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Economic–Sanitation–Environmental (Dis)Connections in Brazil: A Trans-Scale Perspective From Minas Gerais State and BH Microregion

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Abstract

Brazil's economic, environmental, and infrastructural landscape is characterised by local and regional inequalities, particularly evident in Minas Gerais state and the municipalities surrounding its capital, Belo Horizonte (BH) microregion. This research examines three primary domains: (a) economic metrics such as GDP per capita, wages, and formal employment; (b) the availability of clean water and sewage systems; and (c) the frequency of emergency decrees. It aims to ascertain whether these factors can delineate economic, health, and socio-environmental divides within the BH microregion and between its urban and rural areas. Economically, a pronounced gap exists between GDP growth and wage stability, underscoring disparities between the BH microregion and the broader state. While the BH microregion boasts higher salaries and GDP, it also grapples with a heightened cost of living. Disparities in water and sewage infrastructure are stark between urban and non-urban locales, with the latter often lacking access. Emergency decrees are correlated with municipal GDP, with lower-GDP areas experiencing more crises, albeit to a lesser extent in the BH microregion. Cluster analysis reveals a nexus between frequent emergencies, lower GDP, and improved access to water and sewage services. Addressing these challenges requires comprehensive public policies to foster local well-being and alleviate economic, infrastructural, and environmental disparities within both the state and the BH microregion.

Keywords
Brazil; development studies; drinking water; emergency declaration; Minas Gerais; regional planning; sanitation infrastructure; sewage coverage; social inequalities; socio-environmental justice

1. Introduction

Boundaries serve to delineate entities, spanning from physical bodies to constructed edifices, from local neighbourhoods to sovereign nations. Their demarcation not only separates distinct units but also establishes the framework for interaction within the shared socio-spatial environment across various scales and dimensions (Vis, 2018). Even when boundaries are clearly defined by one entity and understood by others in proximity, this does not necessarily imply an equitable distribution of control within the broader spatial context. The mutual formation of boundaries often reflects asymmetrical power dynamics, shaping the parameters governing the flow or obstruction of resources, such as people, finances, infrastructure, and services (Iossifova et al., 2020; Santos, 1996).

Furthermore, influential actors operating at larger scales may exert pressure to maintain or dismantle certain boundaries, thereby influencing local or regional socio-political and economic configurations (Bourdieu, 2014). From a transdisciplinary standpoint, the distinctions between local and regional categories transcend mere physical dimensions, encompassing multiple layers such as legal, administrative, political, economic, and sociocultural factors. These layers exhibit varying degrees of fluidity, allowing for intersections or impositions that underscore the socially constructed nature of scales and the heterogeneous socio-spatial variables that shape them (Marston, 2000).

Illustratively, consider the watershed basin as an ecosystem unit composed of the main watercourse, its tributaries, and the surrounding lands forming the drainage network. While topographical relief morphometrically defines the basin, its dynamic nature arises from geological, climatic, land use, lithological, and vegetative features (Teodoro et al., 2007; Tundisi & Matsumura-Tundisi, 2010), constituting an open system.

Legal delineations of rivers often serve as territorial borders between municipalities or even states and countries within the same basin, impacting their interrelations. The physical boundaries of watersheds establish a regional identity, facilitating the formation of committees, defining their territorial scope, and setting the eligibility criteria for participation. Despite the committee's aim to establish common guidelines for water management, each municipality retains relative autonomy in local development, influencing the power dynamics between larger and smaller spaces. Policies regarding water and sanitation in one municipality can significantly impact downstream counterparts, either positively through responsible environmental practices or negatively through permissive approaches to unsustainable economic activities (Falkenmark & Folke, 2002).

However, lax regulations on land and water use, coupled with ineffective environmental and health institutions, can lead to adverse consequences for downstream areas, from water scarcity to disasters (Jedd & Smith, 2022; Wolf et al., 2023; World Health Organization, 2019). In essence, regional hydro-ecological management cannot supersede the legal boundaries of local administrations, resulting in a complex interplay

of power dynamics favouring politically and economically dominant actors across different scales (Arrojo-Agudo, 2021; Heller, 2020, 2022). Local governments which are sympathetic to the delegation of public water and sanitation service management to the for-profit actors legitimate three privatisation goals: (a) amplify these actors' political influence and maximise their profits; (b) legitimise their natural monopoly, which is an opportunity to increase prices, neglect quality and reduce costs; and (c) create an imbalance of power in the relations of these actors with consumers and with the state that provided them a long-term concession. Such overlapping aspects undermine the human right to water and sanitation (Arrojo-Agudo, 2021; Heller, 2022). Poor or economically unequal countries are the spaces where such issues frequently occur.

