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COVID-19 EPIDEMIC WAVES IN HUNGARY AND THEIR REGIONAL DISTRIBUTION

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ABSTRACT

This paper reviews the most important spatial features of the pandemic waves in Hungary to discover their regional distribution, focusing on morbidity and mortality data. It is based on a descriptive statistical analysis examining the general epidemic situation in Hungary as well as comparing the pandemic waves. The examination also presents a general review of the COVID-19 pandemic waves and their changes in terms of space and time, exploring the typical spatial patterns. The applied regional analysis contains an examination at various geographical scales ranging from national (NUTS 1) to county (NUTS 3) and micro-regional (LAU 1) territorial levels. The most important results highlight the significant existing inequalities which can be detected among epidemic waves as well as at different territorial levels.

Keywords: *COVID-19; epidemic wave; regional, inequality; Hungary*

INTRODUCTION

The COVID-19 pandemic completely turned our lives upside down in the spring of 2020. Since then, a huge amount of knowledge has accumulated in the examination of different health, social or economic effects of the epidemic. One of them is the spatial aspect, which has primary information on the outbreak and the spreading of the pandemic or the territorial distribution of the epidemic waves (Uzzoli et al., 2021). These spatial consequences can especially be analysed between the beginning of 2020 and the end of 2022.

The COVID-19 disease caused by the novel coronavirus (SARS-CoV-2) has spread to almost all countries in the world, with more than 665 million confirmed cases as of 3 October 2023, and has killed more than 6.7 million people (https://coronavirus.jhu.edu/). (Note: the latest global epidemiological data announcement was on 3 October 2023, because Johns Hopkins University has stopped collecting data as of this date.) COVID-19 promises to be a defining global health event of the 21st century, leading to substantial damage in terms of human lives and economic costs (Wei et al., 2022). In the first year of the pandemic (mainly during the first and the second wave in 2020), countries diverged in terms of the speed, scale, and intensity with which they implemented preventive interventions (Pan et al., 2020). Despite the beginning of the vaccination in the first quarter of 2021, the countries found themselves in an unexpected situation again, because the pandemic rebounded across the world, resulting in an even higher third epidemic wave (Li et al., 2021). In conclusion, the

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global COVID-19 pandemic over the past five years with six consecutive epidemiological waves indicates that the world learned many lessons, and among them also defined a wide range of spatial or territorial effects (Amin et al., 2022). Generally, the pandemic has affected many spheres of life, but some social groups (e.g. elderly people) were most affected (Sekulić, 2023).

The COVID-19 pandemic had already had six epidemic waves in the majority of countries, as well as in Hungary between March 2020 and December 2022. The pandemic has many territorial characteristics regarding its spatial spreading or regional distribution of infectious and death cases.

The initial – first three waves of COVID-19 infections were largely caused by the emerging variants of concern (e.g. Alpha mutation) (Lin et al., 2022). After the onset of vaccination, globally relevant inequalities in the vaccinated population contributed to forming new variants, resulting further in the fourth, fifth and sixth epidemic waves in the world (e.g. Omicron mutation) (Dutta, 2022). The various epidemic waves significantly differed from each other in their dynamics, the number of infected people, the mortality rate and their regional differences (e.g. Kunno et al., 2021; Tang et al., 2022; Wieland, 2020).

Cities and urban regions have an essential role in the dynamics of the novel coronavirus pandemic (Florida, 2020; Tešić et al., 2020). For example, the high number and rate of local population or density rate (Stier et al., 2021) or social interactions (Angel et al., 2020) in urbanized regions influence the formation of epidemic waves (Szirmai et al., 2023). The social interactions between cities and their agglomerations (e.g. commuting) also play a primary role in the spatial spreading of the novel coronavirus (Gu et al., 2020). Moreover, closed communities in urban regions (e.g. hospitals, elderly homes, etc.) can also result in a higher risk of infections (Kim et al., 2017). These are the main reasons that cities and urban regions are the most vulnerable during the pandemic (Adhikari and Pantaleo, 2020). The hierarchical diffusion has a spatial effect on the development of different pandemic waves and their spreading from urban regions towards the geographical peripheries (Sigler et al., 2020). Besides hierarchical diffusion, neighbourhood spatial effects can contribute to the epidemic spread (Bailey et al., 2020).

This paper aims to describe and compare the characteristics of different COVID-19 epidemic waves and their spatial distribution via the case study of Hungary. It consists of four major structural parts. After presenting the most important aims and applied methods with the sources of information and data, there is a brief description of the general coronavirus situation in Hungary. The major part of the paper contains the highlighted results and experiences of a statistical examination focusing on the comparison of the Hungarian epidemic waves and their spatial features. The primary results will be presented at different spatial levels from national through regional to local levels. The final chapter advances with the conclusions based on spatiality.

METHODS AND DATA

The paper especially examines the novel coronavirus epidemic waves and their spatial characteristics in Hungary. The primary questions are the following:

- What are the main features of the COVID-19 pandemic in Hungary?
- What is the typical regional pattern of the COVID-19 disease and death in Hungary?
- How did the regional pattern of the pandemic change during the six relevant waves in Hungary?

The paper is mainly based on quantitative techniques such as applying descriptive statistics, which analyses national tendencies and spatial inequalities, as well as comparing epidemic waves in Hungary. The examined secondary data are taken from official sources (e.g., Hungarian Central Statistical Office – www.ksh.hu, National Pandemic Website - koronavirus.gov.hu, National Institute for Public Health – https://www.nnk.gov.hu/). Temporally, the statistical data analysis is based on the period between 4 March 2020 and 31 December 2022. The main reason is on the one hand, the first two confirmed coronavirus cases were announced in Hungary on 4 March 2020, while the official coronavirus website where the most relevant epidemiological data were announced daily or weekly, was permanently deleted on 31 December 2022.

The emphasis of this analysis is on evaluating the regional distribution of the incidence and prevalence of the COVID-19 disease and death in Hungary, as well as the spatiotemporal spread of the COVID-19 pandemic in terms of the epidemic waves. This is the main reason that those epidemiological indicators were applied, which had spatial relevance. The majority of them were published only at the national level (NUTS 1 level), but some county-level data (NUTS 3) were also reported. It is important to mention that some limitations appeared among the used indicators, especially in their regional division at the sub-national level. The applied epidemiological indicators were available at different geographical scales, which means the datasets of these indicators were not synchronised with each other according to the spatial examination level. Some important epidemiological data were not announced at the sub-national level at all, which does not allow an in-depth spatial analysis. Among the used indicators, only the total number of confirmed cases and the total number of deaths were published at the micro-regional level (at district level) (LAU 1). The regional analysis of these two indicators gives a chance to present regional inequalities at different examination levels from the county to the settlement level. According to this regional analysis, three case studies were used to show the primary results at different geographical scales.

