HRVATSKI GEOGRAFSKI GLASNIK 87/2, 59–89 (2025.)

UDK ????

DOI 10.21861/HGG.2024.87.02.03

Original scientific paper
Izvorni znanstveni rad

Received / Primljeno
2025-04-17 / 17-04-2025

Accepted / Prihvaćeno
2025-10-30 / 30-10-2025

Dino Bečić
Monika Komušanac
Nikola Šimunić

Application of spatial autocorrelation in the analysis of fertility distribution and fertility patterns in Croatia

Primjena prostorne autokorelacije u analizi distribucije fertiliteta i fertilitetnih obrazaca u Hrvatskoj

The paper addresses the measurement of variability of the total fertility rate (TFR) at the NUTS3 and LAU levels for the year 2021. By applying spatial autocorrelation methods, the Global and Local Moran's Index, the hypothesis of TFR value clustering at the regional and local level was tested. In other words, the study answers the question of whether TFR values are spatially grouped or heterogeneously distributed at the selected levels. The research procedure determined the degree of spatial autocorrelation at both observed levels and defined statistically significant clusters. Based on the Getis-Ord Gi* hotspot analysis, spatial patterns of TFR distribution at the LAU level were identified, and in addition to the analysis of z-values, the level of statistical significance of TFR hotspot and coldspot areas was also analyzed. The results of the research provide a deeper insight into the understanding of differences in TFR values between regions and within regions, which are often not detectable using classical statistical-analytical approaches.

Key words: fertility, variability in fertility, spatial autocorrelation, Moran's I, Croatia.

Rad problematizira mjerenje varijabilnosti totalne ili ukupne stope fertiliteta (TFR-a) na NUTS3 i LAU razinama za 2021. godinu. Primjenom jedne od metoda prostorne autokorelacije, globalnog i lokalnoga Moranova indeksa, testirana je hipoteza o klasteriranju vrijednosti TFR-a na regionalnoj i lokalnoj razini. Drugim riječima, daje se odgovor na pitanje jesu li vrijednosti TFR-a prostorno grupirane ili heterogeno raspoređene na odabranim razinama. Istraživačkim je postupkom utvrđen stupanj prostorne autokorelacije na objema predmetnim razinama te su definirani statistički značajni klasteri. Na temelju hotspot analize Getis-Ord Gi* izdvojeni su prostorni obrasci distribucije TFR-a na LAU razini, a osim analize z-vrijednosti analizirana je i razina statističke pouzdanosti hotspot i coldspot područja TFR-a. Rezultati istraživanja omogućuju dublji uvid u razumijevanje razlika u vrijednostima TFR-a između regija i unutar regija koje se često ne mogu detektirati primjenom klasičnih statističko-analitičkih pristupa.

Ključne riječi: fertilitet, varijabilnost fertiliteta, prostorna autokorelacija, Moranov indeks, Hrvatska

INTRODUCTION

In Croatia, as in other countries of the world, fertility patterns are influenced by various socio-economic, cultural, historical, demographic, and spatial factors. The total fertility rate (TFR) in Croatia in 2022, according to EUROSTAT data, was higher than the European Union average and amounted to 1,53.[1] For decades, TFR in Croatia has been below the replacement level of 2.1, in line with global trends present in many European countries. In the early 2010s, TFR ranged between 1.5 and 1.6, with a slight decline during periods of economic crisis. Certain measures to encourage higher fertility rates, such as financial incentives and other benefits, resulted in a moderate increase in TFR, but it still remains relatively low, and challenges such as emigration, economic opportunities, and changes in socio-family norms continue to influence fertility decisions. One of the strategic goals of the Demographic Revitalization Strategy of the Republic of Croatia to 2033 is to create a more supportive environment for families and young people, and understanding demographic trends at the local level, especially specific spatial fertility patterns, is a prerequisite for defining revitalization measures.

Although TFR, as a form of age-standardized rate, is the most commonly used indicator of effective fertility in a population, using descriptive statistical methods (comparing the range of TFR values) it is not possible to determine statistically significant spatial differences in the distribution of fertility at lower administrative units. Spatial autocorrelation methods provide the necessary framework for analyzing spatial patterns of a given phenomenon, allowing the identification of clusters of higher and lower values, i.e. the grouping and analysis of spatial relationships that are not visible and observable using standard statistical-analytical approaches. The analysis of fertility variability in this paper is based on the application of one of the spatial autocorrelation methods, namely Moran's Index (global and local), using the Python programming language, in order to test the hypothesis of whether

1 Source: Eurostat (2025), *Fertility indicators*, available at: https://ec.europa.eu/eurostat/databrowser/view/demo_find/default/table?lang=en&category=demo.demo_fer (2. 4. 2025.)

UVOD

U Hrvatskoj, kao i u drugim državama svijeta, obrasci plodnosti* pod utjecajem su različitih socio-ekonomskih, kulturnih, povijesnih, demografskih i prostornih čimbenika. Ukupna (totalna) stopa fertiliteta u Hrvatskoj 2022. godine, prema podatcima EUROSTAT-a, bila je viša od prosjeka Europske unije te je iznosila 1,53.[1] TFR (ukupna stopa fertiliteta, eng. *Total Fertility Rate*) je u Hrvatskoj desetljećima ispod zamjenske vrijednosti od 2,1, tj. u skladu s globalnim trendovima prisutnima u brojnim europskim državama. Početkom 2010-ih TFR je iznosio između 1,5 i 1,6, uz lagani pad tijekom razdoblja ekonomskih kriza. Pojedine mjere za poticanje većih stopa plodnosti, poput financijskih poticaja i drugih prava, rezultirale su umjerenim porastom TFR-a, no on i dalje ostaje relativno nizak, a izazovi poput iseljavanja, ekonomskih prilika i promjena društveno-obiteljskih norma nastavljaju utjecati na odluke o plodnosti. Jedan od strateških ciljeva *Strategije demografske revitalizacije Republike Hrvatske do 2033. godine* jest stvaranje poticajnijega okruženja za obitelji i mlade, a razumijevanje demografskih trendova na lokalnoj razini, osobito specifičnih prostornih obrazaca plodnosti, preduvjet je za definiranje revitalizacijskih mjera.

Iako je TFR, kao oblik standardizirane stope prema dobi, najčešće korišten pokazatelj efektivne plodnosti u nekoj populaciji, metodama deskriptivne statistike (usporedbom raspona vrijednosti TFR-a) nije moguće utvrditi statistički značajne prostorne razlike u distribuciji fertiliteta na nižim upravno-administrativnim jedinicama. Metode prostorne autokorelacije pružaju potreban okvir za analizu prostornih obrazaca određene pojave, omogućujući identifikaciju klastera viših i nižih vrijednosti, tj. grupiranje i analiziranje prostornih odnosa koji nisu vidljivi i uočljivi primjenom standardnih statističko-analitičkih pristupa. Analiza varijabilnosti fertiliteta u radu temelji se na primjeni jedne od metoda prostorne autokorelacije, odnosno Moranova indeksa (globalnog i lokalnog), uz pomoć programskoga jezika *Python*, da bi se odgovorilo na

* U radu se termini *plodnost* i *fertilitet* koriste kao istoznačnice.

1 Izvor: Eurostat (2025), *Fertility indicators*, dostupno na: https://ec.europa.eu/eurostat/databrowser/view/demo_find/default/table?lang=en&category=demo.demo_fer (2. 4. 2025.)

TFR variations in Croatia are spatially dispersed or clustered. Considering the chosen method, the distribution of fertility in Croatia was observed within the framework of NUTS3 regions and local administrative units (hereinafter LAU), with the aim of determining whether spatial autocorrelation exists at these levels and whether it is statistically significant (according to the range of p-values). On the other hand, based on the concentration of low or high values of the observed variable (fertility), the local Moran's Index will determine the types of clusters that appear at the local level. Accordingly, the main goal of the research is to analyze the spatial patterns of fertility variability in Croatia, and the findings and conclusions arising from the paper will contribute to a better understanding of local and regional differences and may serve as a basis for further research related to revitalization approaches at different spatial levels.

THEORETICAL FRAMEWORK

Croatia, like many European countries, records low post-transitional birth and fertility rates (Čipin and Strmota, 2014). The concept of very low fertility gained importance in the late 1980s and early 1990s, first in the countries of Central Europe (Van de Kaa, 2001; Zaidi and Morgan, 2017). In this context, demographers Ron Lesthaeghe and Dirk Van de Kaa (1986) introduced the term "second demographic transition" to explain new behavioral patterns in developed European societies after the end of the transitional period. The theoretical basis of this phase is grounded in changes in the traditional understanding of family and the emergence of new reproductive patterns. Among the main characteristics are the decline in the number of marriages, the increase in divorces, a higher share of children and unions outside marriage, delayed childbearing, and an increase in age at marriage (Lesthaeghe, 2020; Sobotka et al., 2008; Van de Kaa, 2001; Zaidi and Morgan, 2017).

The total fertility rate (TFR) in Central European countries has been in constant decline since the 1990s, a period marked by political, social, and economic changes (Lutz, 2006). However, in most Central and Eastern European countries, the TFR has significantly recovered in the recent period (Németh et al., 2025).

pitanje jesu li varijacije TFR-a u Hrvatskoj prostorno disperzne ili grupirane. S obzirom na izbor metode distribucija fertiliteta u Hrvatskoj promatrana je u okviru NUTS3 regija i jedinica lokalne samouprave (engl. LAU – Local Administrative Unit, pokrata koja će se rabiti u ostatku rada), a s ciljem utvrđivanja postoji li prostorna autokorelacija na navedenim razinama i je li ona statistički značajna (sukladno rasponu p-vrijednosti). S druge strane, na temelju koncentracije niskih ili visokih vrijednosti promatrane varijable (fertiliteta) lokalni Moranov indeks utvrdit će tipove klastera koji se pojavljuju na lokalnoj razini. Sukladno navedenom, osnovni je cilj istraživanja analizirati prostorne varijabilnosti fertiliteta u Hrvatskoj, a spoznaje i zaključci, koji proizlaze iz rada, doprinijet će boljem razumijevanju lokalnih i regionalnih razlika te mogu poslužiti kao osnova za daljnja istraživanja vezana uz pristupe revitalizaciji na različitim prostornim razinama.

TEORIJSKI OKVIR

Hrvatska, poput mnogih europskih zemalja, bilježi niske posttranzicijske stope nataliteta i fertiliteta (Čipin i Strmota, 2014). Koncept izrazito niska fertiliteta dobiva na važnosti krajem 1980-ih i početkom 1990-ih, najprije u državama Srednje Europe (Van de Kaa, 2001; Zaidi i Morgan, 2017). U tom kontekstu demografi Ron Lesthaeghe i Dirk Van de Kaa (1986) uvode pojam „druga demografska tranzicija" da bi objasnili nove obrasce ponašanja u razvijenim europskim društvima nakon završetka tranzicijskoga razdoblja. Teorijska osnova ove faze temelji se na promjenama u tradicionalnom poimanju obitelji i pojavi novih reproduktivnih obrazaca. Među glavnim obilježjima ističu se pad broja sklopljenih brakova, porast rastava, veći udio izvanbračne djece i zajednica, odgađanje rađanja te porast dobi pri sklapanju braka (Lesthaeghe, 2020; Sobotka i dr., 2008; Van de Kaa, 2001; Zaidi i Morgan, 2017).

Ukupna stopa fertiliteta (TFR) u zemljama Srednje Europe u stalnom je padu od 1990-ih godina, razdoblja obilježenog političkim, društvenim i ekonomskim promjenama (Lutz, 2006). No, u većini zemalja Srednje i Istočne Europe TFR se znatno oporavio u recentnom razdoblju (Németh

Numerous authors point out that low TFR values in developed European countries are primarily the result of complex social, economic, political, and cultural factors (Lutz, 2006; Sobotka, 2003; Sobotka et al., 2008; Van de Kaa, 2001; Vasireddy et al., 2023; Wang and Sun, 2016; Zaidi and Morgan, 2017). The trend of fertility decline has been present since the second half of the 20th century and is linked to the increase in education and employment of women (Aldieri and Vinci, 2013; Snopkowski et al., 2016; Testa, 2014; Vasireddy et al., 2003). The extension of education, greater participation of women in the labor market, and the rise of their economic independence changed the traditional division of roles within the family (Van de Kaa, 2001). In addition to individual factors, the relationship between education and fertility is also shaped by contextual elements such as family and social policies, macro-economic disturbances, and socio-normative patterns (Vasireddy et al., 2003).

The variability of sub-replacement fertility in economically developed countries highlights the importance of institutional support and public policies aimed at young families, especially mothers (Rindfuss et al., 2016). Nordic countries that promote a flexible labor market and a balance between family and professional life record a relatively higher level of fertility (Jalovaara et al., 2019). However, comparative studies show that family policies do not have a universal effect, especially in the context of different social and economic systems (Vasireddy et al., 2003). Sobotka (2003) analyzed the transitional changes in Central and Eastern Europe from the 1990s, emphasizing that the success of the socio-economic transition strongly influenced changes in reproductive behavior, along with the simultaneous influence of other factors such as modernization, individualization, religiosity, and access to contraception. Similar findings are confirmed by numerous empirical studies on fertility trends in individual Central and Eastern European countries (Akrap, 2011; Akrap and Čipin, 2011; Berde and Drabancz, 2022; Čipin, 2022; Čipin and Međimurec, 2017; Čipin and Strmota, 2014; Kotowska et al., 2008; Potančoková et al., 2008; Sobotka et al., 2008). Additionally, the stability of sub-replacement fertility has also been influenced by external factors such as war-related destruction, economic crises, pandemics, etc. (Bujard and Andersson, 2024; Sobotka et al., 2011).

i dr., 2025). Brojni autori ističu da su niske vrijednosti TFR-a u razvijenim europskim državama prvenstveno posljedica složenih društvenih, ekonomskih, političkih i kulturoloških čimbenika (Lutz, 2006; Sobotka, 2003; Sobotka i dr., 2008; Van de Kaa, 2001; Vasireddy i dr., 2023; Wang i Sun, 2016; Zaidi i Morgan, 2017). Trend smanjenja plodnosti prisutan je još od druge polovice 20. stoljeća i povezuje se s porastom obrazovanja i zapošljavanja žena (Aldieri i Vinci, 2013; Snopkowski i dr., 2016; Testa, 2014; Vasireddy i dr., 2003). Produžetak obrazovanja, veća prisutnost žena na tržištu rada i porast njihove ekonomske neovisnosti mijenjaju tradicionalnu podjelu uloga unutar obitelji (Van de Kaa, 2001). Uz individualne čimbenike odnos obrazovanja i fertiliteta oblikuju i kontekstualni elementi poput obiteljskih i socijalnih politika, makroekonomskih poremećaja i društveno-normativnih obrazaca (Vasireddy i dr., 2003).

Varijabilnost ispodzamjenskoga fertiliteta u ekonomski razvijenim državama naglašava važnost institucionalne potpore i javnih politika usmjerenih na mlade obitelji, osobito majke (Rindfuss i dr., 2016). Nordijske zemlje koje promiču fleksibilno tržište rada i ravnotežu između obiteljskog i profesionalnog života, bilježe relativno višu razinu plodnosti (Jalovaara i dr., 2019). Ipak, komparativne studije pokazuju da obiteljske politike nemaju univerzalan učinak, osobito u kontekstu različitih društvenih i ekonomskih sustava (Vasireddy i dr., 2003). Sobotka (2003) analizira tranzicijske promjene u Srednjoj i Istočnoj Europi od 1990-ih, naglašavajući kako je uspješnost socioekonomske tranzicije snažno utjecala na promjene u reproduktivnom ponašanju, uz istovremeno djelovanje drugih faktora poput modernizacije, individualizacije, religioznosti i pristupa kontracepciji. Slično potvrđuju i brojna empirijska istraživanja fertilitetnih kretanja pojedinih država Srednje i Istočne Europe (Akrap, 2011; Akrap i Čipin, 2011; Berde i Drabancz, 2022; Čipin, 2022; Čipin i Međimurec, 2017; Čipin i Strmota, 2014; Kotowska i dr., 2008; Potančoková i dr., 2008; Sobotka i dr., 2008). Također, na stabilnost ispodzamjenskoga fertiliteta utjecali su i vanjski čimbenici kao što su ratna stradavanja, ekonomske krize, pandemija i sl. (Bujard i Andersson, 2024; Sobotka i dr., 2011).

In terms of fertility trends, Croatia does not differ significantly from other Central European countries. TFR below the replacement level in Croatia appeared in the late 1960s, and by the first half of the 1990s it had decreased to below 1.5 children per woman (Čipin and Međimurec, 2017). In the last decade, TFR has been relatively stable, with minor fluctuations in the trend, ranging between 1.40 and 1.63 (EUROSTAT, 2022). The main factors of sub-replacement fertility in Croatia stem from social, economic, cultural, and similar influences, as well as external factors (Akrap, 2011; Akrap and Čipin, 2011; Belić, 2023; Belić and Mišetić, 2021; Čipin and Međimurec, 2017; Čipin and Strmota, 2014). In addition to general social and economic differences, reproductive motivation is also influenced by the mechanisms of reconciling family and work life, specific forms of employment (e.g. precarious work), opportunity costs of parenthood, the inadequacy of housing policy measures aimed at young people, and the like (Akrap, 2011; Akrap and Čipin, 2011; Čipin, 2011; Čipin and Međimurec, 2017). In addition to the factors that led to the postponement of childbearing at the national level, fertility trends are further shaped by regional heterogeneity, primarily through geographical and historical differences in settlement, i.e. pronounced regional disparities (Marošević, 2020). Therefore, the analysis of fertility variations is crucial for the development of locally adapted demographic revitalization measures.