While some Brazilian social policies have mitigated income inequality (e.g., Bolsa Família programme), challenges persist, especially in the realm of economic development, access to public services, and resilience to disasters (Gobetti, 2024). Analysing multidimensional poverty necessitates an integrated approach, combining economic data with indicators of well-being, such as sanitation access and susceptibility to hazards. The regional/subregional level of analysis would capture the specificities of these dimensions (Fahel & Teles, 2018). As the regional scale being considered gets smaller, the challenges of the municipalities therein become more evident (Góes & Karpowicz, 2019).

By examining these aspects within the context of the Minas Gerais (MG) state, which shares geographic and demographic characteristics with the rest of the nation (Institute of Applied Economics Research, 2012), insights into hidden processes at the national level can be gleaned. In this study, we examine socio-spatial disparities across three key dimensions: economic dynamics, infrastructure development, and emergency management. We focus on the state of MG and the Belo Horizonte (BH) microregion, contrasting multiple socio-spatial units and tracing their development over time.

This study's three key dimensions are intrinsically linked to specific Sustainable Development Goals (SDGs), reflecting their profound significance in achieving global sustainability. First, the examination of the economic variables (GDP per capita, average salary, and admissions and dismissals of formal work) aligns directly with SDG 1 (no poverty), SDG 8 (decent work and economic growth), and SDG 10 (reduced inequalities), as these elements are fundamental to addressing economic disparities and fostering inclusive growth. Second, the analysis of public access to drinking water and sewage systems is central to SDG 6 (clean water and sanitation), highlighting the critical role of infrastructure in ensuring basic human needs and health. Third, the focus on the evolution of emergency decrees connects with SDG 11 (sustainable cities and communities) and SDG 13 (climate action), underscoring the importance of resilient urban planning and response to environmental challenges. These aspects demonstrate direct linkages to these SDGs and exemplify the interconnectedness of these global goals. For instance, effective emergency management, a key component of this study, indirectly influences other areas, such as public health (SDG 3) and education continuity (SDG 4), producing a cascading effect. This integrative approach underlines the criticality of prioritising these aspects in public policy agendas at all levels to address the multifaceted challenges of sustainable development holistically.

The guiding question of this work is: Are these three sets of variables—GDP per capita, average salary, and admissions and dismissals of formal work; drinking water and sewage collection services; and municipal emergency decrees—useful to identify economic, health, and environmental invisible boundaries? The next

sections of this article are organised as follows: In Section 2, the definitions of concepts such as scale, region, rural and urban are given. Section 3 details the characteristics of MG state and the BH microregion and describes the variables, data sources, and statistical methods adopted. In Section 4, the data and analysis evidencing the boundaries are presented and discussed. Section 5 concludes the article.

2. Conceptual Framing

A region is a junction between territory and the social environment that amalgamates a common history and identity with practices of self-organised solidarity, political rules, cultural repertoires, and economic specificities (Brito, 2008; Santos, 1996). The official definition of a region in Brazil considers it the hierarchical congregation of a set of municipalities, based on the dynamism of their concrete components, which unite and transform them, such as the urban network (Brazilian Institute of Geography and Statistics [IBGE], 2017). A microregion is characterised as pieces of the region that present different economic features (production, distribution, exchange, and consumption) between them (IBGE, 1990). For statistical purposes of regional delimitation as a spatial structure, the IBGE (1990) considers the municipal and state limits established by official political-administrative acts, which means municipalities and states are the units that form microregions and regions. The simultaneous visualisation of the state, microregional, and municipal scales collaborate to identify if one dynamic is reflected in the other, as well as if there are governance issues expressed in anachronistic political and economic mentalities, resulting in layers of inequalities (Gabardo et al., 2021) in employment opportunities, access to infrastructure, and protection against disaster risks.