The paper also presents a detailed comparison of the epidemic waves in Hungary, describing their characteristics. The sectioning of the six epidemic waves is based on the current number of active COVID-19 cases and their temporal changes. This indicator gives relevant information in real-time on the real number of potentially infected people in the country, which is important for healthcare and its allocation. Thus, the long-term changes of this indicator also provide comprehensive information about the increasing or decreasing tendency of the given epidemic wave, while its highest number indicates the peak of the wave.

Finally, it is also worth highlighting that this manuscript is not intended to examine the connection between epidemiological data and different socio-economic indicators (see e.g. Fitriadi et al., 2022; Páger et al., 2024) or the determinants of excess mortality in COVID-19 deaths (see e.g. Arsenovic, 2023; Michálek, 2022). However, the literature review provides additional information on the spatial pattern of the Hungarian socio-economic and health inequalities. This literature review also gives relevant information on Hungary's epidemic position among East-Central European countries.

LITERATURE REVIEW

The aim of the literature review is twofold. On the one hand, it introduces a brief description of the Hungarian inequalities and their regional distribution. The relevant information can help to understand the cause-and-effect relationship between socio-economic and health inequalities in Hungary, which play a relevant role in the epidemic phenomenon. On the other hand, the literature review also makes a comparison between Hungary and other Central or Eastern European countries (e.g., Slovakia, Romania, Serbia) according to the relevant antecedents on examination of the COVID-19 epidemic situation. This brief comparative section can help to define Hungary's epidemic indicators in an international context.

The regional distribution of the socio-economic inequalities (see e.g. GDP per capita, employment and unemployment rate, income, etc.) in Hungary has the following main spatial dimensions connected to one another regionally or as settlements (Nemes Nagy, 2006; Nemes Nagy, Tagai, 2011; Kincses, Tóth, 2020; Berkes, Dusek, 2023):

- At the national level, there is a dualism between the capital city, Budapest and the countryside. The capital city and its surrounding area (agglomeration) have the most advantageous socio-economic position and stand out like an island from the country's spatial structure.
- At the macroregional level, there is a Western-Eastern relation mainly between the western and the eastern part of the country. The former has a better, and the latter has a worse socio-economic position with-

in the country. However, there are also disadvantaged areas in the western part, while the eastern part as a whole cannot be considered only disadvantaged. Within each part of the country, micro-regional differences are primarily marked.
- At the micro-regional level, especially urban-rural or centre-periphery differences can be experienced. For instance, the geographic periphery along the borderline of the country cannot be considered as an economic and social periphery as a whole, because the western border region is a dynamic edge of Hungary. Bigger cities or county seats and their surrounding areas have better socio-economic positions in the Eastern part of the country.

Overall, the most favourable micro-regions and settlements of the country are in the North Western and Central parts of Hungary, while the most unfavourable areas stand in the South Western and North Eastern parts.

The spatial pattern of the socio-economic inequalities demonstrates the dichotomy of health inequalities and the widening health gap between the Eastern and the Western parts of the country (Egri, Tánczos, 2015). Lower levels of premature mortality rate, higher levels of life expectancy or better chances for access to healthcare can be found in the North Western part of the capital city and its agglomeration or the bigger cities and county seats of the Eastern part. Poor health conditions, shorter life expectancy or barriers to healthcare accessibility can be experienced mainly in the South Western and North Eastern parts of the country (Uzzoli et al., 2020).

The health status of the population living in a given area is influenced by numerous socio-economic factors, such as educational attainment, income status, housing and working conditions, ageing index, access to education and healthcare, subjective well-being etc., which could have had a marked impact on how serious the patient's condition was due to the infection during the COVID-19 pandemic, whether they needed hospital care, and how run their survival chances (Páger et al., 2024). Overall, the coronavirus pandemic affected in a different way the social groups and therefore different parts of the country. COVID-19 mortality rates were higher in areas with higher proportions of the elderly, poorer general health status, and higher rates of low-income status than the national average (Páger et al., 2024). Ultimately, the spatial structure of COVID-19 mortality was very similar to the spatial structure of health inequalities in Hungary.

Hungary has a contradictory epidemic situation in an international comparison, especially among East-Central European countries, according to the number of confirmed COVID-19 cases and deaths. Hungary was in the middle field of these countries due to the total number of infections per capita, mainly between 2020 and 2022, while it was among the worst performers in terms of coronavirus mortality rates (Pál et al., 2021). Compared to the V4 (Poland, the Czech Republic, Slovakia) and other larger neighbouring countries (Serbia, Romania), Hungary had the highest mortality rate (2.3%), which was also higher than the European average (0.8%) (Uzzoli, 2022).

Compared to other East-Central European countries, the first pandemic wave was mild in Hungary, resulting in relatively low numbers of new coronavirus cases (Gombos et al., 2020). However, the first wave also resulted in low infection and death rates in these countries compared to Western European countries, because they imposed tight restrictions at the very beginning of the pandemic (Röst et al., 2020). The second and third waves caused a very serious epidemiological situation in Hungary as well as in the East Central European countries, and the effect of the pandemic was more severe on them than on the Western European countries (Kovalcsik et al., 2021). The health crisis caused by the COVID-19 pandemic varied sharply across and within these countries (Urbanovics et al., 2021). For example, urban-rural differences in infection rates disappeared, and the cities were in a relatively favourable position in terms of mortality, thanks to their better health care and generally higher resilience (Igari, 2021). Hungary started vaccination early in the spring of 2021 and was a leader among both Western and Eastern European countries. Later, the vaccination procedure slowed down and by 2022, the country was more in the middle range of the European countries (Páger et al., 2024). In neighbouring East-Central European countries, the vaccination rate also lagged behind Western European averages.

Overall, Hungary was in a disadvantaged epidemic situation compared to the neighbouring East-Central European countries (e.g. Serbia, Slovakia, Romania) during the pandemic, primarily in terms of death rates caused by COVID-19.

RESULTS

The most important results are presented in three parts of this chapter, describing the three different applied statistical analyses to discover the Hungarian epidemic waves.

The first part examines the COVID-19 pandemic in Hungary in the light of some epidemiological indicators.

The pandemic appeared in Hungary on March 4, when two patients were confirmed. In contrast, the first recovered patient was detected two weeks later, on March 12 (Kovács et al., 2020), and the first death occurred on March 15 (Gombos et al., 2020). From the beginning, the official government data and information source website was: koronavirus.gov.hu. On 11 March 2020, the Hungarian government declared a state of epidemic emergency lasting until 18 June 2020, and the state of emergency was reinstated on 11 November 2020. The second announced state of emergency was extended several times and was valid until 31 May 2022.

There were more than 2.1 million confirmed COVID-19 cases in Hungary according to the final official announcement (31 December 2022), and Hungary belonged to the middle field among the European countries during the pandemic years (https://covid19.who.int/table). The total number of deaths was 48,495, while the mortality rate was 2.2%, which was one of the highest numbers and rates in Europe (Table 1). The number of COVID-19 recovered cases was 2,123,750. The total infection rate was more than 22.5, but it is based on only confirmed cases, and the real number of infected cases could be higher. The procedure of vaccination started at the end of 2020, but mass vaccination happened only in April and May of 2021. The first booster was introduced at the beginning of August 2021, while the second booster was introduced in January 2022.