U pogledu trendova kretanja fertiliteta Hrvatska se ne razlikuje znatno od ostalih srednjoeuropskih država. TFR ispod razine jednostavna obnavljanja stanovništva u Hrvatskoj se javlja krajem 1960-ih godina, a do prve polovice 1990-ih godina smanjuje se na razinu ispod 1,5 djece po jednoj ženi (Čipin i Međimurec, 2017). U posljednjem je desetljeću TFR relativno stabilan, a s manjim oscilacijama u trendu kreće se u rasponu između 1,40 i 1,63 (EUROSTAT, 2022). Glavni čimbenici ispodzamjenskoga fertiliteta u Hrvatskoj proizlaze iz djelovanja društvenih, ekonomskih, kulturoloških i sl. čimbenika te vanjskih utjecaja (Akrap, 2011; Akrap i Čipin, 2011; Belić, 2023; Belić i Mišetić, 2021; Čipin i Međimurec, 2017; Čipin i Strmota, 2014). Međutim, konkretni mehanizmi djelovanja tih čimbenika vidljivi su kroz povećanu učestalost nestabilnih oblika rada koji odgađaju financijski doseg za roditeljstvo, visoke oportunitetne troškove karijernih prekida za žene te stambenu nesigurnost mladih parova. Osim općih društvenih i ekonomskih razlika na reproduktivnu motivaciju također utječe i mehanizmi usklađivanja obiteljskoga i poslovnoga života, specifični oblici rada (npr. prekarni rad), oportunitetni troškovi roditeljstva, nedostatnost mjera stambene politike usmjerenih prema mladima i sl. (Akrap, 2011; Akrap i Čipin, 2011: Čipin, 2011; Čipin i Međimurec, 2017). Osim čimbenika koji su doveli do odgađanja rađanja na nacionalnoj razini fertilitetne trendove dodatno oblikuje regionalna heterogenost, ponajprije kroz geografske i povijesne razlike u naseljenosti, tj. izraženi regionalni dispariteti (Marošević, 2020). Stoga je analiza fertilitetnih varijacija ključna za oblikovanje lokalno prilagođenih mjera demografske revitalizacije.

Approaches to fertility and the measurement of fertility variability

In the context of contemporary demographic development and regional differences, it is important to emphasize that the economic and socio-cultural causes of the fertility transition do not act equally in countries with different income levels, which confirms the complexity of the process itself (Wang and Sun, 2016). This complexity is also evident at the sub-national level, where the spatial dimension plays a key role in understanding contemporary fertility patterns (Campisi et al., 2019). Early studies highlighted dif-

Pristupi fertilitetu i mjerenje varijabilnosti fertiliteta

U kontekstu suvremenoga demografskog razvoja i regionalnih razlika važno je istaknuti da ekonomski i socio-kulturni uzroci fertilitetne tranzicije ne djeluju jednako u zemljama različita dohodovnoga statusa, što potvrđuje složenost samoga procesa (Wang i Sun, 2016). Ta se složenost očituje i na podnacionalnoj razini, gdje prostorna dimenzija ima ključnu ulogu u razumijevanju suvremenih obrazaca plodnosti (Campisi i dr., 2020). Rana istraživanja isticala su razlike

ferences between rural and urban areas, with higher fertility in rural areas (Fiori et al., 2014). Trovato and Grindstaff (1980) explained these differences with the compositional hypothesis, based on differences in education, income, and employment, while Riederer and Beaujouan (2023) further emphasized the influence of traditional norms and lifestyles. Although these differences are decreasing, they have not disappeared completely, and more recent trends show an increase in fertility in the suburbs and peripheral zones of larger cities (Fiori et al., 2014; Kulu, 2013; Kulu et al., 2009; Riederer and Beaujouan, 2023). In the analysis of spatial fertility patterns, demographic, geographic, infrastructural, and institutional factors play an important role: such as the level of industrialization, capital investment, transport position, access to education and health care, and public policies (Belić and Mišetić, 2021). Urbanization further affects the postponement of childbirth and lower fertility (Riederer and Beaujouan, 2023). Martine et al. (2013), comparing 181 countries, conclude that there is no direct and one-way impact of urbanization on fertility decline, precisely due to the complexity of the conditioning factors. Many authors emphasize that fertility is a complex and behaviorally determined phenomenon, which is why it is not possible to determine a universal pattern of variability (Aldieri and Vinci, 2013; Fiori et al., 2014; Martine et al., 2013; Riederer and Beaujouan, 2023; Sear et al., 2016; Vasireddy et al., 2023; Wang and Sun, 2016).

Monitoring fertility trends is essential for analyzing the influence of various variables and understanding trends and spatial differences in fertility. In addition to dominant demographic processes, the level of fertility is also affected by irregular circumstances such as economic crises or pandemics. For example, Winkler-Dworak et al. (2024) analyze short-term fluctuations in births during the COVID-19 pandemic in low-fertility countries. Among the main causes of the fertility decline during 2022 were economic uncertainty, the level of government intervention, and the dynamics of the implementation of vaccination programs.

Considering the relationship between economic cycles and fertility fluctuations, traditional economic models are mostly based on an increase in births during economic crises (counter-cyclical trend), while

između ruralnih i urbanih sredina, s višim fertilitetom u ruralnim područjima (Fiori i dr., 2014). Trovato i Grindstaff (1980) te razlike objašnjavaju kompozicijskom hipotezom, temeljenom na razlikama u obrazovanju, prihodima i zaposlenosti, dok Riederer i Beaujouan (2023) dodatno naglašavaju utjecaj tradicionalnih norma i životnih stilova. Iako se te razlike smanjuju, one ne nestaju u potpunosti, a noviji trendovi pokazuju porast fertiliteta u predgrađima i perifernim zonama većih gradova (Fiori i dr., 2014; Kulu, 2013; Kulu i dr., 2009; Riederer i Beaujouan, 2023). U analizi prostornih obrazaca fertiliteta važnu ulogu imaju demografski, geografski, infrastrukturni i institucionalni čimbenici – poput stupnja industrijalizacije, kapitalnih ulaganja, prometnoga položaja, pristupa obrazovanju i zdravstvu te javnih politika (Belić i Mišetić, 2021). Urbanizacija dodatno utječe na odgodu rađanja i niži fertilitet (Riederer i Beaujouan, 2023). Martine i dr. (2013) uspoređujući 181 državu, zaključuju da ne postoji izravan i jednosmjeran utjecaj urbanizacije na smanjenje plodnosti, upravo zbog složenosti faktora uvjetovanja. Brojni autori naglašavaju da je fertilitet složen i bihevioralno određen fenomen zbog čega nije moguće utvrditi univerzalni obrazac varijabilnosti (Aldieri i Vinci, 2013; Fiori i dr., 2014; Martine i dr., 2013; Riederer i Beaujouan, 2023; Sear i dr., 2016; Vasireddy i dr., 2023; Wang i Sun, 2016).

Praćenje fertilitetnih kretanja ključno je za analizu utjecaja različitih varijabla te razumijevanje trendova i prostornih razlika u plodnosti. Na razinu fertiliteta, osim dominantnih demografskih procesa, utječu i neregularne okolnosti poput ekonomskih kriza ili pandemija. Primjerice, Winkler-Dworak i sur. (2024) analiziraju kratkoročne oscilacije u rađanjima tijekom pandemije COVID-19 u zemljama s niskom plodnošću. Među glavnim uzrocima pada fertiliteta tijekom 2022. godine ističu se ekonomska nesigurnost, razina državne intervencije i dinamika provedbe programa cijepljenja.

Razmatrajući povezanost ekonomskih ciklusa s oscilacijama fertiliteta, tradicionalni ekonomski modeli uglavnom se temelje na porastu rađanja tijekom ekonomskih kriza (kontraciklički trend),

more recent empirical research indicates that birth rates decline during economic crises and periods of rising unemployment (pro-cyclical trend) (Del Bono et al., 2015). A number of authors emphasize that existing research on the pro-cyclical and counter-cyclical nature of aggregate fertility is not sufficiently clear and that, given regional and temporal differences, no single pattern can be entirely universal (Coskun and Dalgic, 2022; Del Bono et al., 2015; Sobotka et al., 2011; Tragaki and Bagavos, 2019). Del Bono et al. (2016) pointed out that unemployment affects parenting decisions in a multidimensional way, changing personal attitudes, especially among women, regarding careers, professional advancement, and family planning, making the identification of fertility patterns an extremely complex phenomenon.

The most common measure of fertility level in a population is the total fertility rate (TFR), which represents the average number of live-born children a given woman would have during her reproductive period, assuming constant age-specific fertility rates and the absence of mortality. TFR, as a period rate standardized by age, is a reliable indicator of realized fertility because it is not dependent on the size of the cohort of women of reproductive age (Čipin, 2022). Since population policy and development priorities are based on expected TFR values, defining spatial fertility patterns at the national and sub-national level is of key importance. Descriptive approaches offer a basic overview of the TFR range, while advanced mathematical-statistical and spatial models are used to quantify spatial variations. Among them, geographically weighted regressions and spatial panel analyses stand out (Benassi and Carella, 2023; Tragaki and Bagavos, 2019). Local regression models enable the understanding of local influences on the spatial variability of TFR (Mucciardi and Bertuccelli, 2013). Vitali and Billari (2017), within the diffusionist approach, emphasize the importance of cultural and economic indicators and the influence of neighboring areas on spatial-temporal fertility patterns. Examples from numerous studies show that TFR values in one area positively correlate with those in neighboring areas, potentially due to similar economic conditions and socio-cultural norms (Campisi et al., 2023; Basten et al., 2012; Belić and Mišetić, 2021; Burillo et al., 2020; Salvati et al., 2020).

dok novija empirijska istraživanja upućuju na to da razina rađanja pada u razdobljima ekonomskih kriza i tijekom povećanja nezaposlenosti (prociklički trend) (Del Bono i dr., 2015). Niz autora ističe da su postojeća istraživanja o prociklič nom i kontraciklič koj naravi agregatnoga fertiliteta nedovoljno jasna i da, s obzirom na razlike među regijama i tijekom vremena, ni jedan obrazac ne može biti posve univerzalan (Coskun i Dalgic, 2022; Del Bono i dr., 2015; Sobotka i dr., 2011; Tragaki i Bagavos, 2019). Del Bono i dr. (2016) ističu da nezaposlenost višedimenzionalno utječe na odluke o roditeljstvu, mijenjajući osobne stavove, osobito kod žena, o karijeri, profesionalnom napredovanju i planiranju obitelji, čineći identifikaciju fertilitetnih obrazaca iznimno složenim fenomenom.

Najčešća mjera razine plodnosti u populaciji jest ukupna stopa fertiliteta (TFR) koja označava prosječan broj živorođene djece koju bi prosječna žena rodila tijekom svojega reproduktivnog razdoblja, uz pretpostavku nepromjenjivosti specifičnih stopa fertiliteta prema dobi i uz izostanak smrtnosti. TFR je, kao periodska stopa standardizirana prema dobi, pouzdan pokazatelj ostvarene plodnosti jer nije ovisan o veličini kohorte žena u fertilnoj dobi (Čipin, 2022). Budući da se populacijska politika i razvojni prioriteti temelje na očekivanim vrijednostima TFR-a, definiranje fertilitetnih prostornih obrazaca na nacionalnoj i subnacionalnoj razini ima ključnu važnost. Deskriptivni pristupi nude osnovni pregled raspona TFR-a, dok se za kvantifikaciju prostornih varijacija koriste napredni matematičko-statistički i prostorni modeli. Pritom se ističu geografski ponderirane regresije i prostorne panel-analize (Benassi i Carella, 2023; Tragaki i Bagavos, 2019). Lokalni regresijski modeli omogućuju razumijevanje lokalnih utjecaja na prostornu varijabilnost TFR-a (Mucciardi i Bertuccelli, 2013). Vitali i Billari (2017), u okviru difuzionističkoga pristupa, ističu važnost kulturnih i ekonomskih pokazatelja te utjecaja susjednih područja na prostorno-vremenske fertilitetne obrasce. Primjeri brojnih istraživanja pokazuju da vrijednosti TFR-a u jednom prostoru pozitivno koreliraju s onima u susjednim područjima, potencijalno zbog sličnih ekonomskih uvjeta i društveno-kulturoloških norma (Campisi i dr., 2023; Basten i dr. 2012; Belić i Mišetić, 2021; Burillo i dr. 2020; Salvati i dr. 2020).

The basic concepts, methods, and applications of spatial autocorrelation are established and discussed by numerous authors (Anselin, 1988; Dubé and Legros, 2014; Fischer and Getis, 2009; Getis and Ord, 1992; Moran, 1948). Spatial autocorrelation is a fundamental concept in spatial analysis and represents the correlation between the values of a given feature and the geographically (locationally) proximate values of the same variable (Diniz-Filho et al., 2003). By applying various indicators, such as Moran's Index, Geary's C, LISA (Local Indicators of Spatial Association), Gi* statistics (Getis-Ord Gi*), etc. the degree to which a set of spatial features tends to cluster in space (positive spatial autocorrelation) or tends to disperse (negative spatial autocorrelation) is measured.

Based on the measurement of spatial autocorrelation, it is possible to identify patterns of spatial distribution of variables (Dubé and Legros, 2014). Spatial analyses are focused on quantitative differences in the explanation or prediction of phenomena in space and are widely applied in demographic research. Therefore, the frequent use of spatial autocorrelation methods in fertility analyses, whether independently or in combination with multivariate approaches, is not surprising. The Global Moran's Index is used to identify hierarchical clusters of similar TFR values, while the Local Moran's Index provides insight into spatial patterns within regions. Due to their ability to detect local differences, both variants are widely applied in national analyses of fertility variability, as confirmed by numerous studies (Belić, 2023; Belić and Mišetić, 2021; Benassi and Carella, 2023; Burillo et al., 2020; Campisi et al., 2019; Egidi and Salvati, 2014; Jung et al., 2019; Salvati et al., 2020; Tosun and Yang, 2018).

Spatial autocorrelation enables a multidimensional approach to fertility variability – from the analysis of spatial distribution and identification of clusters of high and low values, to a deeper understanding of the influence of local factors, spatial neighborhood, and changes in fertility patterns over time, which is why it was chosen as the main research method in this study.

Osnovne koncepte, metode i primjene prostorne autokorelacije postavljaju i problematiziraju brojni autori (Anselin, 1988; Dubé i Legros, 2014; Fischer i Getis, 2009; Getis i Ord, 1992; Moran, 1948). Prostorna autokorelacija temeljni je koncept u prostornoj analizi, a predstavlja korelaciju među vrijednostima jedne značajke i geografski (lokacijski) bliskih vrijednosti iste varijable (Diniz-Filho i dr., 2003). Primjenom različitih pokazatelja, primjerice Moranova indeksa, Geary C indeksa, LISA-e (engl. Local Indicators of Spatial Association), Gi* statistike (Getis Ord-Gi*) i sl., mjeri se stupanj do kojega skup prostornih jednica (entiteta) prema vrijednosti pojave pokazuje tendenciju okupljanja u prostoru (pozitivna prostorna autokorelacija) ili tendenciju raspršivanja (negativna prostorna autokorelacija).

Na temelju mjerenja prostorne autokorelacije moguće je izdvojiti obrasce prostorne raspodjele varijabli (Dubé i Legros, 2014). Prostorne analize usmjerene su na kvantitativne razlike u objašnjenju ili predikciji fenomena u prostoru te nalaze široku primjenu u demografskim istraživanjima. Nije stoga iznenađujuća česta primjena metoda prostorne autokorelacije u analizama fertiliteta, bilo samostalno bilo u kombinaciji s multivarijantnim pristupima. Globalni Moranov indeks koristi se za identifikaciju hijerarhijskih klastera sličnih TFR vrijednosti, dok lokalni Moranov indeks omogućuje uvid u prostorne obrasce unutar regija. Zbog svoje sposobnosti otkrivanja lokalnih razlika obje se varijante široko primjenjuju u nacionalnim analizama fertilitetne varijabilnosti, što potvrđuju brojna istraživanja (Belić, 2023; Belić i Mišetić, 2021; Benassi i Carella, 2023; Burillo i dr., 2020; Campisi i dr., 2020; Egidi i Salvati, 2014; Jung i dr., 2019; Salvati i dr., 2020; Tosun i Yang, 2018).

Prostorna autokorelacija omogućuje višedimenzionalni pristup varijabilnosti fertiliteta – od analize prostornoga razmještaja i identifikacije klastera visokih i niskih vrijednosti do dubljega razumijevanja utjecaja lokalnih čimbenika, prostornoga susjedstva i promjena fertilitetnih obrazaca kroz vrijeme, zbog čega je i izabrana kao temeljna istraživačka metoda u radu.

SPATIAL FRAMEWORK, DATA AND METHODS

The paper is based on the clustering of total fertility rate (TFR) values for the year 2021 at the level of HR NUTS3 regions and the LAU level. According to the National Classification of Statistical Regions of the Republic of Croatia from 2021, the NUTS3 level consists of 21 regions (counties). Counties in Croatia are units of regional self-government, while units of local self-government are cities and municipalities that belong to them administratively and territorially (Law on Local and Regional Self-Government NN33/01, 60/01, 129/05, 109/07, 125/08, 36/09, 150/11, 144/12, 19/13, 137/15, 123/17, 98/19, 144/20). The total number of regional and local self-government units in Croatia is 576. The research includes TFR values at the NUTS3 level (21 units) and the local self-government or LAU level (556 units). The boundaries of the analyzed area correspond to the administrative-territorial division of the Republic of Croatia into counties, cities, and municipalities. The spatial distribution of TFR at the mentioned levels refers to the 2021 census year, i.e. the latest official data on the population by sex and age. Total fertility rates are not published in official (state) statistical sources and publications and were therefore calculated for 2021 based on provided vital statistics data from the Croatian Bureau of Statistics, i.e. data on the age of mothers and the number of live births by five-year age groups. TFR values for NUTS3 regions were taken from the EUROSTAT platform.