In the Brazilian geohistorical context, urban and rural spaces are distinct but linked zones. The urban setting is a space moved by capitalist social practices, concentrating the economic, political, and symbolic power that operates social relations dialectically. The main spatial object of the urban setting is the city. The city is an ambivalent form-content that: promotes human densification while segregating its inhabitants; catalyses and quickly circulates wealth, resulting in prosperity for the few while promoting precarious work for the many; encourages network actions while atomises the social movements and social conflicts (Lefebvre, 1974, 2016; Santos, 1985). The city is the locus of various infrastructures, which are technical objects that instrumentalise, enhance, and zone non-material forms of everyday sociability, such as flows of people, contracts, communication, and goods. The gradations of availability and quality of these technical objects in city subspaces make clear the existence of distributional imbalances of well-being (Haesbaert, 2013; Lefebvre, 2016; Santos, 1985). However, the urban goes beyond the city and advances into the countryside. The Brazilian socioeconomic formation of the rural zones expresses the unequal development in the network territory derived from the flows of command and control dictated by the urban processes. Ambiguously, the primary activities (of productive or extractive nature) that capitalist forces exert on the rural zones naturalise non-capitalist relations locally, from denying labour rights to the persistence of slavery-like work (Haesbaert, 2009; Martins, 1985, 1996). Thus, the urban space dynamizes while absorbing the rural zones, forming a *rurban* space (Silva et al., 2002). It is an articulation between extractive activities (e.g., mining, originating from concentrated capital, and participating in the global circuit of commodities, with negative local socio-environmental impact), industry, commerce, and services in the city (Silva et al., 2002) or through agro-industrial complexes connected to the global market, which gives rise to land concentration, expulsion of peasants, and precarious work conditions (Siqueira & Osório, 2001). Due to the outstanding importance of agriculture for the Brazilian economy, the new policies to strengthen family

farming, certifications of sustainable extractivism, and ecotourism also point to a process of rural renovation and empowerment, allowing it to have a less asymmetrical integration with the urban space.

All these aspects are being considered by the recent Brazilian institutional territorial discussions to comprehend the contemporary ways of hybridisations or continuum between rural and urban (IBGE, 2023b). However, the differentiation between these spaces remains, as distinct territories and zones with specific land use policies, financing lines and subsidies, instruments of taxation, etc. One of the relevant territorial dividing lines is the (in)access to water and sewage public infrasystems. Another is the type of susceptibility to hazards. Despite the slow pace of these infrasystems in reaching peripheral urban areas, in rural ones, they are persistently postponed, requiring residents to seek self-provision strategies. While the urban area becomes partially defined by the places where the water and sewage pipes can reach, the rural area, in contrast, becomes partially defined as a place where water provision is made by trucks, direct surface water collection, water wells, or rainwater collection, with unverified potability and requiring rationing strategies, thus resulting in distinct hygienic implications between them. Rural and urban vulnerabilities to natural hazards differ regarding spatial extensions and types of damaged or destroyed objects, each demanding specific response measures and recovery times. The above-mentioned scales and spaces indicate that their boundaries, in some cases, are rigid, constituted by symbolic and concrete walls, regulations, and checkpoints that dictate the prohibited and access zones of (dis)connections between them (Santos, 1985). In others, these limits are fluid regarding the actors, objects, and actions they activate or mobilise.

This study adopts a framework for the analysis of socio-spatial disparities across three critical dimensions: economic dynamics, infrastructure development, and susceptibility to hazards. We conduct a comparative analysis between the scales of the MG state and the BH microregion and scrutinise the urbanisation process by juxtaposing urban and rural areas and tracing their temporal evolution. The economic dynamics analysis examines the relationship among municipal economic activity levels, average salaries, and labour market dynamics, employing the national minimum wage as a benchmark for economic assessment. This approach facilitates the examination of economic disparities and their spatial manifestations. In addressing infrastructural development, our focus narrows to the provision of basic public services, specifically drinking water and sewage collection, and their accessibility to citizens. This analysis underscores the infrastructural disparities between urban and non-urban areas, emphasising the challenges in achieving universal access to essential services. The third aspect scrutinises the local capacity to cope with hazards, assessed through municipal emergency decrees. In Brazil, such decrees are issued only after a disaster has occurred, indicating losses and damages beyond the local capacity to manage. Therefore, these decrees serve as a reliable institutional measure of local resilience (Valencio et al., 2022). After analysing the dynamics of each aspect and delineating the borders between political-administrative scales and urban and rural areas, we present a multidimensional examination of the interplay among economics, infrastructure, and disasters. This aims to identify how economic and infrastructural factors influence susceptibility to hazards.