Table 1. Some epidemiological indicators of the COVID-19 pandemic in Hungary, 2022

Epidemiological indicator	31.12.2022
Total number of confirmed COVID-19 cases	2,185,816
Total number of confirmed COVID-19 cases per 1 million inhabitants	225,342
Total number of COVID-19 death cases	48,495
Total number of COVID-19 death cases per 1 million inhabitants	4,999
Total number of COVID-19 recovered cases	2,123,750
Total number of COVID-19 recovered cases per 1 million inhabitants	218,943
Mortality rate (death cases/confirmed cases, %)	2.2
Total infection rate (confirmed cases/population, %)	22.5
Cumulative uptake of at least one dose (1 dose/population, %) Cumulative uptake primary course (2 doses/population, %) Cumulative uptake first booster (3 doses/population, %) Cumulative uptake second booster (4 doses/population, %)	66.2 63.9 40.2 3.9

Data source: koronavirus.gov.hu

The vaccination rate was lower than the European average because the rate of basic immunization, including the first and the second dose, did not reach 70% at the end of 2022. European Centre for Disease Prevention and Control's vaccine tracker gives up-to-date data on the vaccination rate in the European Union (https://qap.ecdc.europa.eu/public/extensions/COVID-19/vaccine-tracker.html#uptake-tab). The announcement shows that the cumulative vaccine uptake rate of one dose in the total population is 75.5% (14.12.2022). Moreover, the cumulative vaccine uptake rate of the primary course is 73.0% in the EU/EEA countries, while the rate of the first booster is 54.6% and the rate of the second booster is 12.7%. Hungary's vaccination rates are among the lowest in Europe.

Hungary's epidemiological situation has changed from one epidemic wave to another according to the number and rate of infected cases as well as death cases (Uzzoli et al., 2021).

The second part of this chapter compares the epidemic waves in Hungary. Between March 2020 and December 2022, altogether six epidemic waves were detected in Hungary. During 2020 and 2021, strong seasonality was experienced in the existence of these waves. The majority of them started in autumn or in winter, and there was a sharp borderline between autumn and winter waves because the increasing and decreasing tendency of the current epidemic waves changed day by day. Usually, after winter waves a longer transitional period of several months occurs, lasting until the end of Summer. During these transitional periods, the current epidemic wave has stagnated. On the other hand, the sixth epidemic wave formed during the summer of 2022, which was a non-ordinary epidemic situation compared to the former waves. Naturally, these sixth waves were usually observed all over the world.

The following epidemic waves were detected according to their initial and closing date:

1. The first epidemic wave is between 4 March 2020 and 9 August 2020.
2. The second epidemic wave is between 10 August 2020 and 16 February 2021.
3. The third epidemic wave is between 17 February 2021 and 2 September 2021.
4. The fourth epidemic wave is between 3 September 2021 and 4 January 2022.
5. The fifth epidemic wave is between 5 January 2022 and 28 June 2022.
6. The sixth epidemic wave is between 29 June 2022 and 31 December 2022[1].

The run of the epidemic curve based on the current number of active cases shows the intensity and the evolution of the COVID-19 pandemic in Hungary (Figure 1). The lowest number of active cases was detected during the first and the sixth epidemic waves. There were 132 times the difference between the number of active cases of the first and the third wave. On the other hand, the third wave had the highest number of active cases. The second and the fourth waves were very similar to each other, while the fifth one was the most intensive because the highest number of active cases could be concentrated in the shortest time. The longest transitional period occurred between the fifth and the sixth wave in 2022. Between the second and the third, as well as the fourth and the fifth, was a concrete borderline because the continuously decreasing tendency of the former wave suddenly transformed into an increasing tendency from one day to the next, and it indicated the starting date of the following wave.

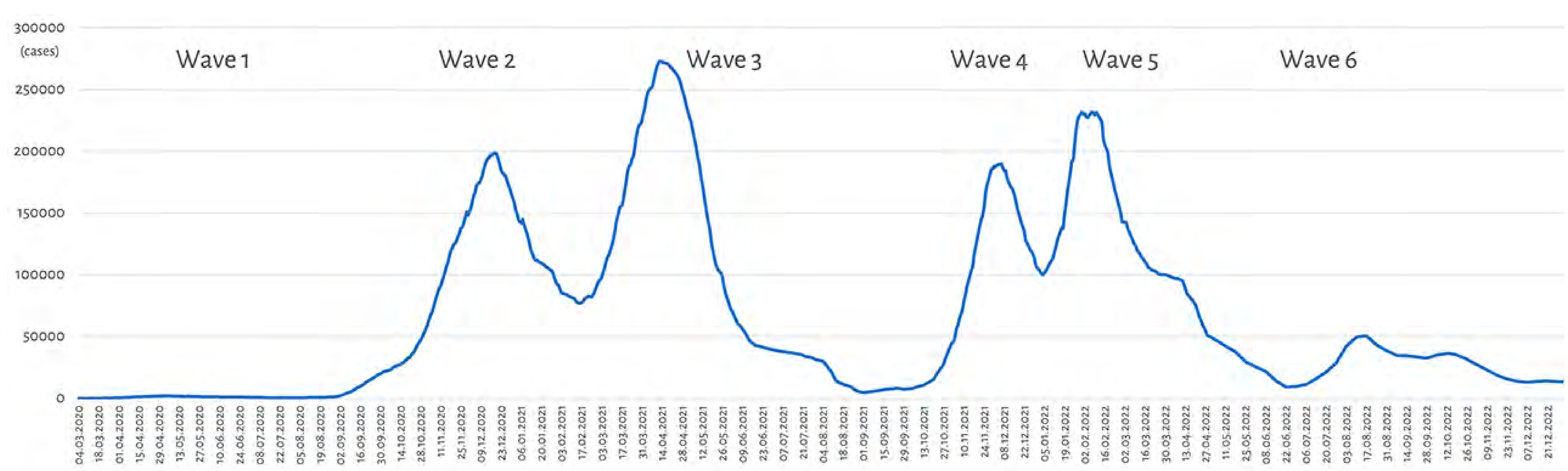


Figure 1. Total number of active COVID-19 cases in Hungary between 4 March 2020 and 31 December 2022

Data source: koronavirus.gov.hu

In the comparison of the six waves in Hungary, significant differences are shown (Figure 2, Figure 3). Firstly, there was an eighty-fold difference between the first and the second wave. Secondly, the total number of coronavirus cases confirmed during the given wave continuously increased wave by wave (except for the sixth wave). Thirdly, the highest number of confirmed cases was experienced during the fifth wave, while the

[1] This is the last officially detected epidemic wave in Hungary, but its closing date is unknown because the official epidemic data publishing finished on 31 December 2022.

highest number of deaths was in the third wave. Fourthly, the number of death cases continuously decreased wave by wave after the third wave. It means the vaccination was started during the third wave, and it protected vaccinated people against the serious health consequences of the COVID-19 disease during the fourth, fifth and sixth waves.