This study is based on a cross-sectional use of the total fertility rate (TFR) for the year 2021, which entails certain methodological limitations. TFR is a standardized indicator that provides an up-to-date and easily interpretable picture of current reproductive patterns (Bongaarts & Sobotka, 2012). However, it is a hypothetical measure that is sensitive to short-term fluctuations and to the so-called tempo effect of delayed childbearing. During periods of intense postponement of births, TFR temporarily declines, only to increase again once previously delayed births are realized. A particular challenge is the year 2021, when the TFR level in Croatia reached 1.63—one of the highest values in the last decade (EUROSTAT,

PROSTORNI OKVIR, PODATCI I METODE

Rad se temelji na klasterizaciji vrijednosti totalne stope fertiliteta (TFR-a) 2021. godine na razini HR NUTS3 regija i LAU razini. Prema Nacionalnoj klasifikaciji statističkih regija Republike Hrvatske 2021. godine, NUTS3 razinu čini 21 regija (županija). Županije su u Hrvatskoj jedinice regionalne samouprave, dok su jedinice lokalne samouprave gradovi i općine koje im administrativno i teritorijalno pripadaju (Zakon o lokalnoj i područnoj (regionalnoj) samoupravi NN33/01, 60/01, 129/05, 109/07, 125/08, 36/09, 150/11, 144/12, 19/13, 137/15, 123/17, 98/19, 144/20). Ukupan broj jedinica regionalne i lokalne samouprave u Hrvatskoj je 576. Istraživanje obuhvaća vrijednosti TFR-a na NUTS3 razini (21 jedinica) te razini jedinica lokalne samouprave ili LAU razini (556). Granice analiziranoga područja podudaraju se s administrativno-teritorijalnom podjelom Republike Hrvatske na županije, gradove i općine. Prostorna distribucija TFR-a na spomenutim razinama odnosi se na popisnu 2021. godinu, tj. zadnje službene podatke o sastavu stanovništva prema spolu i starosti. Stope ukupnoga (totalnoga) fertiliteta ne objavljuju se u službenim (državnim) statističkim izvorima i publikacijama te su stoga izračunate za 2021. godinu na temelju ustupljenih podataka vitalne statistike Državnoga zavoda za statistiku Republike Hrvatske, tj. podataka o starosti majki i broju živorođenih po petogodišnjim dobnim skupinama. Vrijednosti TFR-a za NUTS3 regije preuzeti su s EUROSTAT-ove platforme.

Treba istaknuti da se istraživanje temelji na prosječnom korištenju ukupne stope fertiliteta (TFR) za 2021. godinu, što nosi određena metodološka ograničenja. TFR je standardizirani pokazatelj koji pruža ažurnu i lako tumačeću sliku o aktualnim reproduktivnim obrascima (Bongaarts i Sobotka, 2012), no riječ je o hipotetskoj mjeri osjetljivoj na kratkoročne oscilacije i tzv. tempo-efekt odgode rađanja. Tijekom razdoblja najintenzivnije odgode rađanja TFR privremeno pada, a poraste kasnije, kad se odgođena rađanja realiziraju. Poseban izazov predstavlja 2021. godina, u kojoj je razina TFR-a u Hrvatskoj iznosila 1,63 – jedna od viših vrijednosti u posljednjem

2022). This increase, partly linked to short-term circumstances, may diverge from longer-term trends (Čipin et al., 2024). Comparisons of period TFR with cohort fertility indicators suggest that fertility in Croatia is underestimated by approximately 0.2 children per woman (Belić, 2025), with differences being more pronounced in rural areas (0.3–0.4) than in urban areas (around 0.1). Since most of the analyzed LAU units are rural and transitional areas, it is possible that the TFR partly masks the actual fertility patterns, which may contribute to the weaker and more fragmented spatial autocorrelation observed in the results. These limitations do not diminish the value of applying spatial methods, rather they point to the need for contextualization of findings and cautious interpretation of results. In line with the established practice of research on spatial patterns of fertility based on one-year data (Campisi et al., 2020; Bongaarts & Sobotka, 2012), it is necessary to emphasize that the cross-sectional TFR has methodological limitations and to consider their potential impact on the outcomes.

Global spatial autocorrelation of fertility was analyzed using the Global Moran's Index (Moran's I), while for a more detailed insight into spatial differences in fertility at the NUTS3 and LAU levels, the Local Moran's Index (Local Moran's I, LISA – Local Indicators of Spatial Autocorrelation) was used. A positive value of Moran's I indicates a tendency to form clusters of high or low fertility, while a negative value suggests that areas with high fertility are surrounded by those with low fertility and vice versa.[2] In the context of this study, the definition of high and low fertility is based on the statistical approach of spatial autocorrelation, not on the range of absolute values (absolute thresholds). A value close to zero indi-

2 Low fertility refers to fertility below the replacement level (sub-replacement fertility), where TFR is less than 2.1 children per woman, which is the level required to maintain population size in most developed countries. In some countries with higher mortality, the replacement level can be up to 3.4. Very low fertility refers to a TFR below 1.5 children per woman. Lowest-low fertility refers to a TFR below 1.3 children per woman. This level is often found in East Asian and Southern European countries. On the other hand, high fertility refers to a TFR of 5.0 or more. This level is often associated with less developed countries where high birth rates result from social and economic factors, such as lack of access to contraception and lower levels of female education. See: Billari and Kohler, 2004; Chen et al., 2024..

desetljeću (EUROSTAT, 2022). Taj porast, dijelom povezan s kratkoročnim okolnostima, može odstupati od dugoročnijih trendova (Čipin i dr., 2024). Usporedbe periodskoga TFR-a s prilagođenim i kohortnim pokazateljima upućuju na podcjenjivanje stvarne razine fertiliteta za približno 0,2 djeteta po ženi (Belić, 2025), pri čemu su razlike izraženije u ruralnim (0,3 – 0,4) nego u urbanim područjima (oko 0,1). Budući da većinu analiziranih LAU jedinica čine ruralna i prijelazna područja, moguće je da TFR djelomično maskira stvarne obrasce fertiliteta, što može pridonijeti slabijoj i rascjepkanijoj prostornoj autokorelaciji. Takva ograničenja ne umanjuju vrijednost primjene prostornih metoda, već upućuju na potrebu kontekstualizacije nalaza i oprezne interpretacije rezultata. U skladu s praksom istraživanja prostornih obrazaca fertiliteta na jednoj godini (Campisi i dr., 2020; Bongaarts i Sobotka, 2012), nužno je naglasiti da presječni (*cross-sectional*) TFR ima metodološka ograničenja te razmotriti njihov mogući utjecaj na rezultate.

Globalna prostorna autokorelacija fertiliteta analizirana je pomoću globalnog Moranova indeksa (*Moran's I*), dok je za detaljniji uvid u prostorne razlike fertiliteta na NUTS3 i LAU razini korišten lokalni Moranov indeks (engl. Local Moran's I, LISA, Local Indicators of Spatial Autocorrelation). Pozitivna vrijednost Moranova I upućuje na tendenciju formiranja klastera visokoga ili niskoga fertiliteta, dok negativna vrijednost sugerira da su područja s visokim fertilitetom okružena onima s niskim i obrnuto.[2] U kontekstu ovoga istraživanja definicija visokoga i niskoga fertiliteta temelji se na statističkom pristupu prostornoj autokorelaciji, a ne na rasponu apsolutnih vrijednosti (apsolutnih pragova). Vrijednost blizu nule upućuje na odsutnost prostorne autokorelacije, što sugerira nasu-

2 Niski fertilitet jest onaj ispod zamjenske razine (*sub-replacement fertility*), gdje je TFR manji od 2,1 djece po ženi, što je razina potrebna za održavanje populacije u većini razvijenih zemalja. U nekim zemljama s višim mortalitetom zamjenska razina može biti i do 3,4. Vrlo niski fertilitet (*very low fertility*) jest onaj gdje je TFR manji od 1,5 djece po ženi. Najniži fertilitet (*lowest-low fertility*) jest onaj gdje je TFR manji od 1,3 djece po ženi. Ta razina često se javlja u istočnoazijskim i južnoeuropskim zemljama. S druge strane, visoki fertilitet jest onaj gdje je TFR od 5,0 ili više. Ta se razina često povezuje s manje razvijenim zemljama, gdje su visoke stope nataliteta rezultat društvenih i ekonomskih čimbenika poput nedostatka pristupa kontracepciji i niže razine obrazovanja žena. Vidjeti: Billari i Kohler, 2004; Chen i dr. 2024.

cates the absence of spatial autocorrelation, which suggests a random distribution of the observed feature (Moran, 1948). The reliability of the results was assessed using p-values and z-values.

A key element of these calculations is the spatial weights matrix, which formally specifies the spatial relationships among units. It assigns to each unit a set of neighboring units and numerical weights that quantify the intensity of their mutual connectivity. In this study, a first-order *queen contiguity* criterion was applied, whereby units are defined as neighbors if they share a common boundary or vertex. This definition is particularly suitable for irregular administrative polygons, as it ensures that each unit has at least one neighbor and allows for the inclusion of a larger number of neighboring relations. Based on this spatial weights matrix, calculations of global and local indicators of spatial autocorrelation were conducted.

The Local Moran's Index (LISA) enables the identification of local spatial clusters, such as High-High (HH) areas of high fertility surrounded by similarly high-fertility values, and Low-Low (LL) areas of low fertility with a low-fertility environment. This categorization allows for the recognition of spatial fertility patterns without the need for universal thresholds that can be analyzed separately. LISA also detects spatial anomalies—High-Low and Low-High clusters—which indicate deviations compared to neighboring areas (regions) (Anselin, 1995). To identify zones with pronounced fertility patterns, the Getis-Ord Gi* statistic was also used. It identifies so-called hot spots and cold spots, i.e. areas with exceptionally high or low fertility. Using z-values, the Gi* statistic measures the intensity of spatial clustering and provides a clearer representation of the concentration and spatial intensity of a given phenomenon (Getis, 2008). After collecting and processing the vital statistics data obtained upon author request, total fertility rates (TFR) for all cities and municipalities for the year 2021 were calculated according to the following formula:

$$TFR = \frac{\sum ASFR_x * 5}{1000}$$

mičnu raspodjelu promatranoga obilježja (Moran, 1948). Pouzdanost rezultata procijenjena je pomoću *p*-vrijednosti i *z*-vrijednosti.

Ključni element ovih izračuna jest prostorna težinska matrica, koja formalno specificira prostorne odnose među jedinicama. Ona svakoj jedinici pridružuje skup susjednih jedinica te numeričke težine koje kvantificiraju intenzitet njihove međusobne povezanosti. U ovom istraživanju korišten je pristup *queen contiguity* prvoga reda, pri čemu se jedinice definiraju kao susjedne ako dijele zajedničku granicu ili vrh. Ovakva definicija osobito je pogodna za rad s nepravilnim administrativnim poligonima jer osigurava da svaka jedinica ima najmanje jednoga susjeda i omogućuje obuhvaćanje većega broja susjednih odnosa. Na temelju tako specificirane težinske matrice provedeni su izračuni globalnih i lokalnih pokazatelja prostorne autokorelacije.

Lokalni Moranov indeks (LISA) omogućuje identifikaciju lokalnih prostornih klastera, kao što su *High-High* (HH) područja visokoga fertiliteta okružena sličnim visokofertilitetnim vrijednostima te *Low-Low* (LL) područja niskoga fertiliteta i niskofertilitetnoga okruženja. Ova kategorizacija omogućuje prepoznavanje prostornih obrazaca fertiliteta bez potrebe za univerzalnim pragovima koji se mogu zasebno analizirati. LISA također detektira prostorne anomalije – *High-Low* i *Low-High* klastere – koje upućuju na odstupanja u odnosu na susjedna područja, tj. regije (Anselin, 1995). Za identifikaciju zona s izraženim fertilitetnim obrascima korištena je i Getis-Ord Gi* statistika. Ona prepoznaje tzv. vruće točke (*hot spots*) i hladne točke (*cold spots*), odnosno područja s izrazito visokim ili niskim fertilitetom. Pomoću z-vrijednosti Gi* statistika mjeri intenzitet prostorne grupiranosti te pruža jasniji prikaz koncentracije i prostornoga intenziteta određene pojave (Getis, 2008). Nakon prikupljanja i obrade podataka vitalne statistike dobivenih na autorski zahtjev izračunate su ukupne ili totalne stope fertiliteta (TFR) svih gradova i općina 2021. godine prema izrazu:

$$TFR = \frac{\sum ASFR_x * 5}{1000}$$

where ASFR represents the age-specific fertility rate for age group x, calculated using the formula:

pri čemu ASFR predstavlja specifičnu stopu fertiliteta za dobnu skupinu x, koja se računa formulom:

$$ASFR_x = \frac{Numberoflive-bornchildrenmothersaged\,x}{Numberofwomenaged\,x} * 1000$$

$$ASFR_x = \frac{Broj\ živorođene\ djece\ majke\ u\ dobi\ x}{Broj\ žena\ u\ dobi\ x} * 1000$$

The calculation of TFR enables a standardized assessment of fertility at different spatial levels by eliminating the influence of the age structure of the female population. Although fertility fluctuations are a common topic in Croatian demographic research, previous studies have mostly relied on the analysis of crude birth rates (CBR) at various spatial and temporal levels. Such findings, although valuable for understanding the spatial-temporal dynamics of vital events, are not a precise indicator of realized fertility since they include the total population. Given that data on total fertility rates are not available at the LAU level, the first analytical procedure included the calculation of TFR for all cities and municipalities in 2021, in order to apply the selected research methods based on the obtained values, and thus achieve the main goal of the research, which is the identification of differentiated fertility patterns at the LAU level and the comparison of micro-regional differences at the LAU and NUTS3 levels.

The analysis was conducted in the Python programming language, within the Jupyter Notebook environment and the Positron application, which enabled the integration of code, text, and visualizations within a unified research interface. Specialized packages for spatial and statistical analysis were used, such as geopandas, libpysal, contextily, and matplotlib. Jupyter Notebook and Positron allowed for tracking the analytical workflow and creating reproducible reports, while part of the analysis was additionally conducted in QGIS, emphasizing the value of open-source tools in geographic research. This approach relies on the principles of geographic data science and enables the detection of spatial patterns that are not easily observable through traditional statistical approaches (Singleton and Arribas Bel, 2019). In this context, the use of advanced spa-

Izračun TFR-a omogućuje standardiziranu procjenu fertiliteta na različitim prostornim razinama uklanjanjem utjecaja dobne strukture ženskoga stanovništva. Iako su oscilacije fertiliteta česta tema u hrvatskim demografskim istraživanjima, dosadašnja se istraživanja uglavnom oslanjaju na analizu općih stopa nataliteta (engl. *CBR*; *Crude Birth Rate*) na različitim prostornim i vremenskim razinama. Takva saznanja, premda vrijedna za razumijevanje prostorno-vremenske dinamike vitalnih događaja, nisu precizan pokazatelj ostvarene plodnosti s obzirom na to da obuhvaćaju ukupno stanovništvo. Budući da podatci o ukupnim stopama plodnosti nisu dostupni za LAU razinu, prvi je analitički postupak obuhvatio izračun TFR-a za sve gradove i općine 2021. da bi se, prema dobivenim vrijednostima, primijenile odabrane istraživačke metode, tj. ostvario temeljni cilj istraživanja, a to je identifikacija diferenciranih fertilitetnih obrazaca na LAU razini te usporedba mikro-regionalnih razlika na LAU i NUTS3 razini.

Analiza je provedena u programskom jeziku *Python*, unutar okruženja *Jupyter Notebook* i aplikacije *Positron*, što je omogućilo integraciju koda, teksta i vizualizacija unutar jedinstvenoga istraživačkog sučelja. Korišteni su specijalizirani paketi za prostornu i statističku analizu poput *geopandas*, *libpysal*, *contextily* i *matplotlib*. *Jupyter Notebook* i *Positron* omogućili su praćenje analitičkoga tijeka i izradu ponovljivih izvještaja, dok je dio analize dodatno proveden u QGIS-u, čime je naglašena vrijednost otvorenih alata u geografskim istraživanjima. Ovakav pristup oslanja se na principe geografske podatkovne znanosti i omogućuje detekciju prostornih obrazaca koji tradicionalnim statističkim pristupima nisu lako uočljivi (Singleton i Arribas Bel, 2019). Pritom izbor napred-

tial statistical methods, the application of free tools in spatial research, the choice of the main development environment, the transparency of the analysis, and similar aspects are highlighted as key scientific-research contributions to the development of the mentioned concept, using the example of a single demographic variable (fertility).

The methodological approach is based on the main hypothesis of testing the existence of spatial autocorrelation (H1), with three sub-hypotheses that guide the research process (H1a, H1b, and H1c);

H1: The values of the total fertility rate (TFR) in Croatia show statistically significant spatial autocorrelation at the NUTS3 and LAU levels.

H1a: The territory of Croatia is characterized by the presence of statistically significant local clusters of low and high TFR values (Low-Low and High-High), with their spatial concentration expected in certain areas.

H1b: The majority of the total variability in TFR is attributable to differences between LAU units within counties, while variability between counties is negligible, which confirms the importance of micro-spatial analysis of fertility.

