwer Academic Publishers.
- Anselin, L., Bera, A. K., Florax, R., & Yoon, M. J. (1996). Simple diagnostic tests for spatial dependence. *Regional Science and Urban Economics*, 26(1), 77–104. [https://doi.org/10.1016/0166-0462\(95\)02111-6](https://doi.org/10.1016/0166-0462(95)02111-6)
- Baker, D. W. (1999). Reading between the lines: Deciphering the connections between literacy and health. *Journal of General Internal Medicine*, 14(5), 315–317. <https://doi.org/10.1046/j.1525-1497.1999.00342.x>
- Barro, R. J., & Lee, J. W. (2013). A new data set of educational attainment in the world, 1950–2010. *Journal of Development Economics*, 104, 184–198. <https://doi.org/10.1016/j.jdeveco.2012.10.001>
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Booth, C. M., Li, G., Zhang-Salomons, J., & Mackillop, W. J. (2010). The impact of socioeconomic status on stage of cancer at diagnosis and survival: A population-based study in Ontario, Canada. *Cancer*, 116(17), 4160–4167. <https://doi.org/10.1002/cncr.25427>
- Clayton, D., & Kaldor, J. (1987). Empirical Bayes Estimates of Age-Standardized Relative Risks for Use in Disease Mapping. *Biometrics*, 43(3), 671–681. <https://doi.org/10.2307/2532003>
- Cleland, J. G., & Van Ginneken, J. K. (1988). Maternal education and child survival in developing countries: The search for pathways of influence. *Social Science & Medicine*, 27(12), 1357–1368. [https://doi.org/10.1016/0277-9536\(88\)90201-8](https://doi.org/10.1016/0277-9536(88)90201-8)
- Cvejić, S., Babović, M., Petrović, M., Bogdanov, N., & Vuković, O. (2010). *Socijalna isključenost u ruralnim oblastima Srbije* [Social exclusion in rural areas of Serbia]. UNDP Srbija.
- Elhorst, J. P. (2014). *Spatial Econometrics: From Cross-Sectional Data to Spatial Panels*. Springer. <https://doi.org/10.1007/978-3-642-40340-8>
- European Commission. Statistical Office of the European Union. (2013). *Revision of the European Standard Population: Report of Eurostat's task force: 2013 edition*. Publications Office. <https://doi.org/10.2785/11470>
- Eurostat. (2026). *Life expectancy by age and sex* [Data set]. European Commission. https://doi.org/10.2908/DEMO_MLEXPEC
- Filipović, M., Krunić, N., & Zhelenkova, E. (2022). Functional dependence of settlements and its demographic component in the transition phase of the daily urban system. *Journal of the Geographical Institute Jovan Cvijic SASA*, 72(3), 323–339. <https://doi.org/10.2298/IJGI2203323F>
- Gavurová, B., & Vagašová, T. (2017). Assessment of Avoidable Mortality Concepts in the European Union Countries, Their Benefits and Limitations. In U. Comite (Ed.), *Advances in Health Management*. InTech. <https://doi.org/10.5772/67818>
- Gay, J. G., Paris, V., Devaux, M., & de Looper, M. (2011). *Mortality amenable to health care in 31 OECD countries: Estimates and methodological issues* (OECD Health Working Papers No. 55). OECD Publishing. <https://doi.org/10.1787/5kgj35f9f8s2-en>
- Gornick, M. E., Eggers, P. W., & Riley, G. F. (2004). Associations of Race, Education, and Patterns of Preventive Service Use with Stage of Cancer at Time of Diagnosis. *Health Services Research*, 39(5), 1403–1428. <https://doi.org/10.1111/j.1475-6773.2004.00296.x>
- Hayward, M. D., Hummer, R. A., & Sasson, I. (2015). Trends and group differences in the association between educational attainment and U.S. adult mortality: Implications for understanding education's causal influence. *Social Science & Medicine*, 127, 8–18. <https://doi.org/10.1016/j.socscimed.2014.11.024>
- Hoffmann, R., Plug, I., Khoshaba, B., McKee, M., & Mackenbach, J. P. (2013). Amenable mortality revisited: The AMIEHS study. *Gaceta Sanitaria*, 27(3), 199–206. <https://doi.org/10.1016/j.gaceta.2012.08.004>
- Hummer, R. A., & Lariscy, J. T. (2011). Educational Attainment and Adult Mortality. In R. G. Rogers & E. M. Crimmins (Eds.), *International Handbook of Adult Mortality* (Vol. 2, pp. 241–261). Springer. https://doi.org/10.1007/978-90-481-9996-9_12
- Hussain, S. K., Lenner, P., Sundquist, J., & Hemminki, K. (2008). Influence of education level on cancer survival in Sweden. *Annals of Oncology*, 19(1), 156–162. <https://doi.org/10.1093/annonc/mdm413>