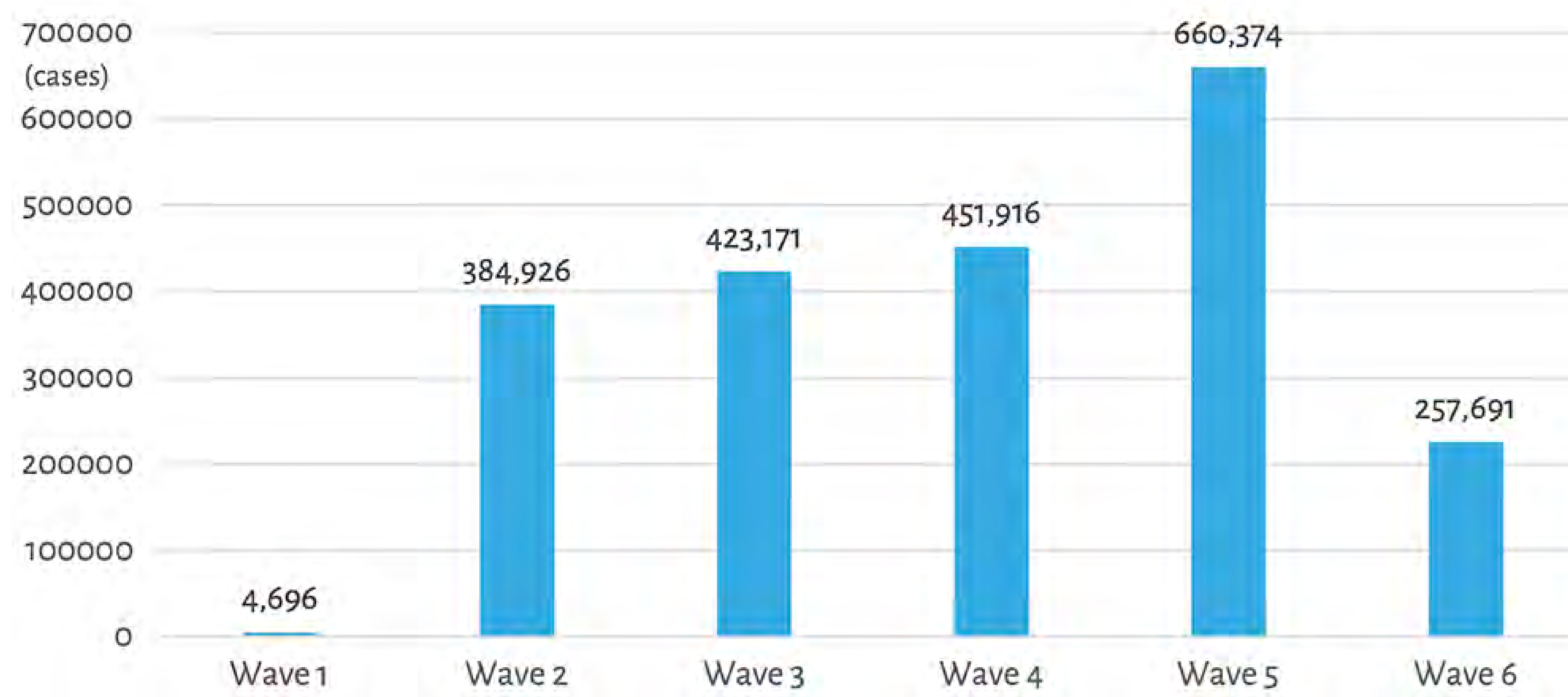


Figure 2. Total number of confirmed COVID-19 cases in Hungary between 4 March 2020 and 31 December 2022

Data source: koronavirus.gov.hu
Primary source: Uzzoli, 2022. p. 103. (in Hungarian)

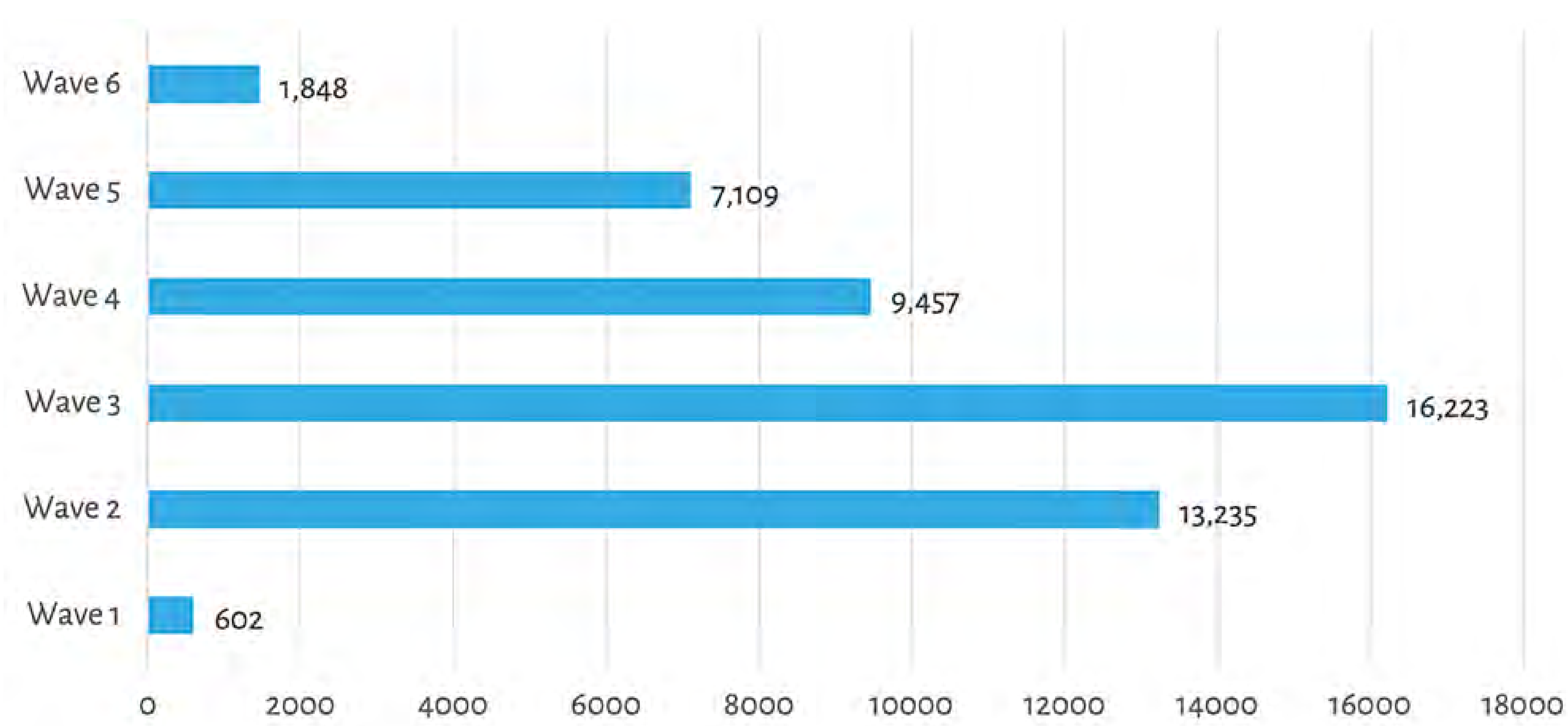


Figure 3. Total number of confirmed COVID-19 death cases in Hungary between 4 March 2020 and 31 December 2022

Data source: koronavirus.gov.hu
Primary source: Uzzoli, 2022. p. 103. (in Hungarian)

In sum, the formation and the progress of each epidemic wave were influenced by different variations of novel coronavirus (SARS-CoV-2), and these had various effects on the health consequences of COVID-19 disease, the speed of the infection process, the mortality rate and the use intensity of healthcare services.