H1c: Statistically significant clusters with high TFR values (High-High) spatially overlap with fertility hotspots identified by the Getis-Ord Gi* statistic, and it is assumed that some of them exceed the replacement fertility threshold (TFR > 2.1).

RESULTS AND DISCUSSION

A In relation to the replacement fertility threshold of 2.10, a total of 82 local self-government units (LAU) or 14.74% of all LAUs in Croatia had a higher TFR, i.e. 9 cities (7.0% of all cities in Croatia including the City of Zagreb) and 73 municipalities (17.1%), while 472 LAUs or 84.9% had a lower TFR (including 119 cities and 353 municipalities), and two LAUs (municipalities) did not register any vital events (births). In 2021, the national TFR value was 1.63 (EUROSTAT, 2022), with 6 LAUs having the same TFR value, 298 LAUs a higher value (53.6% of all LAUs), and 249 LAUs a lower value (44.8% of all LAUs). The average TFR value

nih prostornih statističkih metoda, primjena besplatnih alata u prostornim istraživanjima, odabir glavnoga razvojnog okruženja, transparenetnost analize i sl. ističemo kao glavne znanstveno-istraživačke doprinose u razvoju spomenutoga koncepta, a na primjeru jedne demografske varijable (fertiliteta).

Metodološki se pristup temelji na osnovnoj hipotezi testiranja postojanja prostorne autokorelacije (H1) s tri podvarijante koje usmjeravaju istraživački postupak (H1a, H1b i H1c).

H1: Vrijednosti ukupne stope fertiliteta (TFR) u Hrvatskoj pokazuju statistički značajnu prostornu autokorelaciju na NUTS3 i LAU razini.

H1a: Prostor Hrvatske karakterizira postojanje statistički značajnih lokalnih klastera niskih i visokih vrijednosti TFR-a (*Low-Low* i *High-High*), pri čemu se očekuje njihova prostorna koncentracija u određenim područjima.

H1b: Veći dio ukupne varijabilnosti TFR-a odnosi se na razlike između LAU jedinica unutar županija, dok je među županijama ona zanemariva, što potvrđuje važnost mikroprostorne analize fertiliteta.

H1c: Statistički značajni klasteri s visokom vrijednosti TFR-a (*High-High*) prostorno se podudaraju s fertilitetnim *hotspotovima* Getis-Ord Gi* statistike te se pretpostavlja da dio njih premašuje prag zamjenske razine fertiliteta (TFR > 2.1).

REZULTATI I RASPRAVA

U odnosu na graničnu vrijednost zamjenskoga fertiliteta od 2,10 ukupno je 82 JLS-a ili 14,74 % svih JLS-a u Hrvatskoj imalo viši TFR, tj. 9 gradova (7,0 % svih gradova u RH uključujući i Grad Zagreb) te 73 općina (17,1 %), a niži ukupno 472 JLS-a ili 84,9 % (od toga 119 gradova i 353 općina), dok dva JLS-a (općine) nisu imala registriranu pojavu vitalnoga događaja (rođenja). TFR je 2021. godine na državnoj razini iznosio 1,63 (EUROSTAT, 2022), a ukupno je 6 JLS-ova imalo istu vrijednost TFR-a, 298 JLS-ova višu (53,6 % svih JLS-ova), a 249 JLS-ova nižu vrijednost (44,8 % svih JLS-ova). Prosječna vrijednost TFR-a u gradovima je 2021.

Tab. 1 TFR values at the NUTS3 level in 2021.
Tab. 1. Vrijednosti TFR-a na NUTS3 razini 2021. godine

NUTS3 region / NUTS3 regija	**TFR**
Međimurska županija	1,93
Bjelovarsko-bilogorska županija	1,79
Virovitičko-podravska županija	1,79
Ličko-senjska županija	1,77
Koprivničko-križevačka županija	1,76
Dubrovačko-neretvanska županija	1,75
Zadarska županija	1,74
Brodsko-posavska županija	1,70
Požeško-slavonska županija	1,68
Vukovarsko-srijemska županija	1,68
Sisačko-moslavačka županija	1,68
Splitsko-dalmatinska županija	1,65
Zagrebačka županija	1,64
Osječko-baranjska županija	1,62
Šibensko-kninska županija	1,59
Varaždinska županija	1,56
Krapinsko-zagorska županija	1,54
Grad Zagreb	1,53
Karlovačka županija	1,49
Istarska županija	1,49
Primorsko-goranska županija	1,46

Source: EUROSTAT, (2022)
Izvor: EUROSTAT, (2022)

in cities in 2021 was 1.65, and slightly higher in municipalities—1.85. TFR ranges at the NUTS3 level were between 1.46 (Primorje-Gorski Kotar County) and 1.93 (Međimurje County) (Tab. 1).

After a brief overview of fertility trends at both considered levels, spatial autocorrelation was analyzed using the values of the Global and Local Moran's Index. When observing the results at the NUTS3 spatial level (Fig. 1.a), spatial clustering of units is evident. LISA analysis indicates the presence of four types of clusters: High-High (HH) with 9 units; Low-Low (LL) with 6 units; Low-High (LH) with 4 units; and High-Low (HL) with 2 units.

Spatial relationships between clusters are determined by spatial weights, which define the neighborhood of units and the method of calculating spatial autocorrelation. This refers to a matrix system of relationships between spatial units, which

godine bila 1,65, a u općinama nešto viša, 1,85. Rasponi TFR-a NUTS 3 razine su između 1,46 (Primorsko-goranska županija) i 1,93 (Međimurska županija) (tab.1).

Nakon kratkoga pregleda fertilitetnih trendova na objema razmatranim razinama analizirana je prostorna autokorelacija iskazana vrijednostima globalnoga i lokalnoga Moranova indeksa. Ako se promotre rezultati na NUTS3 prostornoj razini (sl. 1), uočava se prostorno klasteriranje jedinica. LISA analiza upućuje na prisutnost četiriju tipova klastera: *High-High* (HH) s 9 jedinica, *Low-Low* (LL) sa 6 jedinica, *Low-High* (LH) s 4 jedinice i *High-Low* (HL) s 2 jedinice.

Prostorne relacije između klastera određuju se prostornim ponderima koji definiraju susjedstvo jedinica i način izračuna prostorne autokorelacije. Riječ je o matričnom sustavu odnosa između prostornih jedinica kojim se određuje koje su veze re-

determines which connections are relevant for the analysis. To quantify the deviation of individual units from the average, the z-score is used, which shows how far the TFR of a given unit deviates from the average value in the dataset, expressed in standard deviations. Z-scores allow for the identification of significant deviations and were used as one of the criteria for determining clusters. In the context of spatial analysis, z-scores are used as one of the criteria for identifying clusters, with reference thresholds defined as follows:

- $Z > 1 \rightarrow$ units with above-average fertility, potential HH clusters if surrounded by units with similarly high values.
- $Z < -1 \rightarrow$ units with below-average fertility, potential LL clusters if surrounded by units with similarly low values.

The Global Moran's Index (I = 0.2580) indicates a moderate positive spatial autocorrelation, while the p-value of 0.0470 confirms statistical significance at a 95% confidence level. These results confirm the existence of statistically significant spatial autocorrelation of total fertility rate (TFR) values at the NUTS3 level, thereby supporting the hypothesis of spatial clustering of similar fertility values. Although the LISA analysis shows several local clusters, only one High-High cluster was confirmed as statistically significant ($p < 0.05$), which is Koprivnica-Križevci County, indicating limited spatial connectivity of fertility values between NUTS3 regions (Fig. 1 and Fig. 2).

Although the TFR of Koprivnica-Križevci County is 1.79—which is equal to or lower than that of neighboring counties—its classification as a High-High (HH) cluster does not result from absolute values, but from the spatial distribution of fertility. The analysis uses the Local Moran's Index, defined by the formula:

$$I_i = Z_i \sum \quad W_{ij} Z_j$$

where I_i represents the index value for county i, Z_i and Z_j are the standardized TFR values, and W_{ij} is the spatial weight defining the neighborhood between units i and j. A key point is that Koprivnica-Križevci County is the only unit with statistically significant spatial autocorrelation ($p < 0.05$),

levantne za analizu. Za kvantificiranje odstupanja pojedinih jedinica od prosjeka koristi se z-vrijednost (*z-score*), koja pokazuje koliko je TFR određene jedinice udaljen od prosječne vrijednosti u skupu podataka, izraženo u standardnim devijacijama. Z-vrijednosti omogućuju identifikaciju značajnih odstupanja i korištene su kao jedan od kriterija za određivanje klastera. U kontekstu prostorne analize z-vrijednosti koriste se kao jedan od kriterija za identifikaciju klastera, pri čemu su referentni pragovi definirani na sljedeći način:

- $Z > 1 \rightarrow$ jedinice s iznadprosječnim fertilitetom, potencijalni HH klasteri ako su okruženi jedinicama s također visokim vrijednostima.
- $Z < -1 \rightarrow$ jedinice s ispodprosječnim fertilitetom, potencijalni LL klasteri ako su okruženi jedinicama s također niskim vrijednostima.

Globalni Moranov indeks (I = 0.2580) upućuje na umjerenu pozitivnu prostornu autokorelaciju, dok p-vrijednost od 0.0470 potvrđuje statističku značajnost na razini od 95 % pouzdanosti. Ovi rezultati potvrđuju postojanje statistički značajne prostorne autokorelacije vrijednosti ukupne stope fertiliteta (TFR) na NUTS3 razini, čime se potvrđuje hipoteza o prostornom grupiranju sličnih vrijednosti fertiliteta. Iako LISA analiza prikazuje više lokalnih klastera, jedan je *High-High* klaster potvrđen kao statistički značajan ($p < 0.05$), a to je Koprivničko-križevačka županija, što upućuje na ograničenu prostornu povezanost vrijednosti fertiliteta između NUTS3 regija (sl. 1 i sl. 2).

Iako TFR Koprivničko-križevačke županije iznosi 1,79 – što je jednako ili niže od susjednih županija – njezina kategorizacija u *High-High* (HH) klaster ne proizlazi iz apsolutnih vrijednosti, već iz prostorne distribucije fertiliteta. U analizi se koristi lokalni Moranov indeks, definiran formulom:

$$I_i = Z_i \sum \quad W_{ij} Z_j$$

gdje I_i predstavlja vrijednost indeksa za županiju *i*, Z_i i Z_j su standardizirane vrijednosti TFR-a, a W_{ij} prostorni ponder koji definira susjedstvo između jedinica *i* i *j*. Ključna je činjenica da je Koprivničko-križevačka županija jedina jedinica s prostorno statistički značajnom autokorelacijom ($p < 0,05$),

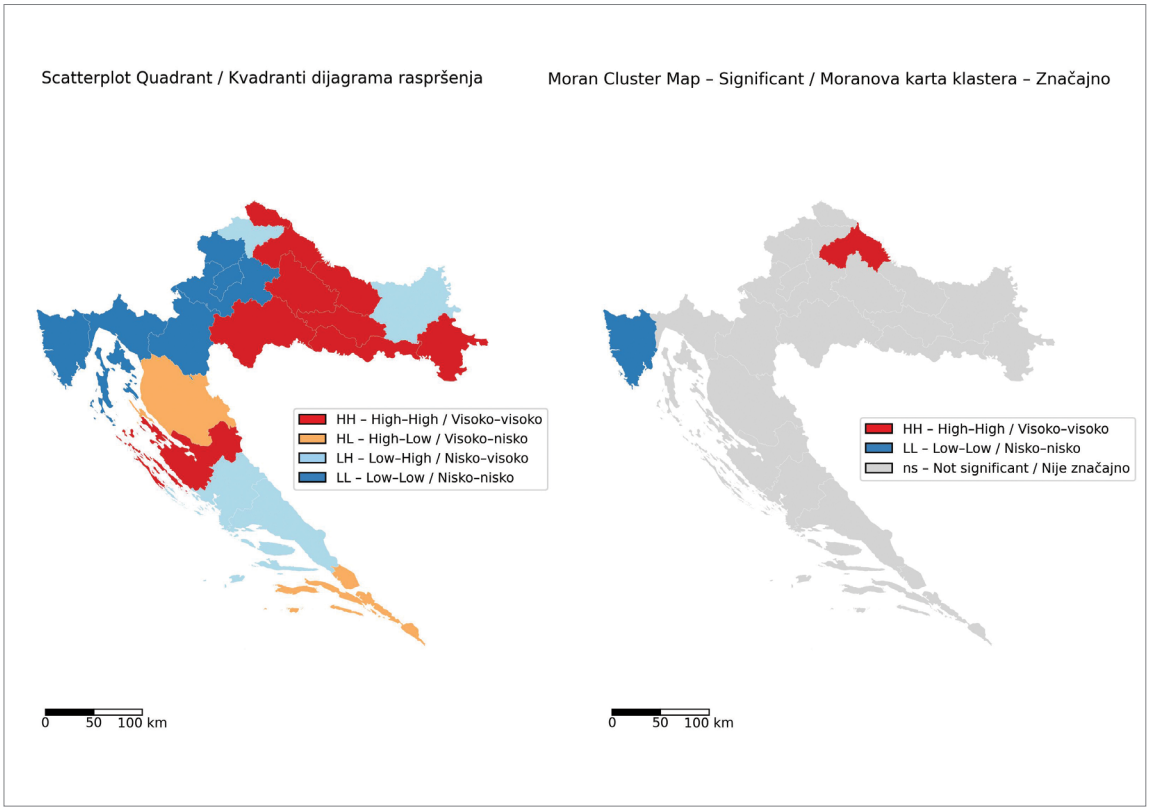

Fig. 1 Spatial autocorrelation at the NUTS3 (LAU) level in Croatia
Sl. 1. Prostorna autokorelacija na NUTS3 razini u Hrvatskoj

confirming that its fertility is consistent with the pattern of neighboring counties (Fig. 3).

Further analysis was conducted on spatial patterns and the degree of association between the values of the Global Moran's Index and the local indicators of spatial autocorrelation (LISA). The results shown on the maps (Fig. 2) indicate the presence of spatial clustering, but with significant differences compared to the NUTS3 level.

LISA analysis shows four types of spatial association: Low-Low (LL) with 180 units, High-High (HH) with 165, Low-High (LH) with 109, and High-Low (HL) with 102 units (Fig. 2.a). However, using the statistical significance threshold ($p < 0.05$), only 70 LAU units fall into significant clusters (Fig. 3.b), indicating a relatively fragmented spatial pattern. The largest grouping of HH clusters is observed in parts of Moslavina and Podravina, central Lika, western Slavonia, and the Zadar hinterland, while LL clusters are concentrated in the Kupa River area,

što potvrđuje da je njezin fertilitet u skladu s obrascem susjednih županija (sl. 3).

Nadalje su analizirani prostorni obrasci i stupanj povezanosti vrijednosti globalnoga Moranova indeksa i lokalnih indikatora prostorne autokorelacije (LISA). Rezultati prikazani na kartama (sl. 2) ukazuju na prisutnost prostornoga grupiranja, ali uz značajne razlike u odnosu na NUTS3 razinu.

LISA analiza pokazuje četiri tipa prostorne povezanosti: *Low-Low* (LL) sa 180 jedinica, *High-High* (HH) sa 165, *Low-High* (LH) sa 109 i *High-Low* (HL) sa 102 jedinice (sl. 2a). Međutim, uz prag statističke značajnosti ($p < 0.05$), samo 70 LAU jedinica ulazi u značajne klastere (sl. 3b), što upućuje na razmjerno fragmentiran prostorni obrazac. Najveće grupiranje HH klastera uočava se u dijelovima Moslavine i Podravine, središnjoj Lici, zapadnoj Slavoniji i zadarskom zaleđu, dok su LL klasteri koncentrirani u pokupskom području, Kordunu i središnjoj Istri. Z-vrijednosti potvrđuju da

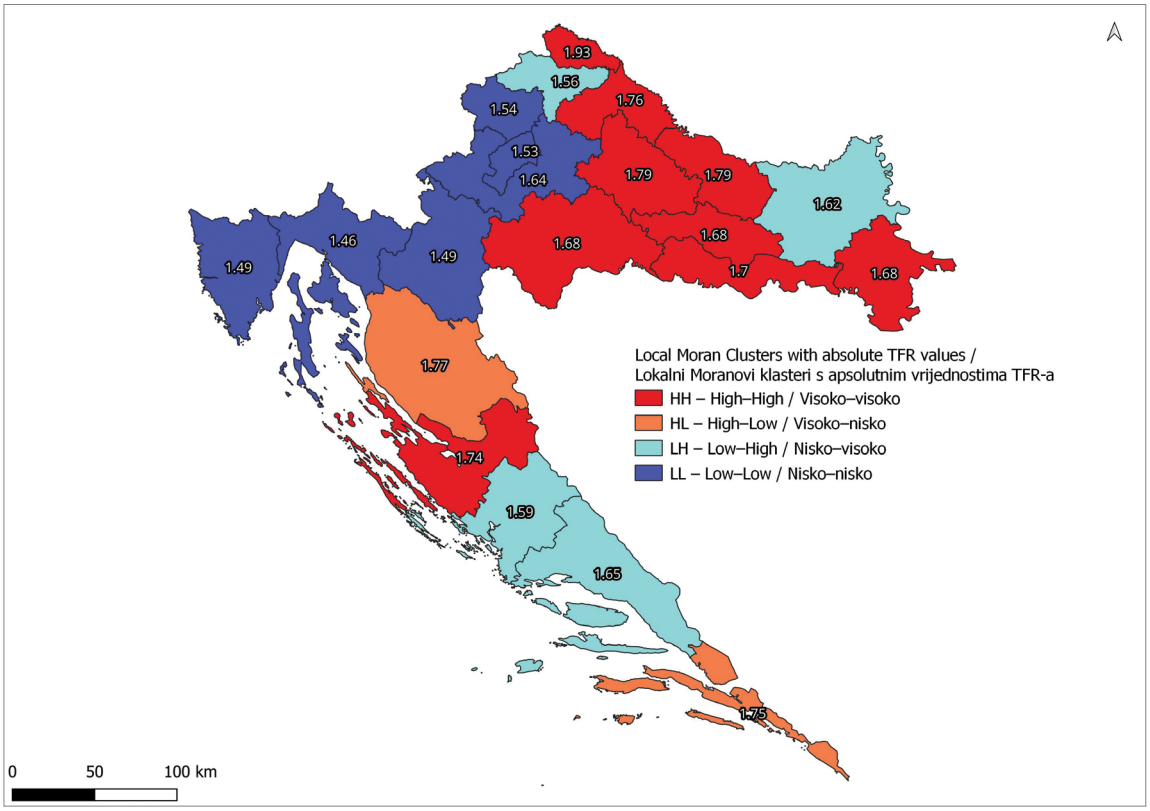

Fig. 2 Spatial autocorrelation at the NUTS3 level in Croatia
Sl. 2. Prostorna autokorelacija na NUTS3 razini u Hrvatskoj

Kordun, and central Istria. Z-values confirm that units in HH clusters have significantly above-average fertility, with some regions standing out with values above 2, i.e. more than two standard deviations above the mean. LL clusters include regions with extremely low fertility ($z < -1$). This spatial distribution confirms clearly separated patterns and indicates a spatial concentration of similar demographic characteristics, thereby also confirming hypothesis H1a (Fig. 4).