- Ilić, M., & Ilić, I. (2018). Cancer mortality in Serbia, 1991–2015: An age-period-cohort and joinpoint regression analysis. *Cancer Communications*, 38(1), Article 10. <https://doi.org/10.1186/s40880-018-0282-3>

- Jansen, T., Rademakers, J., Waverijn, G., Verheij, R., Osborne, R., & Heijmans, M. (2018). The role of health literacy in explaining the association between educational attainment and the use of out-of-hours primary care services in chronically ill people: A survey study. *BMC Health Services Research*, 18(1), Article 394. <https://doi.org/10.1186/s12913-018-3197-4>
- Joksimović, M., & Golić, R. (2017). Indicators of regional inequality in Serbia. *Zbornik Radova - Geografski Fakultet Univerziteta u Beogradu*, (65–1a), 227–249. <https://doi.org/10.5937/zrgfub17652271>
- Kalediene, R., & Petrauskienė, J. (2005). Inequalities in mortality by education and socio-economic transition in Lithuania: Equal opportunities? *Public Health*, 119(9), 808–815. <https://doi.org/10.1016/j.puhe.2004.11.004>
- Kokotović Kanazir, V., Drobnjaković, M., & Panić, M. (2026). A Longitudinal Analysis of Functional Transformation and Demographic Change in Small Towns in Serbia. *Stanovništvo*, 64(1), 49–70. <https://doi.org/10.59954/stnv.767>
- Kokotović Kanazir, V., Panić, M., & Drobnjaković, M. (2024). Value of people—Human capital in Serbia through the prism of educational attainment of young population. *Stanovništvo*, 62(S1), S105–S129 <https://doi.org/10.59954/stnv.625>
- Kossarova, L., Holland, W., Nolte, E., & McKee, M. (2009). *Measuring "avoidable" mortality: Methodological note*. Directorate-General "Employment, Social Affairs and Equal Opportunities." <https://researchonline.lse.ac.uk/id/eprint/46390/>
- Leinsalu, M., Stirbu, I., Vagero, D., Kalediene, R., Kovacs, K., Wojtyniak, B., Wroblewska, W., Mackenbach, J. P., & Kunst, A. E. (2009). Educational inequalities in mortality in four Eastern European countries: Divergence in trends during the post-communist transition from 1990 to 2000. *International Journal of Epidemiology*, 38(2), 512–525. <https://doi.org/10.1093/ije/dyn248>
- LeSage, J., & Pace, R. K. (2009). *Introduction to Spatial Econometrics*. Chapman and Hall/CRC. <https://doi.org/10.1201/9781420064254>
- Link, B. G., & Phelan, J. (1995). Social Conditions As Fundamental Causes of Disease. *Journal of Health and Social Behavior*, 35(Extra Issue), 80–94. <https://doi.org/10.2307/2626958>
- Lleras-Muney, A. (2005). The Relationship Between Education and Adult Mortality in the United States. *Review of Economic Studies*, 72(1), 189–221. <https://doi.org/10.1111/0034-6527.00329>
- Lokar, K., Zagar, T., & Zadnik, V. (2019). Estimation of the Ecological Fallacy in the Geographical Analysis of the Association of Socio-Economic Deprivation and Cancer Incidence. *International Journal of Environmental Research and Public Health*, 16(3), Article 296. <https://doi.org/10.3390/ijerph16030296>
- Lorant, V., Thomas, I., Deliège, D., & Tonglet, R. (2001). Deprivation and mortality: The implications of spatial autocorrelation for health resources allocation. *Social Science & Medicine*, 53(12), 1711–1719. [https://doi.org/10.1016/S0277-9536\(00\)00456-1](https://doi.org/10.1016/S0277-9536(00)00456-1)
- Lović Obradović, S., & Vojković, G. (2021). The Impact of Spatial-Demographic Disparities on Fertility Variations in Serbian Municipalities—An Example of Hidden Content Research. In M. Krevs (Ed.), *Hidden Geographies* (pp. 379–399). Springer International Publishing. https://doi.org/10.1007/978-3-030-74590-5_18
- Mackenbach, J. P. (2006). *Health inequalities: Europe in profile*. UK Presidency of the EU. https://ec.europa.eu/health/ph_determinants/socio_economics/documents/ev_060302_rd06_en.pdf
- Mackenbach, J. P. (2017). Nordic paradox, Southern miracle, Eastern disaster: Persistence of inequalities in mortality in Europe. *European Journal of Public Health*, 27(suppl 4), 14–17. <https://doi.org/10.1093/eurpub/ckx160>