3. Methodology

3.1. Area of Study

MG is the fourth largest state in Brazil, with 583,513.98 km^2 (IBGE, 2022), equivalent to 2.4 times the size of the UK. This state is divided into 853 municipalities, the greatest number across Brazilian states,

representing 15.3% of the country (see Figure 1). It has a total population of 21,411,923 inhabitants (10.0% of the country) and a population density of 36.5 inhabitants/km^2 (IBGE, 2022). Still, significant variations are observed in its constituent municipalities, with a population ranging from 833 (Serra da Saudade) to 2,315,560 (BH) inhabitants, and population density from 1.3 (Santa Fé de Minas) to 7,609.9 inhabitants/km^2 (BH; IBGE, 2022). As displayed in Figure 1, the territorial area of the municipalities is also diverse, ranging from less than 5 km^2 to over 10,000 km^2, and the urbanisation level ranges from 0.2% to 98.7% of the territory of the municipalities. Hence, MG is an essential state to be studied, as, on one hand, it has the greatest diversity of demographic features compared to other Brazilian states, and, on the other, it is similar to the diversity observed at the national scale (IBGE, 2022; Institute of Applied Economics Research, 2012). Coloured in green in Figure 1 are the 24 municipalities that integrate the BH microregion, where BH, the state capital, is located.

MG state is also an environmental micro-expression of the whole country. In terms of ecoregions, it has three of the six main biomes of Brazil: *mata atlântica* (rainforest, humid, mild temperatures, typical of south and southeast areas and coastal zones), *cerrado* (savannah, dry, warm temperatures, typical of centre-west, southeast and northeast parts of the country), and *caatinga* (xeric shrubland, desert, hot temperatures, typical of the northeast region of the country; Figure 2a). In addition, concerning the distribution of the population, the proportion of municipalities in each population range (according to the official bands defined by IBGE, 2022) is similar to Brazil (Figure 2b). Therefore, by analysing the MG state, one could obtain a first picture of the expected panorama for the country.

Zooming in on the BH microregion, it is the most urbanised, demographically dense, and economically active area of the state: Of the 14 municipalities in the state with over 40 km^2 of urban area, six are in the BH microregion. Hence, it is vital to compare the processes occurring in the BH microregion with those occurring across the MG state to clarify the role of urbanisation. Figure 3 exhibits the spatio-temporal evolution of the urbanisation process. The state capital, BH, at the centre of the map (Municipality 11), was already highly urbanised (blue) in the decade of 1980. By the next decade, the observed urban area (blue and maroon) covered almost the entirety of BH municipality and significantly expanded the urban area of its neighbours. Municipalities more distant from the state capital tend to have lower and later urbanisation. The BH microregion has a characteristic, common to other microregions in the southeast macro-region part of the country, of constituting a space in which the density of productive, financial, technological, and informational investments catalyses a greater urban population contingent and induce metropolization (Santos, 1996). This becomes evident in the way in which the urban features of the state capital merge with the surrounding municipalities, forming concentric urbanisation rings, especially in the west–northwest axis in which the urban territory advanced over rural areas, particularly in the municipalities of Contagem, Betim, Ribeirão das Neves, Vespasiano, Ibirité, e Santa Luzia in the decade of 1990. By the time the economic, infrastructural, and emergency decreeing datasets used in this study started, in 2006, the urbanisation in the BH microregion had already settled, with a concentration in the municipalities close to BH municipality in the west–northwest direction, and the absence of new significant horizontal expansion (i.e., non-observation of significant areas in pink and lime of Figure 3). However, the urban dynamics in the core of the BH microregion penetrate the rural world at the edges, from workers who live in the countryside and work in the city to new technologies coming from urban centres dictating the rhythm of extractive and productive activities in the countryside (Silva et al., 2002).