The third part of the chapter defines regional inequalities of the COVID-19 pandemic in Hungary at different geographical scales in the light of three different case studies. Barriers to access to regional data on the COVID-19 pandemic in Hungary, mentioned in the previous methodological chapter, were the main limitations of an in-depth (sub-national) regional analysis of this paper. Only two indicators, such as the number of COVID-19 cases and the number of COVID-19 deaths, could be applied in the regional analysis and could visualize their spatial distribution. Here are the most informative case studies of these two indicators at different geographical scales from county (NUTS 3) to settlement (LAU 1) level.

The first case study examines weekly new confirmed COVID-19 cases at the county level (NUTS 3) and the result shows the regional pattern of the geographical hotspots of different epidemic waves (Figure 4). The spatial pattern is continuously changed in space and time during the given epidemic wave according to different phases. This changing pattern could even be observed from week to week. Only during the first and the sixth waves are formed 'classical' geographical hotspots such as the capital city and its surroundings. In other waves, especially infection chains that affected the whole country affected the spatial distribution of weekly new confirmed cases was affected. Another important fact of this case study is that the beginning–increasing period of each wave usually started in more developed and urbanized regions of the country, while pe-

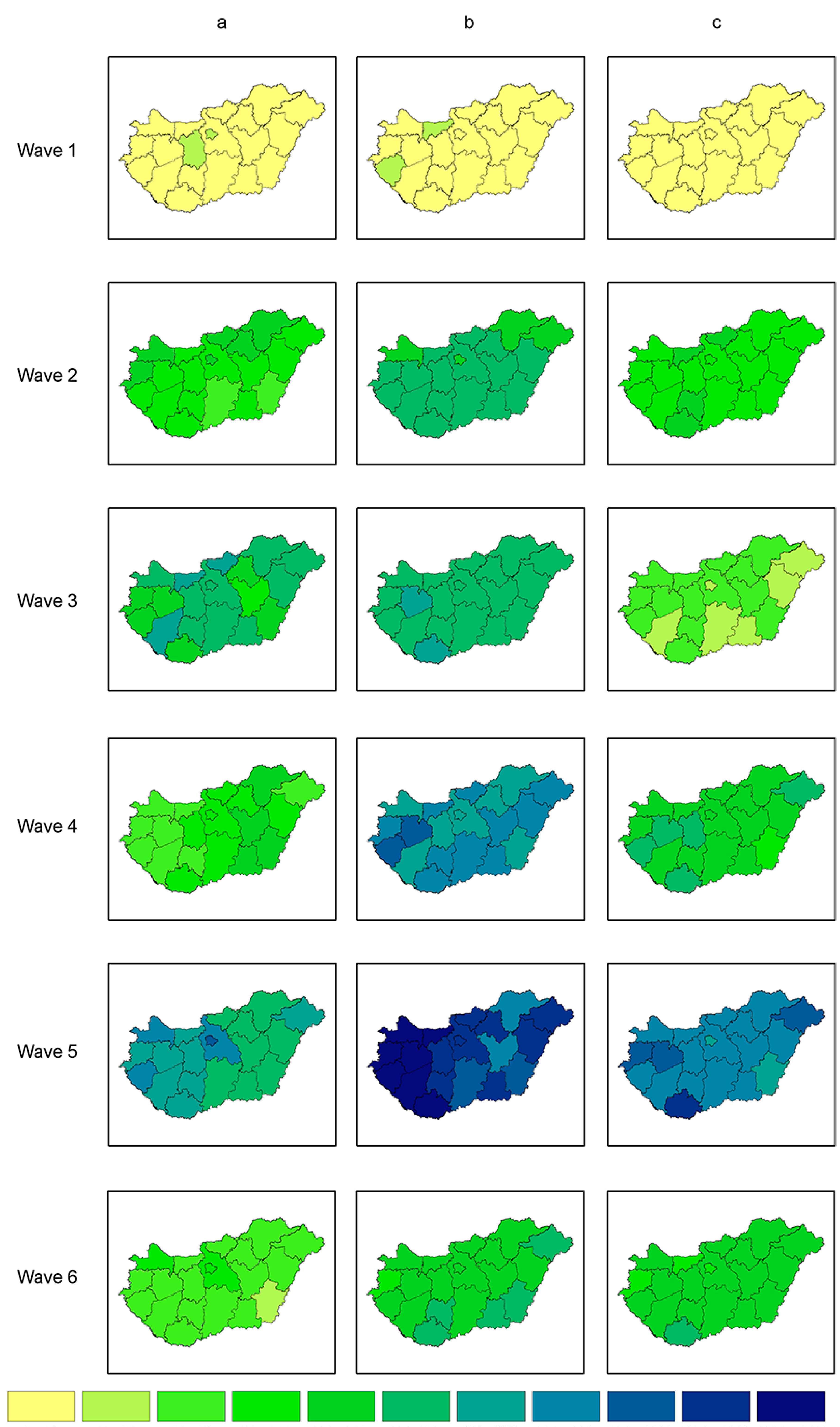


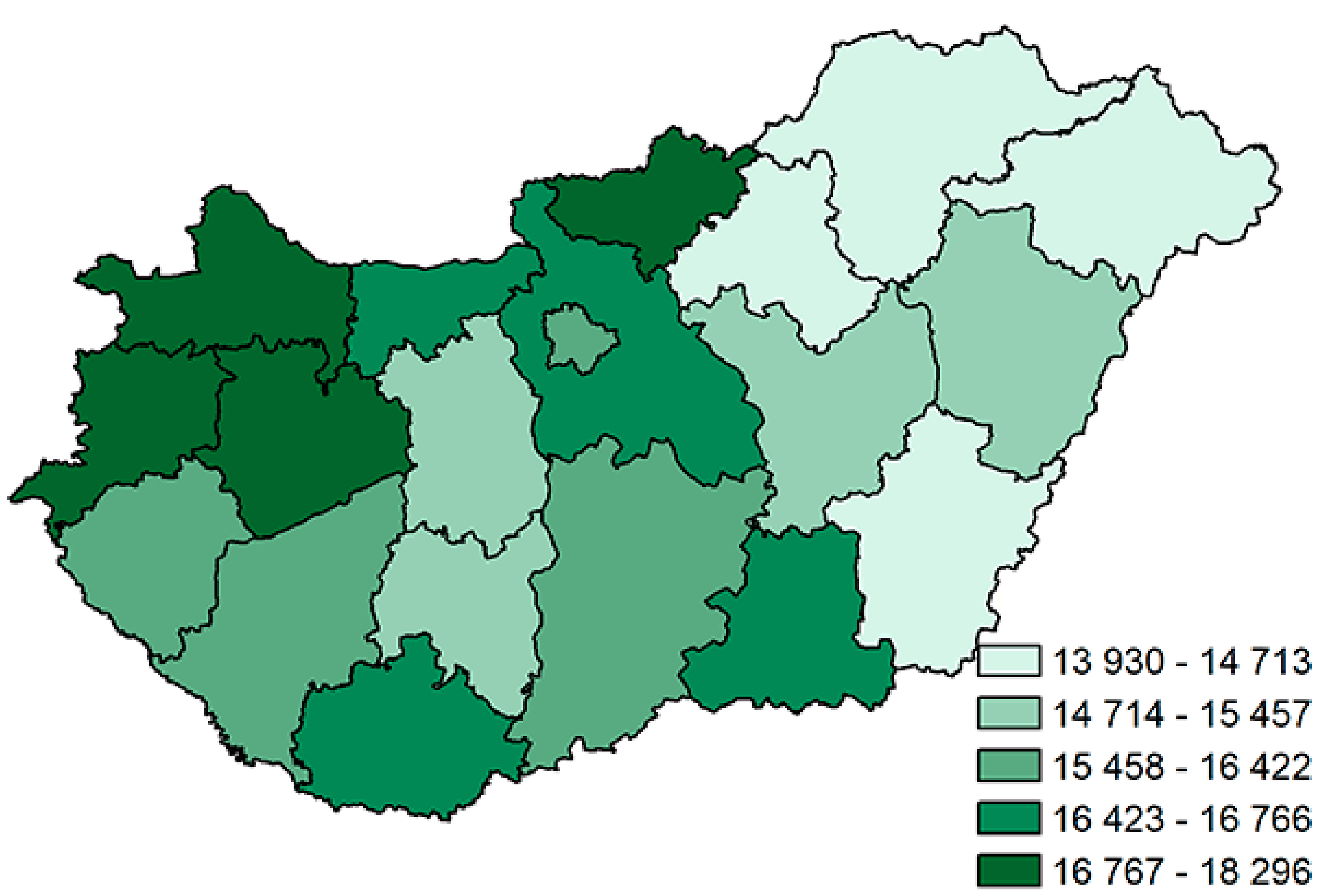
Figure 4. Weekly new confirmed COVID-19 cases per 100,000 inhabitants in the counties of Hungary (NUTS 3) during the different phases of the epidemic waves between March 2020 and December 2022

Legend: a – One week of the epidemic wave in the increasing period; b One week of the epidemic wave in the peak period; c – One week of the epidemic wave in the decreasing period

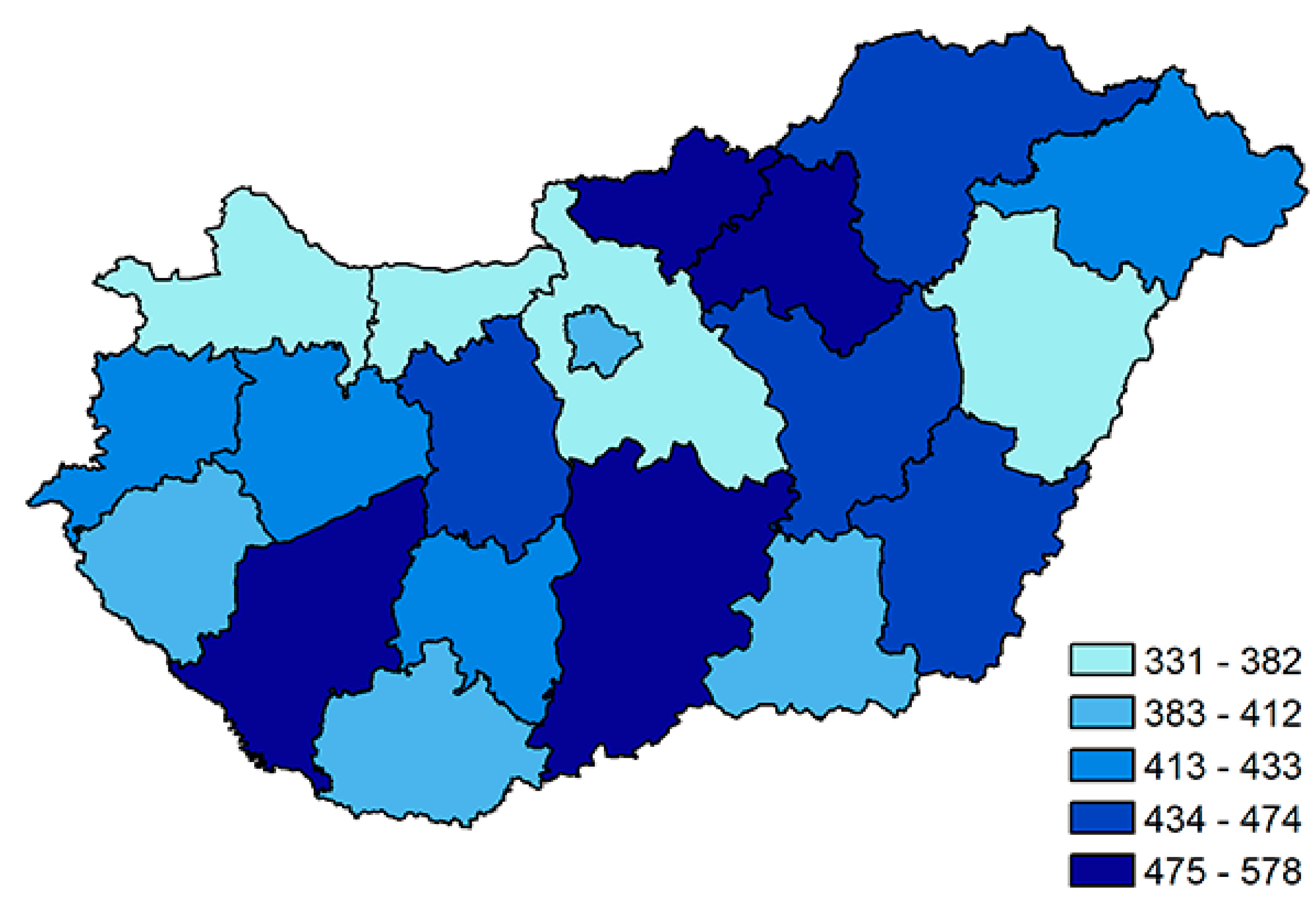
Note: Among epidemiological indicators, only the number of new confirmed COVID-19 cases was officially announced weekly during the pandemic in Hungary. Data source: koronavirus.gov.hu; Primary source: Uzzoli, 2023. p. 33. (in Hungarian) ripheries became more infected areas during the later period in the progress of the given epidemic wave (during the peak and the decreasing period).