The Global Moran's Index ($I = 0.0819$) indicates weak but statistically significant positive spatial autocorrelation, which means that units with similar TFR values still tend to cluster, but with less spatial cohesion compared to the NUTS3 level. The expected index under the assumption of random distribution is -0.0018, and the z-value of 2.9197 indicates a significant deviation from random spatial distribution. Statistical significance is confirmed at a 95% confidence level ($p = 0.0040$), which leads to the rejection of the null hypothesis of spatial randomness.

jedinice u HH klasterima imaju znatno iznadprosječan fertilitet, pri čemu se neke regije izdvajaju s vrijednostima većima od 2, odnosno više od dvije standardne devijacije iznad prosjeka. LL klasteri obuhvaćaju regije s izrazito niskim fertilitetom ($z < -1$). Ova prostorna raspodjela potvrđuje jasno razdvojene obrasce i upućuje na prostornu koncentraciju sličnih demografskih karakteristika, čime je hipoteza H1a također potvrđena (sl. 4).

Globalni Moranov indeks ($I = 0.0819$) upućuje na slabu, ali statistički značajnu pozitivnu prostornu autokorelaciju, što znači da jedinice sa sličnim TFR-om ipak imaju tendenciju grupiranja, ali s manjom prostornom kohezijom u usporedbi s NUTS3 razinom. Očekivani indeks pod pretpostavkom slučajne distribucije iznosi –0.0018, a z-vrijednost od 2.9197 upućuje na značajno odstupanje od slučajne prostorne distribucije. Statistička značajnost potvrđena je na razini od 95 % pouzdanosti ($p = 0.0040$), zbog čega je odbačena hipoteza prostorne slučajnosti.

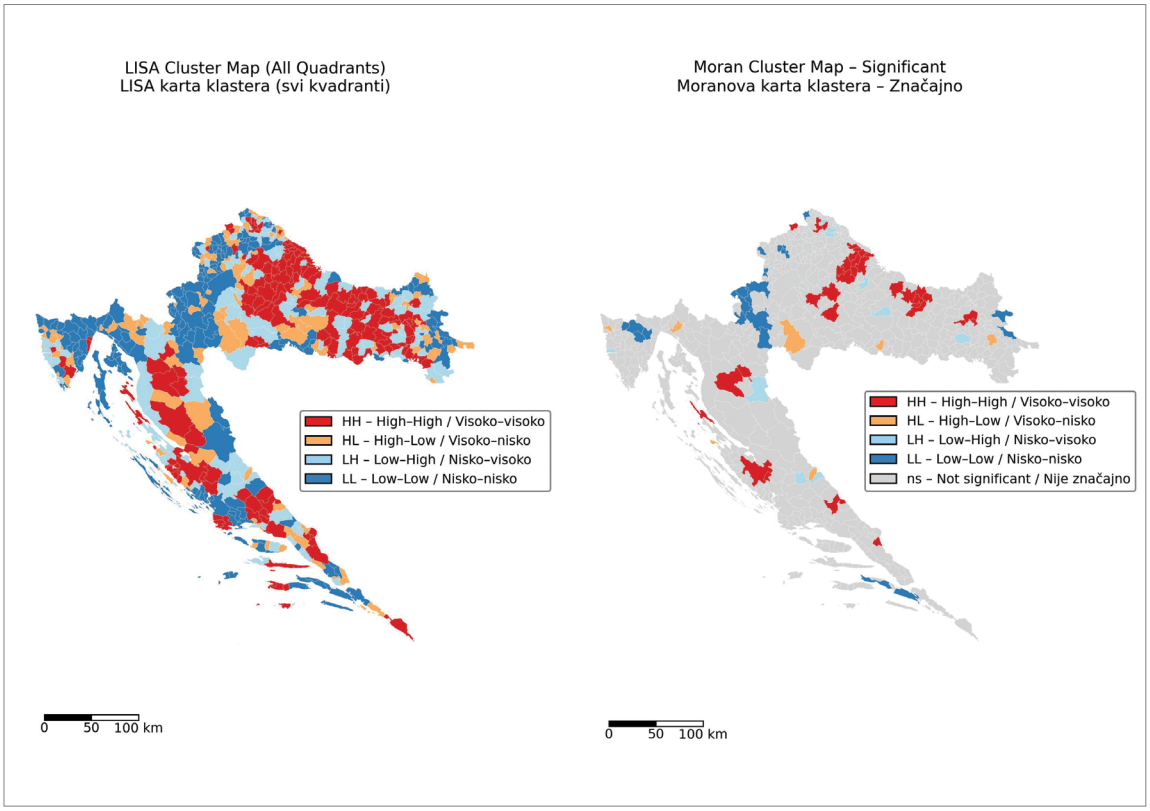

Fig. 3 Spatial autocorrelation at the LAU level in Croatia
Sl. 3. Prostorna autokorelacija na LAU razini u Hrvatskoj

When comparing Global Moran's Index values, it is important to distinguish between statistical significance and effect size. Statistical significance (p- and z-values) indicates the likelihood that the observed spatial pattern is not random. At the LAU level, due to the large number of smaller units, even low spatial autocorrelation (e.g. Moran's I = 0.0819) can be statistically significant ($p < 0.05$), indicating a slight but real clustering of similar TFR values. In contrast, at the NUTS3 level—with a smaller number of larger units; higher index values are required for clustering to be clearly expressed. Therefore, the interpretation of results should be aligned with the spatial level of analysis, as the strength of the effect varies depending on the size and number of units. TFR, as a general indicator, requires such contextualization for proper interpretation of spatial patterns.

Out of 29 local self-government units with more than 20,000 inhabitants, only 9 have a higher TFR than the NUTS3 level, and these are: Slavon-

Prilikom usporedbe vrijednosti galobalnog Moranova indeksa važno je razlikovati statističku značajnost od veličine učinka. Statistička značajnost (p- i z-vrijednosti) pokazuje vjerojatnost da uočeni prostorni obrazac nije slučajan. Na LAU razini, zbog velikog broja manjih jedinica, i niska prostorna autokorelacija (npr. Moran's I = 0.0819) može biti statistički značajna ($p < 0.05$), upućujući na blago, ali realno grupiranje sličnih TFR vrijednosti. Nasuprot tomu, na NUTS3 razini – s manjim brojem većih jedinica – potrebne su veće vrijednosti indeksa da bi grupiranje bilo jasno izraženo. Stoga interpretaciju rezultata treba uskladiti s prostornom razinom analize jer jačina učinka varira ovisno o veličini i broju jedinica. TFR kao opći pokazatelj zahtijeva takvu kontekstualizaciju za ispravno tumačenje prostornih obrazaca.

Od 29 jedinica lokalne samouprave s više od 20.000 stanovnika samo 9 ima veći TFR od NUTS3 razine, a to su: Slavonski Brod, Dubrovnik,

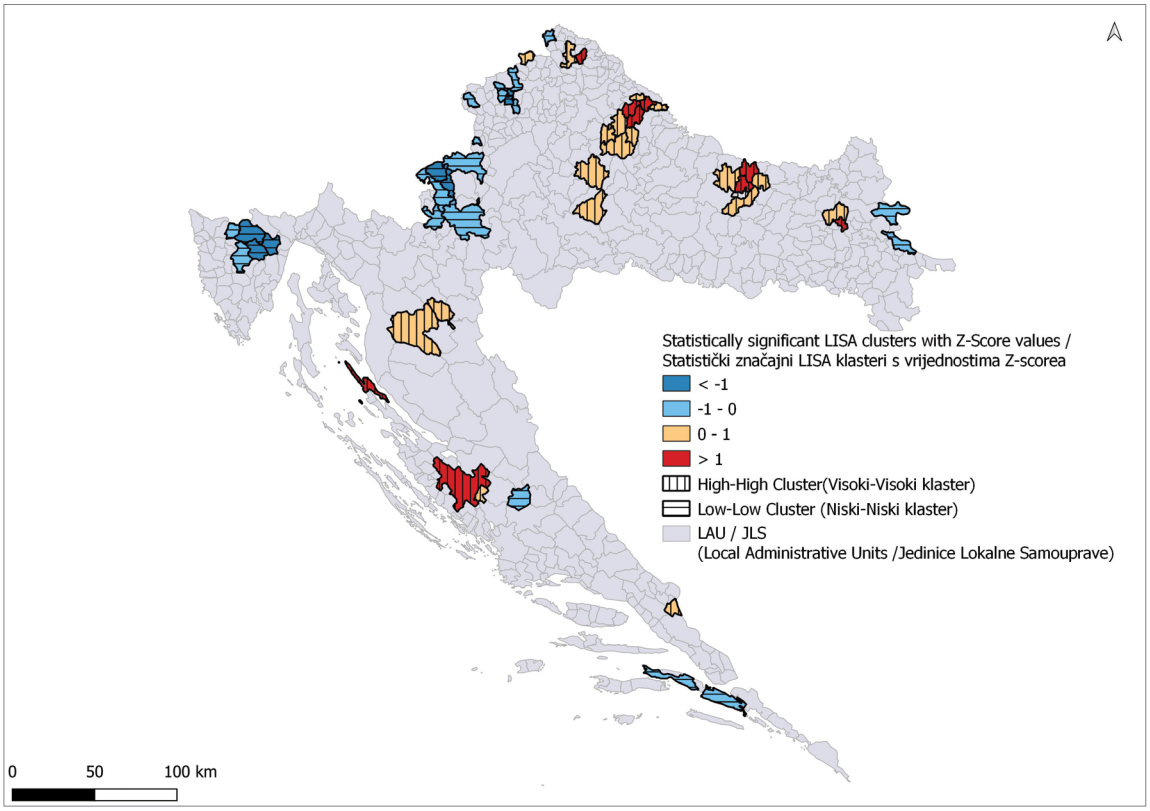

Fig. 4 Relationship and spatial distribution of clusters and z-values
Sl. 4. Međuodnos i prostorna raspodjela klastera i z-vrijednosti

ski Brod; Dubrovnik; Križevci; Kutina; Petrinja; Sinj; Solin; Šibenik; and Vinkovci. All other local self-government units have a lower TFR than the county, i.e. NUTS3 level (Fig. 5; Table 2).

This finding indicates that fertility in larger urban centers generally remains below the county average, confirming the broader pattern of lower fertility in urban environments compared to smaller towns and rural areas. Exceptions (such as Slavonski Brod, Dubrovnik, Križevci, or Sinj) point to the presence of specific local factors—such as more favorable socio-economic conditions, migration patterns, or the availability of family-oriented services—that may contribute to higher fertility rates. This further underlines the importance of micro-level analysis, since local variations cannot be fully captured by observing only aggregated county-level data.

By applying a multilevel (random-intercept) model, with Local Administrative Units (LAU)

Križevci, Kutina, Petrinja, Sinj, Solin, Šibenik, Vinkovci. Sve ostale jedinice lokalne samouprave imaju niži TFR od županijske, odnosno NUTS3 razine (sl. 5; tab. 2).

Ovaj nalaz pokazuje da se u većim urbanim središtima fertilitet uglavnom zadržava na nižoj razini od županijskoga prosjeka, što potvrđuje opći obrazac nižega fertiliteta u gradskim sredinama u odnosu na manje gradove i ruralna područja. Iznimke (poput Slavonskog Broda, Dubrovnika, Križevaca ili Sinja) upućuju na postojanje specifičnih lokalnih čimbenika – poput povoljnijih socio-ekonomskih prilika, migracijskih obrazaca ili dostupnosti usluga za obitelji – koji mogu djelovati u smjeru viših stopa fertiliteta. Time se dodatno potvrđuje važnost analize na mikroprostornoj razini jer se lokalne varijacije ne mogu uočiti isključivo promatranjem agregiranih županijskih podataka.

Primjenom višerazinskoga (*random-intercept*) modela, u kojem su jedinice lokalne samouprave

Tab. 2 LAUs with a higher fertility rate compared to the NUTS3 level
Tab. 2. LAU s većom stopom fertiliteta u odnosu na NUTS3 razinu

LAU	TFR LAU	TFR NUTS3
Križevci	1,79	1,76
Kutina	1,75	1,68
Petrinja	1,72	1,68
Sinj	1,76	1,65
Slavonski Brod	1,72	1,70
Solin	1,77	1,65
Šibenik	1,62	1,62
Vinkovci	1,76	1,68
Dubrovnik	1,80	1,75

Source: EUROSTAT, 2022.
Izvor: EUROSTAT, 2022.

nested within counties (NUTS3), it was established that only 3.7% of the total variability in TFR can be attributed to differences between counties (ICC = 0.037), while the remaining 96.3% reflects heterogeneity between LAU units within counties. In other words, spatial variability in fertility is far more pronounced at the micro level. Descriptive measures further support this difference: at the LAU level, the standard deviation of TFR is 0.47 with a coefficient of variation of 0.28, whereas at the county level it is only 0.14 with a coefficient of variation of 0.08. These results confirm hypothesis H1b, namely that fertility variability is more pronounced at the lower administrative level, and underscore the importance of micro-spatial analysis of fertility.

The analysis of spatial autocorrelation of TFR at the NUTS3 and LAU levels confirms the existence of spatial patterns, despite differences in the strength of clustering. The NUTS3 level shows more pronounced but spatially limited association, while the LAU level, although with lower values, records statistically significant patterns due to the larger number of units. The observed differences, especially between major urban centers and medium-sized towns, highlight the importance of local demographic measures. These findings provide a basis for further analysis using the Getis-Ord Gi* statistic, in order to more precisely map so-called fertility hot and cold spots.

(LAU) ugniježđene unutar županija (NUTS3), utvrđeno je da se svega 3,7 % ukupne varijabilnosti TFR-a može pripisati razlikama između županija (ICC = 0,037), dok se preostalih 96,3 % odnosi na heterogenost između LAU jedinica unutar županija. Drugim riječima, prostorna varijabilnost fertiliteta daleko je izraženija na mikroprostornoj razini. Deskriptivne mjere dodatno potvrđuju ovu razliku: na razini LAU jedinica standardna devijacija TFR-a iznosi 0,47 uz koeficijent varijacije od 0,28, dok na razini županija iznosi svega 0,14 uz koeficijent varijacije od 0,08. Takvi rezultati potvrđuju hipotezu H1b da je varijabilnost fertiliteta izraženija na nižoj administrativnoj razini te naglašavaju važnost mikroprostorne analize fertiliteta.

Analiza prostorne autokorelacije TFR-a na NUTS3 i LAU razini potvrđuje postojanje prostornih obrazaca unatoč razlikama u jačini grupiranja. NUTS3 razina pokazuje izraženiju, ali prostorno ograničenu povezanost, dok LAU razina, iako s nižim vrijednostima, bilježi statistički značajne obrasce zbog većega broja jedinica. Uočene razlike, posebno između većih urbanih središta i srednje velikih gradova, upućuju na važnost lokalnih demografskih mjera. Ti su nalazi osnova za daljnju analizu putem Getis-Ord Gi* statistike radi preciznijega kartiranja tzv. vrućih i hladnih fertilitetnih žarišta.