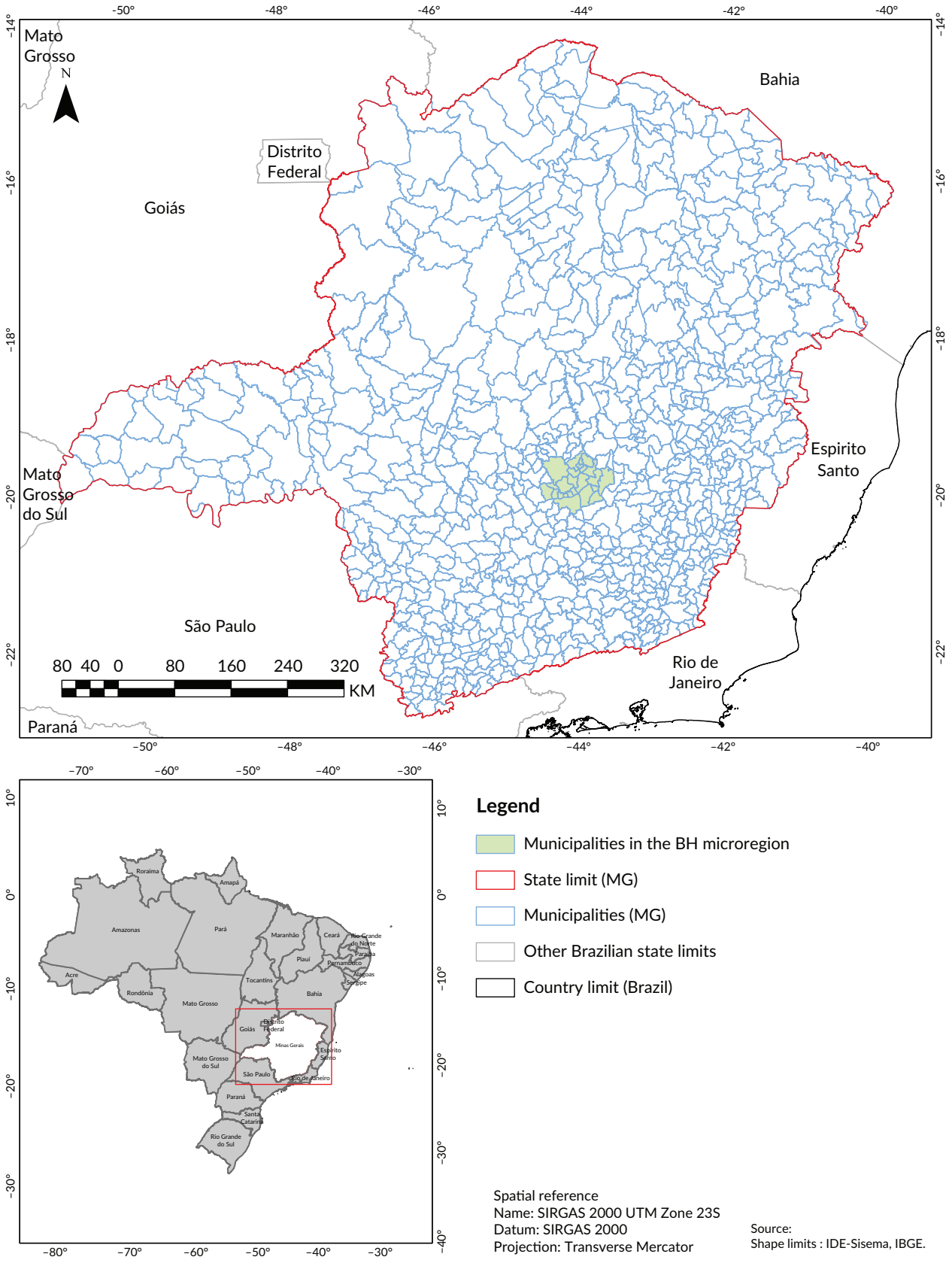

Figure 1. Location of MG state and the BH microregion in the Brazilian territory. Source: Authors' work based on data from IBGE (2023a) and IDE-Sisema (2023).