The second case study examines the regional distribution of three epidemiological indicators at the county level (NUTS 3), which shows a typical spatial pattern (Figure 5). This pattern is very similar to the spatial structure of the Hungarian health inequalities because it is basically affected by centre-periphery and western-eastern territorial relations (Uzzoli et al., 2020). Firstly, a higher number of confirmed COVID-19 cases is registered in the most developed counties of Hungary. These are standing in the central and western parts of the country, containing the capital city, Budapest, too. Secondly, a lower number of confirmed cases is detected in less developed counties, mainly in the eastern part of Hungary. On the one hand, this finding is coming from the lower economic power of these counties, but on the other hand, it might be a result of lower testing activities regarding the local population's more disadvantaged socio-economic position. Thirdly, the higher number of COVID-19 deaths belongs to less developed counties, which is determined by the spatial pattern of the Hungarian health inequalities. Populations living in less developed counties have poorer health with lower levels of life expectancy and higher levels of mortality. Lastly, besides centre-periphery spatial relation, the western-eastern spatial pattern of the examined indicators highlights the role of neighbourhood effects of the pandemic.

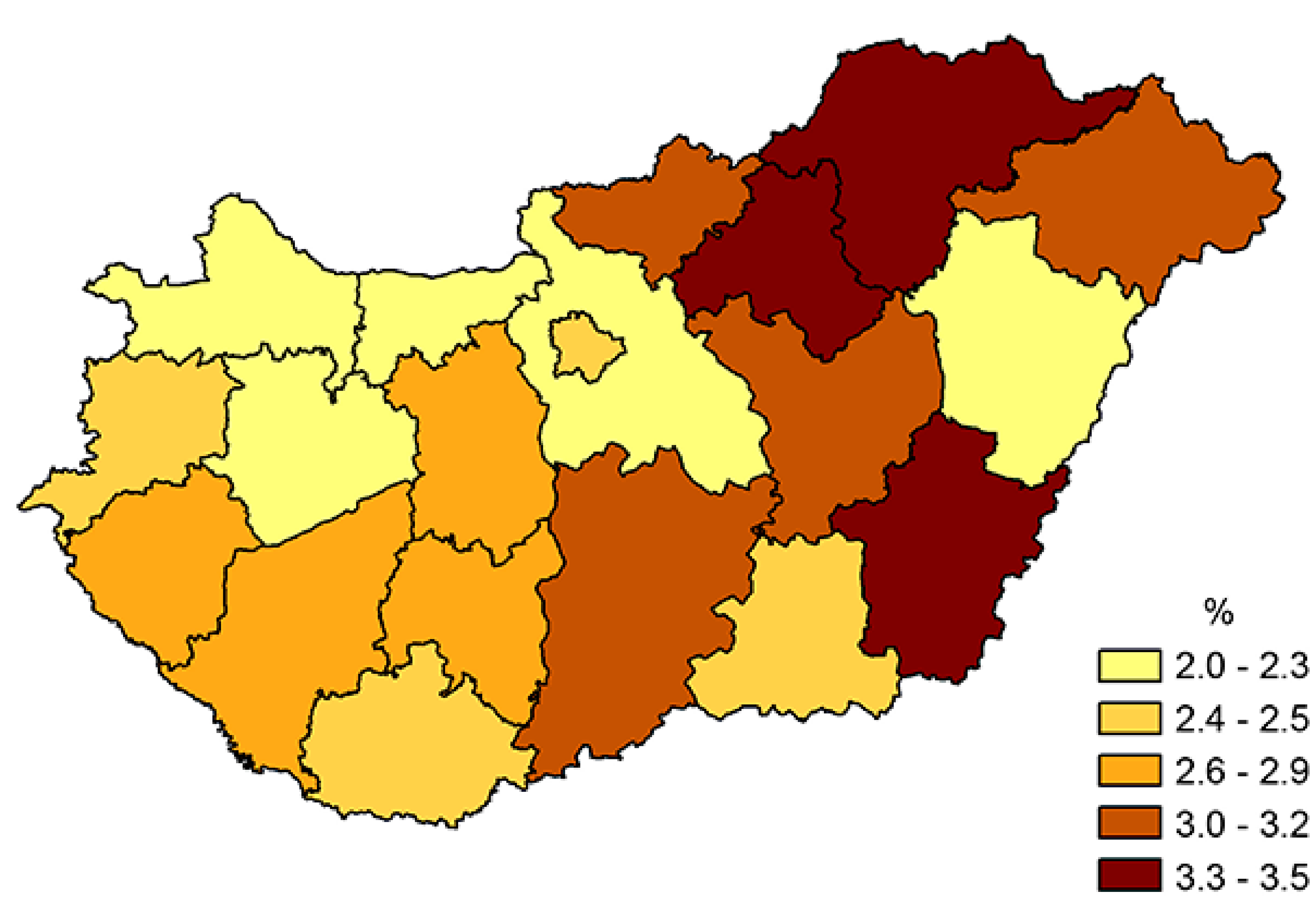
The third case study examines the regional distribution of three epidemiological indicators at the district level (LAU 1), which shows a more sophisticated spatial pattern (Figure 6). There are significant differ-