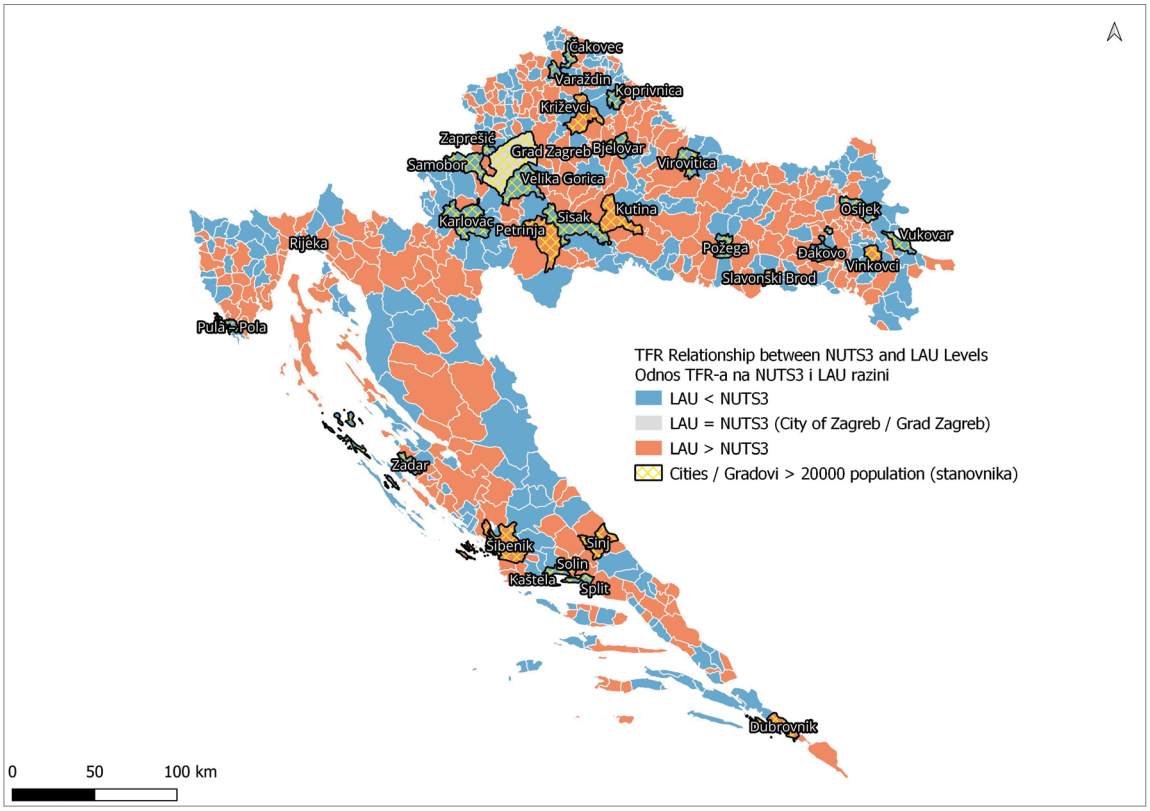

Fig. 5 Relationship between TFR at the LAU and NUTS3 levels in Croatia
Sl. 5. Međuodnos TFR-a na LAU i NUTS3 razini u Hrvatskoj

The results of the Getis-Ord Gi* analysis further confirm the presence of spatial patterns in the distribution of TFR at the LAU level. Z-values indicate pronounced hotspots in parts of Slavonia, central Lika, and the wider area around Bjelovar, Koprivnica. On the other hand, clearly defined coldspots appear in western and northwestern Croatia—including Istria, the Rijeka-Kvarner and Zagreb areas, the wider Karlovac area, and Hrvatsko Zagorje—as well as in some regions with lower intensity, such as eastern Croatia the central Dalmatian coast, the Zadar area, and the islands of southern Dalmatia (Fig. 6).

In addition to the analysis of z-values, the level of statistical confidence was also examined, which further clarifies the spatial distribution of areas with higher (hotspots) and lower (coldspots) TFR. This analysis not only identifies spatial patterns but also highlights the level of their statistical significance, enabling a deeper understanding of local demographic dynamics (Fig. 7).

Rezultati Getis-Ord Gi* analize dodatno potvrđuju prisutnost prostornih obrazaca u distribuciji TFR-a na LAU razini. Z-vrijednosti upućuju na izražene *hotspotove* u dijelovima Slavonije, središnje Like te širem području Bjelovara, Koprivnice. S druge strane, jasno su definirani *coldspotovi* u zapadnoj i sjeverozapadnoj Hrvatskoj – uključujući Istru, riječko-kvarnersko i zagrebačko područje, širi karlovački prostor i Hrvatsko zagorje – kao i u nekim regijama slabijega intenziteta, poput krajnjega istoka, obale srednje Dalmacije, zadarskoga područja i otoka južne Dalmacije (sl. 6).

Osim analize z-vrijednosti, analizirana je i razina statističke pouzdanosti koja dodatno pojašnjava prostornu distribuciju područja s višim (*hotspots*) i nižim (*coldspots*) TFR-om. Ova analiza ne samo da identificira prostorne uzorke već naglašava razinu njihove statističke značajnosti, čime se omogućuje značajnije razumijevanje lokalnih demografskih dinamika (sl. 7).

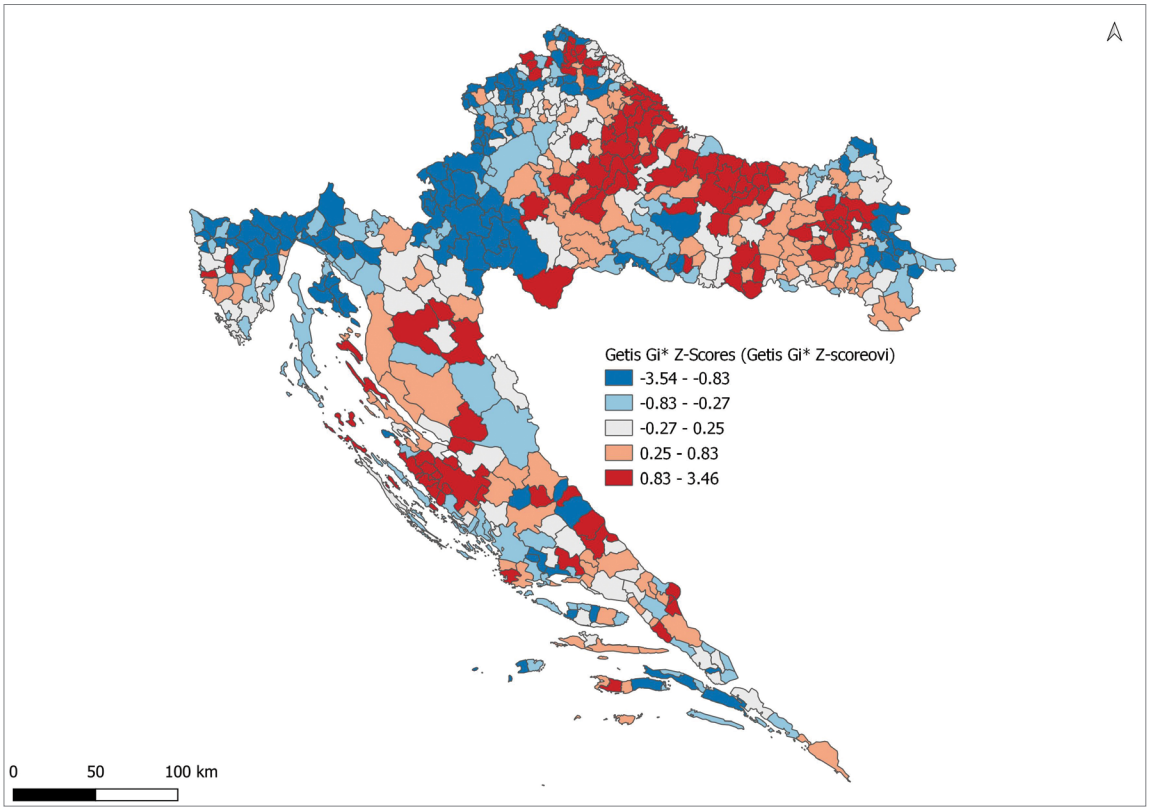

Fig. 6 Z-values of the Getis-Ord Gi* statistic
Sl. 6. Z-vrijednosti Getis-Ord Gi* statistike

When interpreting these results, it is important to note that the analysis is based on cross-sectional data for 2021, which limits their representativeness in a broader temporal context. Spatial fertility patterns could differ if data from another year, alternative fertility measures (e.g. cohort or tempo-adjusted TFR), or different definitions of spatial neighborhood were applied. Therefore, the identified clusters should not be interpreted at the level of individual units in isolation, but rather in terms of broader patterns, regions and areas where clusters and outliers emerge. In this sense, the main contribution of the results lies in identifying spatial tendencies, while individual units should be considered in relation to their neighborhood rather than independently.

The most statistically pronounced hot spots, with over 95% confidence, are concentrated in the Moslavina and Podravina regions, while the most pronounced cold spots extend from western Banovina and parts of Kordun towards the broader Pokuplje area (Fig. 8).).

Pri tumačenju ovih rezultata potrebno je imati na umu da se analiza temelji na presječnim podatcima za 2021. godinu, što ograničava njihovu reprezentativnost u širem vremenskom kontekstu. Prostorni obrasci fertiliteta mogli bi se djelomično razlikovati kada bi se koristili podatci za neku drugu godinu, alternativne mjere fertiliteta (npr. kohortni), ili drukčije definicije prostornoga susjedstva. Stoga identificirane klastere nije preporučljivo interpretirati na razini pojedinih jedinica izolirano, već je analitički važnije uočavanje širih obrazaca – regija i područja u kojima se klasteri i *outlieri* pojavljuju. U tom je smislu doprinos ovih rezultata prije svega u identificiranju prostornih tendencija, dok pojedine jedinice treba promatrati u odnosu na svoje susjedstvo, a ne izdvojeno.

Statistički najizraženiji *hotspotovi* s više od 95 % pouzdanosti, koncentrirani su u području Moslavine i Podravine, dok se najizraženiji cold-spotovi protežu od zapadne Banovine i dijelova Korduna prema širem području Pokuplja (sl. 8)

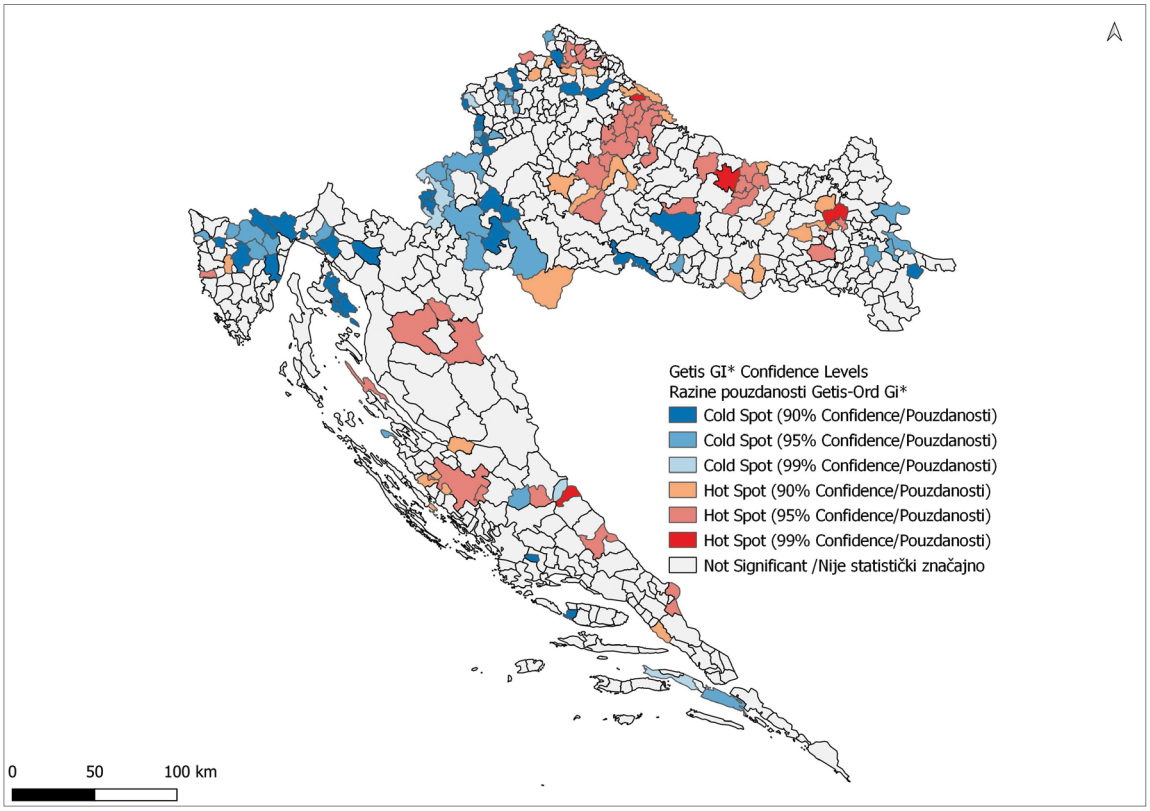

Fig. 7 Statistically significant hotspot and coldspot areas in Croatia
Sl. 7. Statistički značajna *hotspot* i *coldspot* područja Hrvatske

By combining the mentioned levels of clustering (Local Moran's Index and Getis-Ord Gi* statistic), LAU units were identified that belong to High-High or Low-Low clusters and are also hotspots or coldspots with at least 95% confidence. For example, Sinj, Bjelovar, and Čakovec are part of High-High clusters and show 99% statistical significance as Getis-Ord Gi* hotspots. Samobor and Vukovar, on the other hand, are within Low-Low clusters and have 95% statistical significance as Getis-Ord Gi* coldspots (Fig. 9).

Transitional zones, that is, LAU units located on the borders of pronounced clusters, may play an important role in shaping regional demographic patterns. Cities such as Karlovac, Sisak, Kutina, Osijek, Virovitica, Koprivnica, Križevci, and Zaprešić are located at the edges of high or low TFR clusters and represent potential focal points for the spread of positive or negative fertility trends. However, given the complexity of fertility determinants, such assumptions cannot be generalized. While

Kombinacijom navedenih razina klasteriranja (lokalni Moranov indeks i Getis-Ord Gi* statističkim metodama) izdvojene su LAU jedinice, koje pripadaju *High-High* ili *Low-Low* klasteru i koje su ujedno *hotpostovi* ili *coldpostovi* s najmanje 95 % pouzdanosti. Primjerice, Sinj, Bjelovar i Čakovec dio su *High-High* klastera te imaju statističku značajnost Getis-Ord Gi* *hotspota* na razini od 99 %. Samobor i Vukovar, s druge strane, nalaze se unutar *Low-Low* klastera te imaju statističku značajnost od 95 % Getis-Ord Gi* *coldspotova* (sl. 9).

Prijelazne zone, odnosno LAU jedinice na granicama izraženih klastera, mogu imati važnu ulogu u oblikovanju regionalnih demografskih obrazaca. Gradovi poput Karlovca, Siska, Kutine, Osijeka, Virovitice, Koprivnice, Križevaca i Zaprešića nalaze se na rubovima visokih ili niskih TFR klastera te predstavljaju potencijalna žarišta širenja pozitivnih ili negativnih fertilitetnih trendova. Ipak, s obzirom na kompleksnost determinanti fertiliteta, takve pretpostavke nije moguće

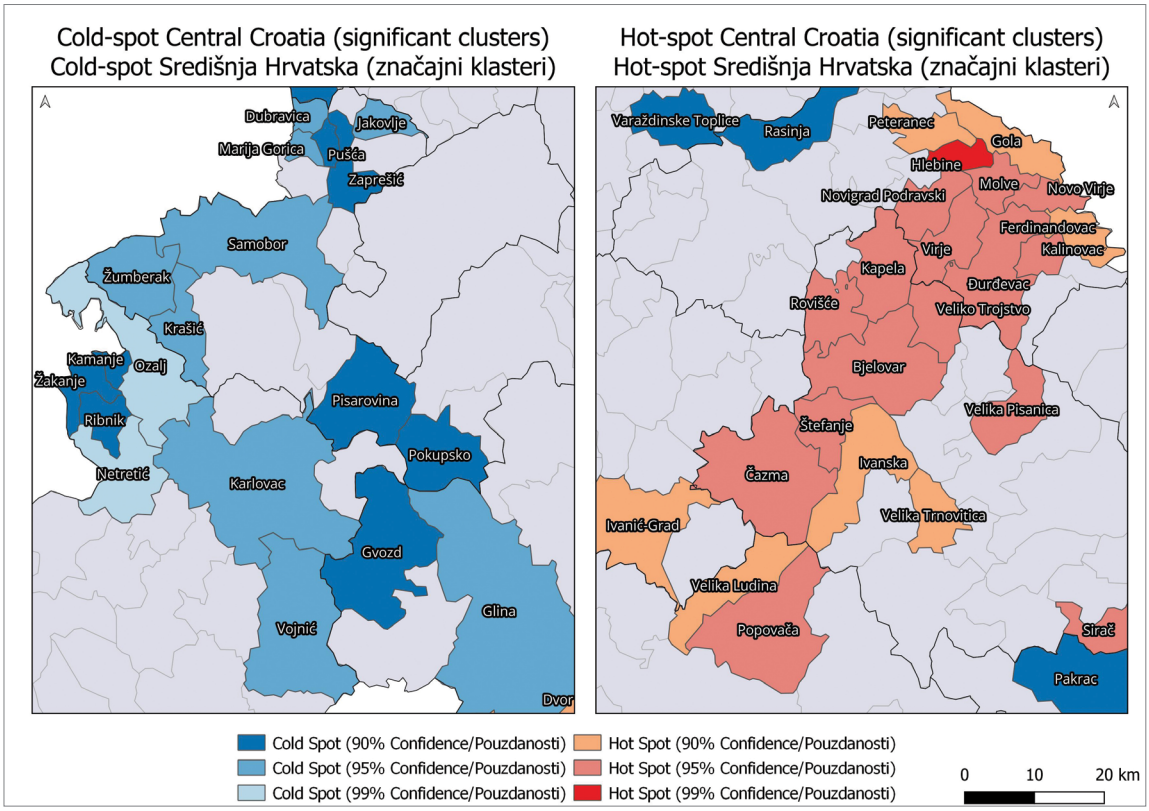

Fig. 8 Statistically significant hotspot and coldspot LAU areas
Sl. 8. Statistički značajna *hotspot* i *coldspot* LAU područja

proximity to a more favorable cluster may facilitate the transfer of positive patterns, the presence of low fertility in the surrounding area may also have the opposite effect. Around Osijek and in the wider area of Bjelovar, Koprivnica, and Virovitica, positive clusters are more prevalent, while the areas of Karlovac, Samobor, and Zaprešić stand out as negative cluster zones.