- Mackenbach, J. P., Cavelaars, A. E. J. M., Kunst, A. E., & Groenhouf, F. (2000). Socioeconomic inequalities in cardiovascular disease mortality. An international study. *European Heart Journal*, 21(14), 1141–1151. <https://doi.org/10.1053/ehj.1999.1990>
- Mackenbach, J. P., Karanikolos, M., & McKee, M. (2013). The unequal health of Europeans: Successes and failures of policies. *The Lancet*, 381(9872), 1125–1134. [https://doi.org/10.1016/S0140-6736\(12\)62082-0](https://doi.org/10.1016/S0140-6736(12)62082-0)
- Mackenbach, J. P., Kulháňová, I., Bopp, M., Deboosere, P., Eikemo, T. A., Hoffmann, R., Kulik, M. C., Leinsalu, M., Martikainen, P., Menvielle, G., Regidor, E., Wojtyniak, B., Östergren, O., & Lundberg, O. (2015). Variations in the relation between education and cause-specific mortality in 19 European populations: A test of the "fundamental causes" theory of social inequalities in health. *Social Science & Medicine*, 127, 51–62. <https://doi.org/10.1016/j.socscimed.2014.05.021>

- Mackenbach, J. P., Stirbu, I., Roskam, A.-J. R., Schaap, M. M., Menvielle, G., Leinsalu, M., & Kunst, A. E. (2008). Socioeconomic Inequalities in Health in 22 European Countries. *New England Journal of Medicine*, 358(23), 2468–2481. <https://doi.org/10.1056/NEJMsa0707519>
- Marinković, I. (2022). The effect of avoidable mortality on life expectancy in Serbia, 2010–2019. *Stanovništvo*, 60(1), 53–68. <https://doi.org/10.2298/STNV220403001M>
- Marinković, I., & Anđelković, M. (2026). Aligning national ageing policy with global principles: Serbia and the Madrid International Plan of Action on Ageing. *Journal of the Geographical Institute Jovan Cvijic, SASA*, 76(1), 139–147. <https://doi.org/10.2298/IJGI250610019M>
- Marmot, M., & Bobak, M. (2005). Social and economic changes and health in Europe East and West. *European Review*, 13(1), 15–31. <https://doi.org/10.1017/S1062798705000037>
- Marshall, R. J. (1991). Mapping Disease and Mortality Rates Using Empirical Bayes Estimators. *Applied Statistics*, 40(2), 283–294. <https://doi.org/10.2307/2347593>
- Milešević, J., Ljubičić, S., Vukotić, D., Zeković, M., Barać, B., Gurinović, M., Glibetić, M., & Marinković, D. (2023). Dietary Intake of Salt from Meat Products in Serbian Population. *International Journal of Environmental Research and Public Health*, 20(5), Article 4192. <https://doi.org/10.3390/ijerph20054192>
- Miletić, R. (2006). Selected indicators of uneven regional development of Serbia. *Glasnik Srpskog Geografskog Društva*, 86(1), 177–190. <https://doi.org/10.2298/GSGD0601177M>
- Miller, T. A. (2016). Health literacy and adherence to medical treatment in chronic and acute illness: A meta-analysis. *Patient Education and Counseling*, 99(7), 1079–1086. <https://doi.org/10.1016/j.pec.2016.01.020>
- Montez, J. K., Hummer, R. A., & Hayward, M. D. (2012). Educational Attainment and Adult Mortality in the United States: A Systematic Analysis of Functional Form. *Demography*, 49(1), 315–336. <https://doi.org/10.1007/s13524-011-0082-8>
- Morgenstern, H. (1995). Ecologic studies in epidemiology: Concepts, principles, and methods. *Annual Review of Public Health*, 16, 61–81. <https://doi.org/10.1146/annurev.pu.16.050195.000425>
- Nikitović, V., Bajat, B., & Blagojević, D. (2016). Spatial patterns of recent demographic trends in Serbia (1961–2010). *Geografije*, 121(4), 521–543. <https://doi.org/10.37040/geografije2016121040521>
- Nolte, E., & McKee, M. (2011). Variations in amenable mortality—Trends in 16 high-income nations. *Health Policy*, 103(1), 47–52. <https://doi.org/10.1016/j.healthpol.2011.08.002>
- Parenteau, M.-P., & Sawada, M. C. (2011). The modifiable areal unit problem (MAUP) in the relationship between exposure to NO₂ and respiratory health. *International Journal of Health Geographics*, 10(1), Article 58. <https://doi.org/10.1186/1476-072X-10-58>
- Penev, G. (2003). Mortality trends in Serbia during the 1990s. *Stanovništvo*, 41(1–4), 93–130. <https://doi.org/10.2298/STNV0304093P>
- Phelan, J. C., Link, B. G., Diez-Roux, A., Kawachi, I., & Levin, B. (2004). “Fundamental Causes” of Social Inequalities in Mortality: A Test of the Theory. *Journal of Health and Social Behavior*, 45(3), 265–285. <https://doi.org/10.1177/002214650404500303>