a. Total number of confirmed COVID-19 cases per 100,000



b. Total number of COVID-19 deaths per 100,000

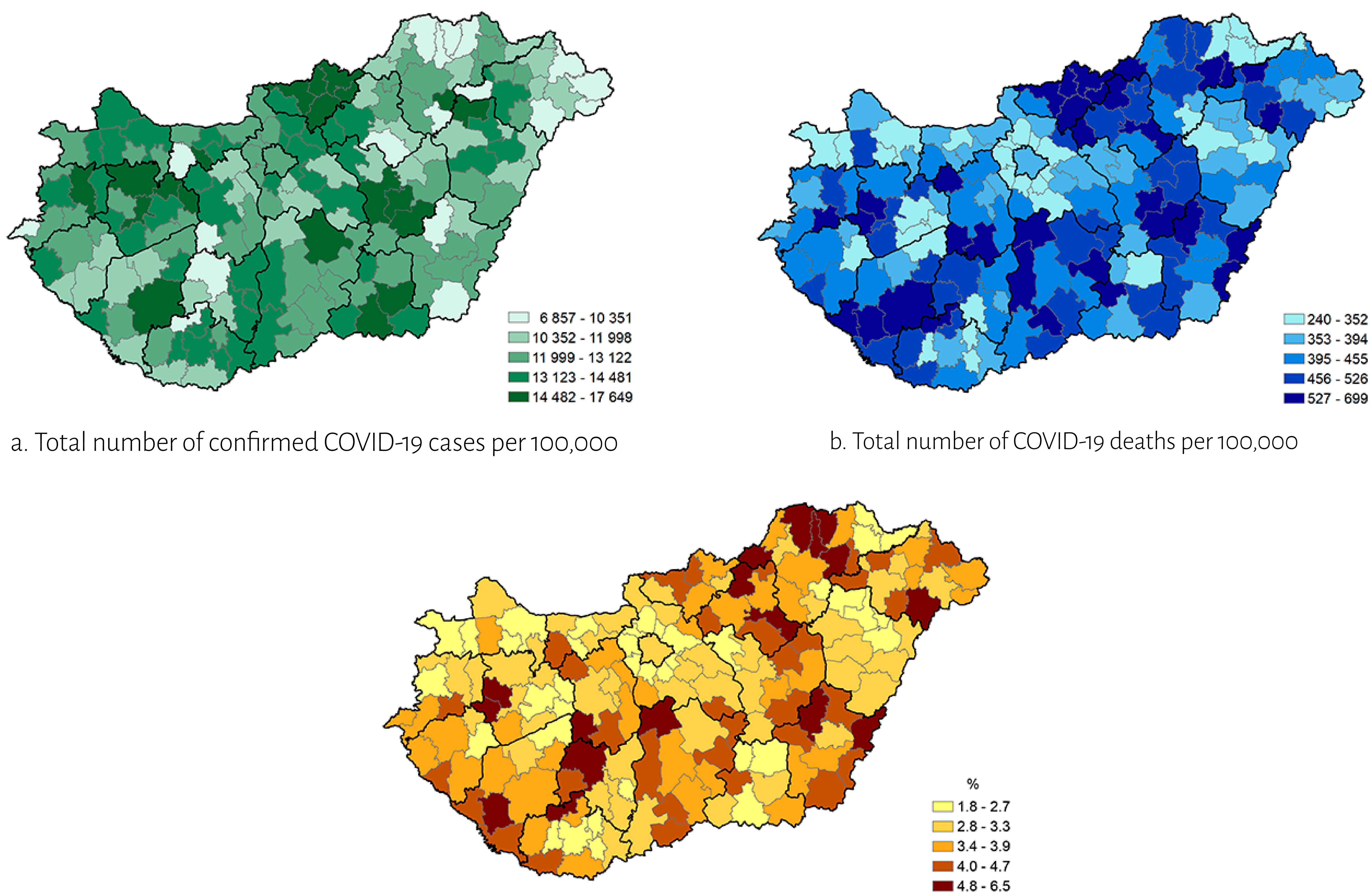


c. COVID-19 mortality rate (death cases/confirmed cases, %)

Figure 5. Regional distribution of some epidemiological indicators in the counties of Hungary (NUTS 3) between 4 March 2020 and 31 January 2022

Note: epidemiological indicator of COVID-19 death cases and its regional distribution at the county level was only once officially announced for the period between 4 March 2020 and 31 January 2022.]
Data source: koronavirus.gov.hu

ences among districts based on the examined indicators. Socioeconomically more disadvantaged districts have a lower risk of being identified as a confirmed COVID-19 case but have a higher risk of death (Oroszi, 2022). Strictly speaking, an inverse spatial association is detected between trends of COVID-19 morbidity and mortality in Hungary. Furthermore, districts with a higher rate of elderly people present a higher number of COVID-19 death cases. Another marked difference basically exists between county seats and their neighbourhood.



a. Total number of confirmed COVID-19 cases per 100,000

b. Total number of COVID-19 deaths per 100,000

c. COVID-19 mortality rate (death cases/confirmed cases, %)

Figure 6. Regional distribution of some epidemiological indicators in the districts of Hungary (LAU 1) between 4 March 2020 and 31 January 2022

Note: epidemiological indicator of COVID-19 death cases and its regional distribution at the district level was only once officially announced for the period between 4 March 2020 and 31 January 2022.
Data source: koronavirus.gov.hu

DISCUSSION

This paper found a marked spatial pattern of infectious and death rates of COVID-19 in Hungary, examining the epidemic waves. Moreover, it is determined by the socio-spatial structure of the country.

Firstly, the most developed and urbanized areas in Hungary are mostly influenced by COVID-19-infected cases, while the peripheries are primarily affected by COVID-19 death cases. Secondly, the socio-economically most developed regions are the sites where epidemic waves are formed. Thirdly, hierarchical diffusion has a spatial effect on the development of different pandemic waves and their spreading towards the geographical peripheries. Fourthly, there are marked seasonality differences among epidemic waves according to their intensity. Lastly, vaccination can +++basically influence regional inequalities of each epidemic wave.

According to the literature, the primary results of this paper also highlighted that districts with poor health conditions were likely to have high COVID-19 mortality rates in 2020 and 2021 (Páger et al., 2024). Due to data limitations at regional scales, the typical spatial pattern of the epidemiological indicators used is in connection with the regional distribution of the Hungarian health inequalities. In addition, Health inequalities are associated with significant socio-spatial inequalities, which have implications for access to healthcare, especially among low-income populations (Levesque et al., 2013; Uzzoli et al., 2020). The significant health inequalities also represented a challenge for health care during the pandemic (Lebihan, 2023), especially in the third epidemic wave, which resulted in the highest COVID-19 death rates and a severe health crisis in Hungary and in East Central Europe as well (Urbanovics et al., 2021).

CONCLUSION

This final chapter gives a concise summary in light of the results regarding the research aim and questions. Conclusions primarily focus on those important findings which have spatial or regional relevance.

After the first epidemic wave in Hungary, infection chains formed within the country resulting in a mass number of COVID-19 cases, but it did not preclude regional differences during the further waves. It means, on the one hand, a nationally high number of COVID-19 cases was associated with regionally different geographical hotspots, which were changed from week to week. On the other hand, the order of counties (NUTS 3 level) has also changed from week to week based on the number of new COVID-19 cases in the proportion of the population.

The spatial pattern of different weekly changing geographical hotspots always transformed during the epidemic waves. In general, the centre-periphery pattern was the most frequent, but the typical neighbourhood spatial effects (e.g. between cities and their agglomerations) also resulted in the western-eastern spatial relation of COVID-19 morbidity and mortality. The socio-spatial consequence of temporal changing spatial pattern is the marked difference between the spatial structure of the initial, the peak and the final phase of the given epidemic wave.

The different periods of each epidemic wave, such as increasing, peak and decreasing periods, went together with a regionally different spatial pattern of the novel coronavirus pandemic in Hungary. In other words, it could occur that the nationally decreasing tendency of new COVID-19 cases (landing in phase) could go together with a regionally increasing tendency. In other words, it may happen that the number of new COVID-19 cases decreased in some counties of the country, while it increased in others at the same time. The taking off, the peak, and the landing phase of the national epidemic curve regionally formed at different times.

The outputs of this examination give relevant information for evidence-based policymaking in future pandemic prevention, mitigation and preparedness regarding their spatial characteristics.

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