Via further analysis, units were identified that simultaneously have a TFR higher than 2.1, belong to HH clusters, and have statistically significant Gi* values (p ≥ 95%) (Fig. 10). These represent the most demographically favorable zones, where fertility exceeds the level needed for simple generational replacement and where high TFR values have been recorded in comparison to neighboring regions. There are a total of 13 such units: Novalja; Benkovac; Runovići; Molve; Mala Subotica; Novo Virje; Virje; Kapela; Slatina; Čađavica; Mikleuš; Nova Bukovica; and Vladislavci.

generalizirati. Iako blizina povoljnijega klastera može olakšati prijenos pozitivnih obrazaca, prisutnost niskoga fertiliteta u okolici može imati i suprotan učinak. Oko Osijeka i u širem području Bjelovara, Koprivnice i Virovitice prisutniji su pozitivni klasteri, dok se područja Karlovca, Samobora i Zaprešića izdvajaju kao prostori negativnih klastera.

Daljnjom analizom izdvojene su jedinice koje istovremeno imaju TFR viši od 2.1, čine HH klastere i imaju statistički značajne Gi* vrijednosti (p ≥ 95 %) (sl. 10). Riječ je o demografski najpovoljnijim zonama gdje fertilitet premašuje razinu potrebnu za jednostavnu generacijsku obnovu i u kojima su registrirane visoke vrijednosti TFR-a u odnosu na susjedne regije. Ukupno je 13 takvih jedinica: Novalja, Benkovac, Runovići, Molve, Mala Subotica, Novo Virje, Virje, Kapela, Slatina, Čađavica, Mikleuš, Nova Bukovica i Vladislavci.

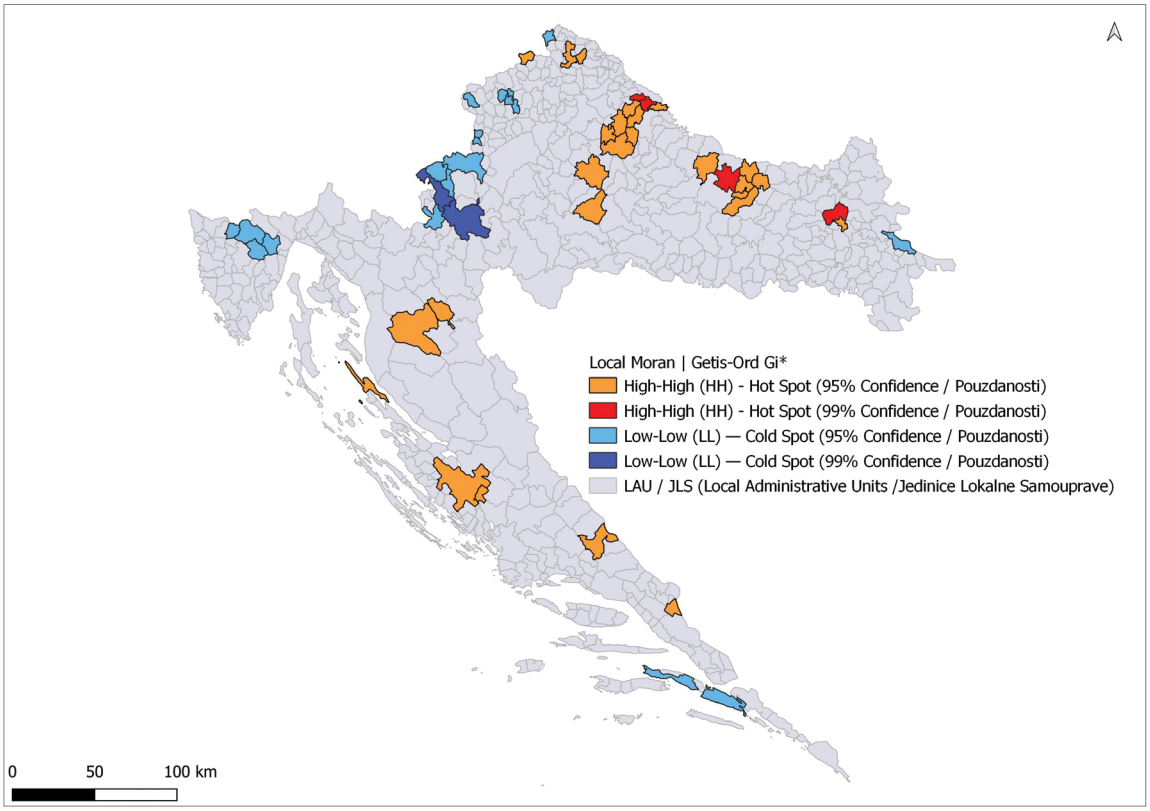

Fig. 9 Selected LAU units based on statistical significance criteria
Sl. 9. Izdvojene LAU jedinice prema kriterijima statističke značajnosti

The mentioned examples show specific spatial overlap according to the defined criteria, thereby confirming hypothesis H1c. In addition to meeting these criteria, the spatial distribution of these units reveals a spatial continuity of statistical significance in terms of replacement-level fertility, particularly in parts of Koprivnica-Križevci and Virovitica-Podravina counties. The combination of relative and absolute significance of TFR enables a more precise identification of areas with pronounced demographic potential and confirms the evident presence of specific local conditions that support above-average reproductive activity. In the context of demographic revitalization, such units deserve special attention, as they can serve as examples of good practice or a basis for comparative research on local measures, institutional support, and patterns that positively influence childbearing decisions.

The observed patterns of spatial autocorrelation in fertility reflect broader demographic and social processes highlighted in the theoretical framework. The

Navedeni primjeri pokazuju specifičnu prostornu podudarnost prema navedenim kriterijima, čime je potvrđena hipoteza H1c. Osim što zadovoljavaju navedene kriterije, iz prostornoga razmještaja tih jedinica razvidan je i prostorni kontinuitet statističke značajnosti zamjenskoga fertiliteta, osobito u dijelovima Koprivničko-križevačke i Virovitičko-podravske županije. Kombinacija relativne i apsolutne značajnosti TFR-a omogućuje preciznije prepoznavanje prostora s izraženim demografskim potencijalom te potvrđuje očito postojanje specifičnih lokalnih uvjeta koji pogoduju iznadprosječnoj reproduktivnoj aktivnosti. U kontekstu demografske revitalizacije upravo takve jedinice zaslužuju posebnu pažnju jer mogu poslužiti kao primjeri dobre prakse ili osnova za komparativna istraživanja lokalnih mjera, institucionalne podrške i obrazaca koji pozitivno utječu na odluke o rađanju.

Dobiveni obrasci prostorne autokorelacije fertiliteta odražavaju šire demografske i društvene procese istaknute u teorijskom okviru. Na prostornu

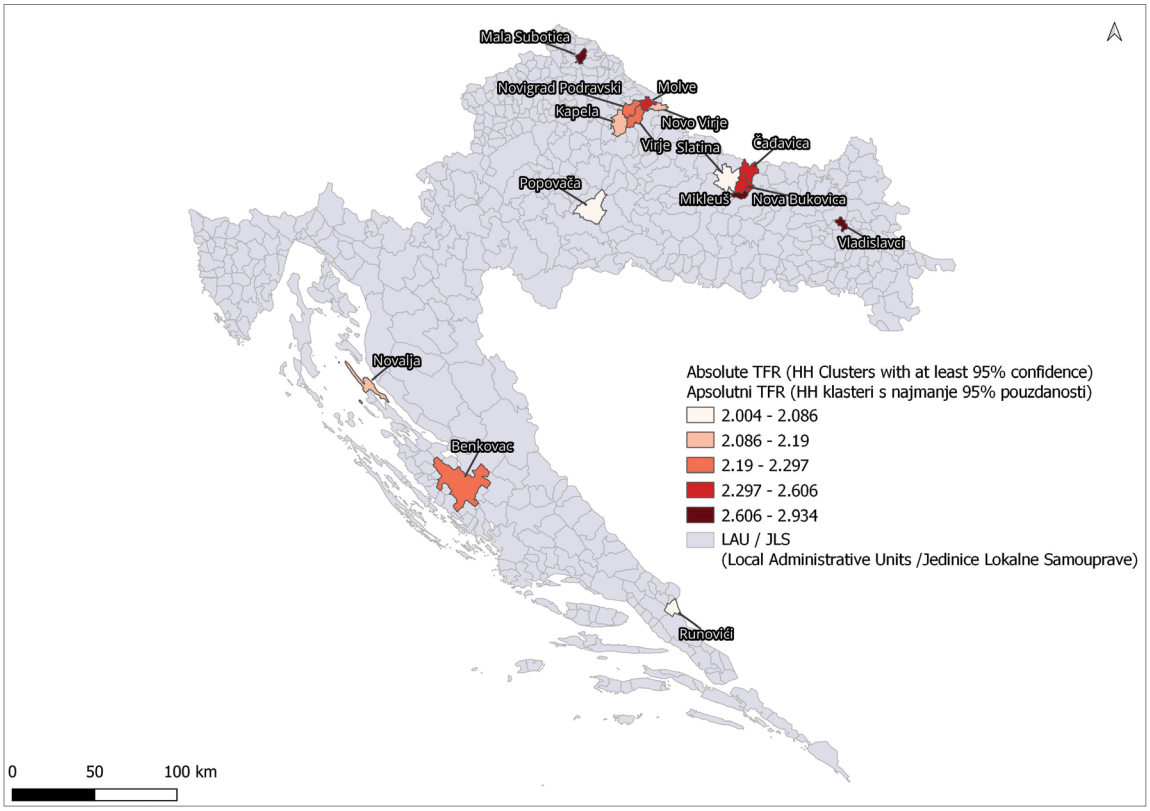

Fig. 10 Selected LAU units based on statistical significance criteria and high absolute TFR
Sl. 10. Izdvojene LAU jedinice prema kriterijima statističke značajnosti i visokim apsolutnim TFR-om

spatial distribution of fertility is shaped by processes of urbanization and suburbanization, differences in socio-economic status and cultural norms, migration flows, and the postponement of childbearing. Urbanized areas, where fertility postponement is more pronounced, display dynamics that differ from rural and transitional areas, where traditional fertility patterns persist for a longer time. These processes explain the spatial heterogeneity of fertility and the formation of certain clusters, but also the relatively low overall level of autocorrelation, since the demographic transition has largely diffused across space and encompasses most areas. The low value of Moran's I observed in this study can be contextualized within broader European trends. Campisi et al. (2020) showed that spatial variability in fertility across Europe has diminished due to the widespread diffusion of postponement behaviors, while recent research for Croatia (Belić, 2025) emphasized the role of rural depopulation in shaping fertility differences. In this respect, the results of this study are not unexpect-

distribuciju fertiliteta utječu procesi urbanizacije i suburbanizacije, razlike u socioekonomskom statusu, migracije te obrasci odgode rađanja. Urbanizirana područja, u kojima je odgoda rađanja izraženija, pokazuju drukčiju dinamiku u odnosu na ruralna i prijelazna područja, gdje su tradicionalni obrasci fertiliteta prisutniji dulje vrijeme. Upravo ti procesi objašnjavaju prostornu heterogenost fertiliteta i formiranje određenih klastera, ali i relativno nisku razinu ukupne autokorelacije jer su obrasci demografske tranzicije u značajnoj mjeri difuzni i zahvaćaju većinu prostora. Niska vrijednost Moranova I u ovom istraživanju može se promatrati u širem europskom kontekstu. Campisi i sur. (2020) pokazali su da se prostorna varijabilnost fertiliteta u Europi smanjuje zbog sve raširenijih obrazaca odgode rađanja, dok recentno istraživanje za Hrvatsku (Belić, 2025) naglašava važnost depopulacije ruralnih područja u oblikovanju fertilitetnih razlika. U tom smislu rezultati ovoga rada nisu neočekivani – prostorna autokorelacija fertiliteta

ed—spatial autocorrelation of fertility in Croatia is low because homogenized patterns of low fertility dominate, with only limited spatial pockets of higher or lower values. The findings are thus consistent with previous research, confirming that the spatial dimension of fertility in Croatia is weaker than might be assumed from macro-level differences. The findings of this study should be considered in light of certain limitations. First, the analysis was conducted for the year 2021, which, due to specific circumstances, recorded a relatively high level of fertility. Since TFR is used as a period measure that is sensitive to tempo effects, the spatial patterns identified here cannot be regarded as definitive. Future research should incorporate longitudinal comparisons across multiple years, alternative measures of fertility such as cohort TFR, and tests of sensitivity to different definitions of spatial neighborhood. Such approaches would enable a more precise assessment of the stability of identified clusters and provide deeper insights into the mechanisms shaping the spatial distribution of fertility in Croatia.

CONCLUSION

This paper focuses on the analysis of spatial fertility patterns in Croatia using spatial autocorrelation methods. The applied methodological framework—Global and Local Moran's Index and the Getis-Ord Gi* statistic proved to be highly effective in detecting spatial clusters and fertility hotspots, and the results confirmed all proposed hypotheses. The findings show that Croatia, despite relative homogeneity at the aggregate level, contains pronounced local differences that are often not revealed by standard statistical methods. The identified High-High and Low-Low clusters, as well as statistically significant hotspots and coldspots, indicate clear demographic patterns that require a spatially tailored approach to population policy. This research thus confirms the importance of detailed spatial fertility analysis, especially in the context of planning local and regional demographic revitalization measures.

From a methodological and research perspective, several levels of scientific contribution can be identified. A contribution is certainly the calculation of TFR at the LAU level, based on which, using the

u Hrvatskoj niska je jer prevladavaju homogenizirani obrasci niskoga fertiliteta, uz tek ograničene prostorne džepove viših ili nižih vrijednosti. Dobiveni rezultati time su u skladu s nalazima drugih istraživanja i potvrđuju da je prostorna dimenzija fertiliteta u Hrvatskoj slabije izražena nego što bi se moglo pretpostaviti na temelju makrorazlika. Rezultate ovoga istraživanja treba promatrati u svjetlu određenih ograničenja. Prije svega, analiza je provedena za 2021. godinu, koja je zbog specifičnih okolnosti zabilježila relativno visoku razinu fertiliteta. Budući da se koristi TFR kao periodska mjera osjetljiva na tempo-efekt, prostorni obrasci dobiveni ovdje ne mogu se smatrati konačnima. Buduća istraživanja trebala bi uključiti longitudinalne usporedbe različitih godina, alternativne mjere fertiliteta poput kohortnoga TFR-a te testiranje osjetljivosti na različite definicije prostornoga susjedstva. Time bi se moglo preciznije utvrditi stabilnost identificiranih klastera i bolje razumjeti mehanizme koji oblikuju prostornu distribuciju fertiliteta u Hrvatskoj.

ZAKLJUČAK

Ovaj je rad usmjeren na analizu prostornih obrazaca fertiliteta u Hrvatskoj primjenom metoda prostorne autokorelacije. Primijenjeni metodološki okvir – globalni i lokalni Moranov indeks te Getis-Ord Gi* – pokazao se vrlo učinkovitim u otkrivanju prostornih klastera i fertilitetnih žarišta, a rezultati su potvrdili sve postavljene hipoteze. Rezultati pokazuju da Hrvatska, unatoč relativnoj homogenosti na agregatnoj razini, sadržava izražene lokalne razlike koje standardne statističke metode često ne otkrivaju. Identificirani *High-High* i *Low-Low* klasteri, kao i prostorno značajni *hotspotovi* i *coldspotovi*, upućuju na jasne demografske obrasce koji zahtijevaju prostorno prilagođen pristup populacijskoj politici. Istraživanje time potvrđuje važnost detaljne prostorne analize fertiliteta, osobito u kontekstu planiranja mjera lokalne i regionalne demografske revitalizacije.

U metodološko-istraživačkom pogledu moguće je izdvojiti nekoliko razina znanstvenoga doprinosa. Doprinos svakako čini izračun TFR-a na LAU razini na temelju kojega je, kombinaci-

combination of spatial autocorrelation methods with GIS tools and analysis in the Python environment, the importance of integrating spatial analysis into contemporary demographic research was confirmed. In this way, not only is the precision of results improved, but transparency and reproducibility of the analytical procedure are also ensured. The extracted results of fertility analysis at the two observed levels, along with the introduction of the spatial dimension, contribute to a clearer identification of local and regional demo-reproductive patterns. The analysis at the LAU level shows that certain municipalities and smaller towns record fertility rates above the replacement level, thus challenging the usual narrative of universal demographic decline.

In conclusion, this paper does not solely represent an analysis of the current fertility situation, it also offers a conceptual and methodological framework applicable to future research on vital events. The use of open-source code, reproducible analysis, and a multi-level approach makes the methodology relevant and applicable within a broader demographic research context. Particular attention should be given to the units that simultaneously recorded high absolute TFR values and spatial statistical significance, as they stand out from the generally unfavorable demographic context. The presented results can thus serve as a basis for future research on fertility trends in specific areas, evaluation of local measures and approaches to demographic revitalization, and the identification of factors that influence fertility variability and levels across different observed scales.

jom metoda prostorne autokorelacije s GIS alatima i analizom u *Python* okruženju, potvrđena važnost integracije prostornih analiza u suvremena demografska istraživanja. Na taj se način ne samo povećava preciznost rezultata već se osigurava i transparentnost te ponovljivost analitičkoga postupka. Izdvojeni rezultati analize fertiliteta na dvije predmetne razine i uvođenje prostorne dimenzije doprinose jasnijoj identifikaciji lokalnih i regionalnih demoreproduktivnih obrazaca. Analiza na razini LAU jedinica pokazuje da pojedine općine i manji gradovi bilježe fertilitet iznad zamjenske razine, čime se dovodi u pitanje uobičajeni narativ o univerzalnom demografskom padu.