- Phelan, J. C., Link, B. G., & Tehranifar, P. (2010). Social Conditions as Fundamental Causes of Health Inequalities: Theory, Evidence, and Policy Implications. *Journal of Health and Social Behavior*, 51(1_suppl), S28–S40. <https://doi.org/10.1177/0022146510383498>
- R Core Team. (2025). *R: A language and environment for statistical computing* (Version 4.5.2) [Computer software]. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Rogers, R. G., Hummer, R. A., & Everett, B. G. (2013). Educational differentials in US adult mortality: An examination of mediating factors. *Social Science Research*, 42(2), 465–481. <https://doi.org/10.1016/j.ssresearch.2012.09.003>
- Rüttenauer, T. (2022). Spatial Regression Models: A Systematic Comparison of Different Model Specifications Using Monte Carlo Experiments. *Sociological Methods & Research*, 51(2), 728–759. <https://doi.org/10.1177/0049124119882467>
- Santric Milicevic M., Bjegovic, V., Terzic, Z., Vukovic, D., Koccev, N., Marinkovic, J., & Vasic, V. (2009). Serbia within the European context: An analysis of premature mortality. *Population Health Metrics*, 7(1), Article 12. <https://doi.org/10.1186/1478-7954-7-12>
- Schwartz, S. (1994). The fallacy of the ecological fallacy: The potential misuse of a concept and the consequences. *American Journal of Public Health*, 84(5), 819–824. <https://doi.org/10.2105/AJPH.84.5.819>

- Shih, Y.-C. T., Bradley, C., & Yabroff, K. R. (2023). Ecological and individualistic fallacies in health disparities research. *JNCI: Journal of the National Cancer Institute*, 115(5), 488–491. <https://doi.org/10.1093/jnci/djad047>
- Simonato, L., Ballard, T., Bellini, P., & Winkelmann, R. (1998). Avoidable mortality in Europe 1955-1994: A plea for prevention. *Journal of Epidemiology and Community Health*, 52(10), 624–630. <https://doi.org/10.1136/jech.52.10.624>
- Statistical Office of the Republic of Serbia. (2022). *Vital statistics: Deaths by municipality of residence, sex, age, and cause of death, 2015–2021* [unpublished tabulations]. Statistical Office of the Republic of Serbia.
- Statistical Office of the Republic of Serbia. (2023). *2022 Census of Population, Households and Dwellings* [microdata file]. Statistical Office of the Republic of Serbia.
- Todd, M. A., Shkolnikov, V. M., & Goldman, N. (2016). Why are well-educated Muscovites more likely to survive? Understanding the biological pathways. *Social Science & Medicine*, 157, 138–147. <https://doi.org/10.1016/j.socscimed.2016.02.041>
- Trajković-Pavlović, L., Popović, M., Bijelović, S., Velički, R., & Torović, L. (2015). Salt content in ready-to-eat food and bottled spring and mineral water retailed in Novi Sad. *Srpski Arhiv Za Celokupno Lekarstvo*, 143(5–6), 362–368. <https://doi.org/10.2298/SARH1506362T>
- Vandenheede, H., Vikhireva, O., Pikhart, H., Kubinova, R., Malyutina, S., Pajak, A., Tamosiunas, A., Peasey, A., Simonova, G., Topor-Madry, R., Marmot, M., & Bobak, M. (2014). Socioeconomic inequalities in all-cause mortality in the Czech Republic, Russia, Poland and Lithuania in the 2000s: Findings from the HAPIEE Study. *Journal of Epidemiology and Community Health*, 68(4), 297–303. <https://doi.org/10.1136/jech-2013-203057>
- Vlajinac, H., Marinkovic, J., Koccev, N., Sipetic, S., Bjegovic, V., Jankovic, S., Stanisavljevic, D., Markovic-Denic, L., & Maksimovic, J. (2008). Years of life lost due to premature death in Serbia (excluding Kosovo and Metohia). *Public Health*, 122(3), 277–284. <https://doi.org/10.1016/j.puhe.2007.06.010>
- Wakefield, J., & Lyons, H. (2010). Spatial Aggregation and the Ecological Fallacy. In A. Gelfand, P. Diggle, M. Fuentes, & P. Guttorp (Eds.), *Handbook of Spatial Statistics* (Vol. 38, pp. 541–558). CRC Press. <https://doi.org/10.1201/9781420072884-c30>
- Walters, S., & Suhrcke, M. (2005). *Socioeconomic inequalities in health and health care access in central and eastern Europe and the CIS: a review of the recent literature* (WHO European Office for Investment for Health and Development Working Paper, Issue 2005/1). World Health Organization Regional Office for Europe. <https://iris.who.int/handle/10665/350352>