Zaključno, ovaj rad ne predstavlja isključivo analizu trenutnoga fertilitetnoga stanja, već nudi konceptualni i metodološki okvir primjenjiv u budućim istraživanjima vitalnih događaja. Korištenje otvorenoga koda, ponovljive analize i višerazinski pristup čini metodologiju relevantnom i primjenjivom u širem demografskom istraživačkom kontekstu. Posebnu pažnju zaslužuju jedinice koje istodobno bilježe visoke apsolutne vrijednosti TFR-a i prostornu statističku značajnost s obzirom na to da se izdvajaju iz općega, nažalost nepovoljna demografskoga okvira. Navedeni rezultati stoga mogu poslužiti kao temelj za buduća istraživanja fertilitetnih trendova u specifičnim prostorima, evaluaciju lokalnih mjera i pristupa demografskoj revitalizaciji te definiranje čimbenika koji uvjetuju varijabilnost i razinu fertiliteta na različitim predmetnim razinama.

References
Literatura

Akrap, A., 2011: Sektor zaposlenosti žena i fertilitet u Hrvatskoj, *Društvena istraživanja* 20 (1), 3-23. DOI: 10.5559/di.20.1.01.

Akrap, A., Čipin, I., 2011: Usklađivanje poslovnoga i obiteljskoga života u Hrvatskoj: utjecaj na fertilitet, *Društvena istraživanja* 20 (1), 47-67. DOI: 10.5559/di.20.1.03.

Aldieri, L., Vinci, C. P., 2013: Education and Fertility: A comparative Micro-econometric Analysis in Europe, *European Journal of Comparative Economics* 10 (1), 109-120. DOI: 10.25428/1824-2979/201301-109-120.

Anselin, L., 1988: *Spatial Econometrics: Methods and Models*, Springer, Dordrecht. DOI: 10.1007/978-94-015-7799-1.

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

Basten, S., Huinink, J., Klüsener, S., 2012: Spatial Variation of Sub-national Fertility Trends in Austria, Germany and Switzerland, *Comparative Population Studies* 36 (2-3), 573-614. DOI: 10.12765/CPoS-2011-08.

Belić, T., Mišetić, R., 2021: Čimbenici varijacije fertiliteta u prostoru – primjer Europe s osvrtom na hrvatsko-mađarsko pograničje, *Podravina* 20 (40), 89-102.

Belić, T., 2023: Stopa nataliteta u Hrvatskoj: lokalna varijabilnost, prostorni obrasci i trendovi od 2001. do 2020. godine, *Hrvatski geografski glasnik* 85 (1), 99-125. DOI: 10.21861/HGG.2023.85.01.04.

Belić, T., 2025: A Spatial Perspective of Birth Delay in Croatia: Is Rural Population Decline a Limiting Factor of National Fertility Rates?, *Društvena istraživanja* 34 (1), 111-135. DOI: 10.5559/di.34.1.06

Benassi, F., Carella, M., 2023: Modelling geographical variations in fertility and population density of Italian and foreign populations at the local scale: a spatial Durbin approach for Italy (2002–2018), *Quality & Quantity* 57 (3), 2147-2164. DOI: 10.1007/s11135-022-01446-1.

Berde, E., Drabancz, A., 2022: The propensity to have children in Hungary, with some examples from other European countries, *Frontiers in Sociology* 7 (1), 1-10. DOI: 10.3389/fsoc.2022.1009115.

Billari, F., Kohler, H.-P., 2004: Patterns of low and lowest-low fertility in Europe, *Population studies* 58 (2), 161-176. DOI: 10.1080/0032472042000213695.

Bujard, M., Andersson, G., 2024: Fertility declines near the end of the COVID-19 pandemic: Evidence of the 2022 birth declines in Germany and Sweden, *European Journal of Population* 40 (1), 1-21. DOI: 10.1007/s10680-023-09689-w.

Bongaarts, J., Sobotka, T., 2012: A demographic explanation for the recent rise in European fertility. *Population and development review* 38 (1), 83-120. DOI: 10.1111/j.1728-4457.2012.00473.x.

Burillo, P., Salvati, L., Matthews, S. A., Benassi, F., 2020: Local-Scale Fertility Variations in a Low-Fertility Country: Evidence from Spain (2002–2017), *Canadian Studies in Population* 47 (4), 279-295. DOI: 10.1007/s42650-020-00036-6.

Campisi, N., Kulu, H., Mikolai, J., Klüsener, S., Myrskylä, M., 2020: Spatial variation in fertility across Europe: patterns and determinants, *Population, Space and Place* 26 (4), 1-18. DOI: 10.1002/psp.2308.

Campisi, N., Kulu, H., Mikolai, J., Klüsener, S., Myrskylä, M., 2023: A Spatial Perspective on the Unexpected Nordic Fertility Decline: The Relevance of Economic and Social Contexts, *Applied Spatial Analysis and Policy* 16 (1), 1-31. DOI: 10.1007/s12061-022-09467-x.

Chen, C., Xiong, X., Tang, G., 2024: A decomposition study on the factors influencing China's total fertility rate changes between 1990 and 2020, *Scientific Reports* 14 (2), 1-13. DOI: 10.1038/s41598-024-79999-4.

Coskun, S., Dalgic, H., 2022: The Emergence of Procyclical Fertility: The Role of Gender Differences in Employment Risk, *CEPR Discussion Paper* (No. DP17316), https://cepr.org/active/publications/discussion_papers/dp.php?dpno=17316 (pristupljeno: 7. 3. 2025.).

Čipin, I., 2011: Obrazovanje i fertilitet zaposlenih žena u Hrvatskoj, *Društvena istraživanja* 20 (1), 25-46. DOI: 10.5559/di.20.1.02.

Čipin, I., Strmota, M., 2014: Druga demografska tranzicija u Hrvatskoj, u: *Demografija u Hrvatskoj – zbornik radova* (ur. Akrap. A. i dr.), Ekonomski fakultet, Zagreb, 65-81.

Čipin, I., Međimurec, P., 2017: Fertilitet i obiteljska politika u Hrvatskoj, *Političke analize* 8 (31), 3-9. Dostupno na: https://hrcak.srce.hr/192425 (pristupljeno: 1. 2. 2025.).

Čipin, I., 2022: *Fertilitet u Republici Hrvatskoj po županijama – predavanje*, Središnji državni ured za demografiju i mlade, Zagreb.

Čipin, I., Međimurec, P., Smolić, Š., Klempić Bogadi, S., Mustač, D., Fabijančić, M., 2024: *Stručno-analitička podloga za izradu Strategije demografske revitalizacije Republike Hrvatske do 2033. godine*.

Del Bono, E., Weber, A., Winter-Ebmer, R., 2015: Fertility and economic instability: the role of unemployment and job displacement, *Journal of Population Economics* 28 (2), 463-478. DOI: 10.1007/s00148-014-0531-y.

Diniz-Filho, J. A. F., Bini, L. M., Hawkins, B. A., 2003: Spatial autocorrelation and red herrings in geographical ecology, *Global Ecology and Biogeography* 12 (1), 53-64. DOI: 10.1046/j.1466-822X.2003.00322.x.

Dubé, J., Legros, D., 2014: *Spatial Econometrics Using Microdata*, ISTE – Wiley, London – Hoboken. DOI: 10.1002/9781119008651.

Egidi, G., Salvati, L., 2021: Changes over time in the spatial structure of fertility rates as a dynamic indicator of urban transformations, *Quality & Quantity* 55 (1), 151-172. DOI: https://doi.org/10.1007/s11135-020-01023-9.

EUROSTAT, 2022: Statistika fertiliteta, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Fertility_statistics (pristupljeno: 11. 1. 2025.).

Fiori, F., Graham, E., Feng, Z., 2014: Geographical variations in fertility and transition to second and third birth in Britain, *Advances in Life Course Research* 21 (1), 149-158. DOI: 10.1016/j.alcr.2013.11.004.

Fischer, M. M., Getis, A., 2009: *Handbook of Applied Spatial Analysis: Software Tools, Methods and Applications*, Springer, Berlin – Heidelberg. DOI: 10.1007/978-3-642-03647-7.

Getis, A., 2008: A History of the Concept of Spatial Autocorrelation: A Geographer's Perspective, *Geographical Analysis* 40 (3), 297-309. DOI: 10.1111/j.1538-4632.2008.00727.x.

Getis, A., Ord, J. K., 1992: The Analysis of Spatial Association by Use of Distance Statistics, *Geographical Analysis* 24 (3), 189-206. DOI: 10.1111/j.1538-4632.1992.tb00261.x.

Jalovaara, M., Neyer, G., Andersson, G., Dahlberg, J., Dommermuth, L., Fallesen, P., Lappegård, T., 2019: Education, gender, and cohort fertility in the Nordic countries, *European Journal of Population* 35 (3), 563-586. DOI: https://doi.org/10.1007/s10680-018-9492-2.

Jung, M., Ko, W., Choi, Y., Cho, Y., 2019: Spatial variations in fertility of South Korea: A geographically weighted regression approach, *ISPRS International Journal of Geo-Information* 8 (6), 1-16. DOI: 10.3390/ijgi8060262.

Kotowska, I., Jóźwiak, J., Matysiak, A., Baranowska, A., 2008: Poland: Fertility decline as a response to profound societal and labour market changes?, *Demographic Research* 19 (22), 795-854. DOI: 10.4054/DemRes.2008.19.22.

Kulu, H., Boyle, P. J., Andersson, G., 2009: High suburban fertility: Evidence from four Northern European countries, *Demographic Research* 21 (31), 915-944. DOI: 10.4054/DemRes.2009.21.31.

Kulu, H., 2013: Why do fertility levels vary between urban and rural areas?, *Regional Studies* 47 (6), 895-912. DOI: 10.1080/00343404.2011.581276.

Lesthaeghe, R., 2020: The second demographic transition, 1986–2020: sub-replacement fertility and rising cohabitation – a global update, *Genus* 76 (10), 1-38. DOI: 10.1186/s41118-020-00077-4.

Lutz, W., 2006: Fertility rates and future population trends: will Europe's birth rate recover or continue to decline?, *International Journal of Andrology* 29 (1), 25-33. DOI: 10.1111/j.1365-2605.2005.00639.x.

Marošević, K., 2020: Lagging regions: The case of Eastern Croatia, *Ekonomski vjesnik* 33 (1), 255-270, https://hrcak.srce.hr/240016 (pristupljeno: 2. 4. 2025.).

Martine, G., Alves, J. E. D., Cavenaghi, S., 2013: Urbanization and fertility decline: Cashing in on structural change. *IIED Working Paper*, International Institute for Environment and Development (IIED), London, https://www.researchgate.net/publication/337607705 (pristupljeno: 11. 1. 2025.).

Moran, P. A., 1948: The Interpretation of Statistical Maps, *Journal of the Royal Statistical Society. Series B (Methodological)* 10 (2), 243-251. DOI: 10.1111/j.2517-6161.1948.tb00012.x.

Mucciardi, M., Bertuccelli, P., 2013: Modelling Spatial Variations of Fertility Rate in Italy, u: *Classification and Data Mining* (ur. Giusti, A. i dr.), Springer, Heidelberg, 251-259. DOI: 10.1007/978-3-642-28894-4_30.

Németh, A. O., Németh, P., Tőkés, L., 2025: Empirical analysis of the differences in the drivers of fertility between CEE countries and the rest of the EU, *Journal of Population Reseach* 42, 15. DOI: 10.1007/s12546-025-09366-1

Potančoková, M., Vaňo, B., Pilinská, V., Jurčová, D., 2008: Slovakia: Fertility between tradition and modernity, *Demographic Research* 19 (25), 973-1018. DOI: 10.4054/DemRes.2008.19.25.

Riederer, B., Beaujouan, E., 2023: Explaining the urban–rural gradient in later fertility in Europe, *Population, Space and Place* 30 (1), 1-16. DOI: 10.1002/psp.2720.

Rindfuss, R. R., Choe, M. K., Brauner-Otto, S. R., 2016: The emergence of two distinct fertility regimes in economically advanced countries, *Population Research and Policy Review* 35 (3), 287-304. DOI: 10.1007/s11113-016-9387-z.

Salvati, L., Benassi, F., Miccoli, S., Rabiei-Dastjerdi, H., Matthews, S. A., 2020: Spatial variability of total fertility rate and crude birth rate in a low-fertility country: Patterns and trends in regional and local scale heterogeneity across Italy, 2002–2018, *Applied Geography* 124 (1), 1-21. DOI: 10.1016/j.apgeog.2020.102321.

Sear, R., Lawson, D. W., Kaplan, H., Shenk, M. K., 2016: Understanding variation in human fertility: what can we learn from evolutionary demography?, *Philosophical Transactions of the Royal Society B* 371 (1692), 1-16. DOI: 10.1098/rstb.2015.0144.

Singleton, A., Arribas-Bel, D., 2021: Geographic Data Science, *Geographical Analysis* 53 (1), 61-75. DOI: 10.1111/gean.12194.

Snopkowski, K., Towner, M. C., Shenk, M. K., Colleran H., 2016: Pathways from education to fertility decline: a multi-site comparative study, *Philosophical Transactions of the Royal Society B* 371 (1692), 1-12. DOI: 10.1098/rstb.2015.0156.

Sobotka, T., 2003: Re-Emerging Diversity: Rapid Fertility Changes in Central and Eastern Europe after the Collapse of the Communist Regimes, *Population* 58 (4-5), 451-485. DOI: 10.2307/3246652.

Sobotka, T., Skirbekk, V., Philipov, D., 2011: Economic recession and fertility in the developed world, *Population and Development Review* 37 (2), 267-306. DOI: 10.1111/j.1728-4457.2011.00411.x.

Sobotka, T., Šťastná, A., Zeman, K., Hamplová, D., Kantorová, V., 2008: Czech Republic: A rapid transformation of fertility and family behaviour after the collapse of state socialism, *Demographic Research* 19 (14), 403-454. DOI: 10.4054/DemRes.2008.19.14.

Testa, M. R., 2014: On the positive correlation between education and fertility intentions in Europe: Individual- and country-level evidence, *Advances in Life Course Research* 21 (1), 28-42. DOI: 10.1016/j.alcr.2014.01.005.

Tosun, M. S., Yang, J., 2018: Determinants of Fertility and Population Policies in MENA Countries, *Economic Research Forum*, Working Paper No. 1219, https://erf.org.eg/publications/determinants-of-fertility-and-population-policies-in-mena-countries/ (pristupljeno: 21. 3. 2025.).

Tragaki, A., Bagavos, C., 2019: Fertility variations in the recession context: the case of Greece, *Genus* 75 (1), 1-15. DOI: 10.1186/s41118-019-0067-1.

Trovato, F., Grindstaff, C. F., 1980: Decomposing the urban–rural fertility differential: Canada, 1971., *Rural Sociology* 45 (3), 448-468, https://reader.library.cornell.edu/docviewer/digital?id=chla5075626_4331_003#page/72/mode/1up.

Van de Kaa, D. J., 2001: Postmodern fertility preferences: From changing value orientation to new behavior, *Pop-*

ulation and Development Review 27 (1), 290-331. DOI: 10.1111/j.1728-4457.2001.00290.x.

Vasireddy, S., Berrington, A., Kuang, B., Kulu, H., 2023: Education and Fertility: A Review of Recent Research in Europe, *Comparative Population Studies* 48 (1), 553-588. DOI: https://doi.org/10.12765/CPoS-2023-21.

Vitali, A., Billari, F. C., 2017: Changing determinants of low fertility and diffusion: a spatial analysis for Italy, *Population, Space and Place* 23 (2), 1-18. DOI: 10.1002/psp.1998.

Wang, Q., Sun, X., 2016: The Role of Socio-political and Economic Factors in Fertility Decline: A Cross-country Analysis, *World Development* 87 (1), 360-370. DOI: 10.1016/j.worlddev.2016.07.004.

Winkler-Dworak, M., Zeman, K., Sobotka, T., 2024: Birth rate decline in the later phase of the COVID-19 pandemic: The role of policy interventions, vaccination programmes, and economic uncertainty, *Human Reproduction Open* 8 (3), 1-13. DOI: 10.1093/hropen/hoae052.

Zaidi, B., Morgan, P. S., 2017: The second demographic transition theory: A review and appraisal, *Annual Review of Sociology* 43 (1), 473-492. DOI: https://doi.org/10.1146/annurev-soc-060116-053442.

Zakon o lokalnoj i područnoj (regionalnoj) samoupravi NN33/01, 60/01, 129/05, 109/07, 125/08, 36/09, 150/11, 144/12, 19/13, 137/15, 123/17, 98/19, 144/20).

Authors
Autori

Dino Bečić (corresponding author) dbecic.geog@pmf.hr
PhD student, University of Zagreb, Faculty of Science, Department of Geography, Trg Marka Marulića 19, 10000 Zagreb, Croatia

Monika Komušanac mkomusana@fhs.hr
Associate Professor, Faculty of Croatian Studies University of Zagreb, Department of Demography and Croatian Emigration, Borongajska cesta 83d, 10000 Zagreb, Croatia

Nikola Šimunić nikola.simunic@imin.hr
PhD, research associate, Institute for Migration Research, Trg S. Radića 3, 10000 Zagreb, Croatia