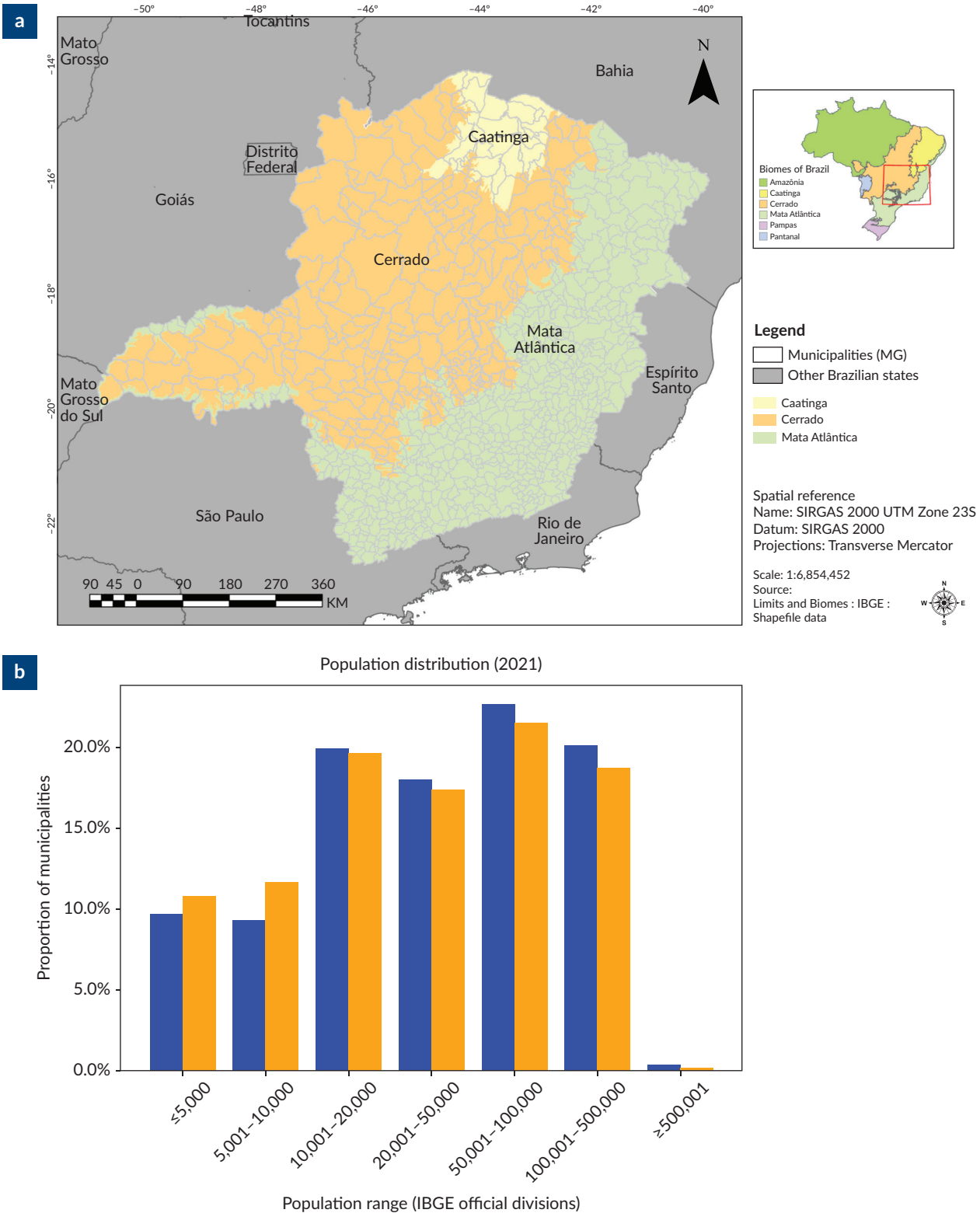

Figure 2. Similar features of the MG state and the country: (a) diversity of biomes in the state, with areas of forest and mild climate typical of south-southeast and coastal zones (Mata Atlântica) and areas of dryland vegetation and warm climate typical of the centre and northeast parts of the country (Cerrado and Caatinga); (b) distribution of population of Brazilian municipalities and MG state municipalities. Source: Authors' work based on data from IBGE (2019, 2022, 2023a) and IDE-Sisema (2023).

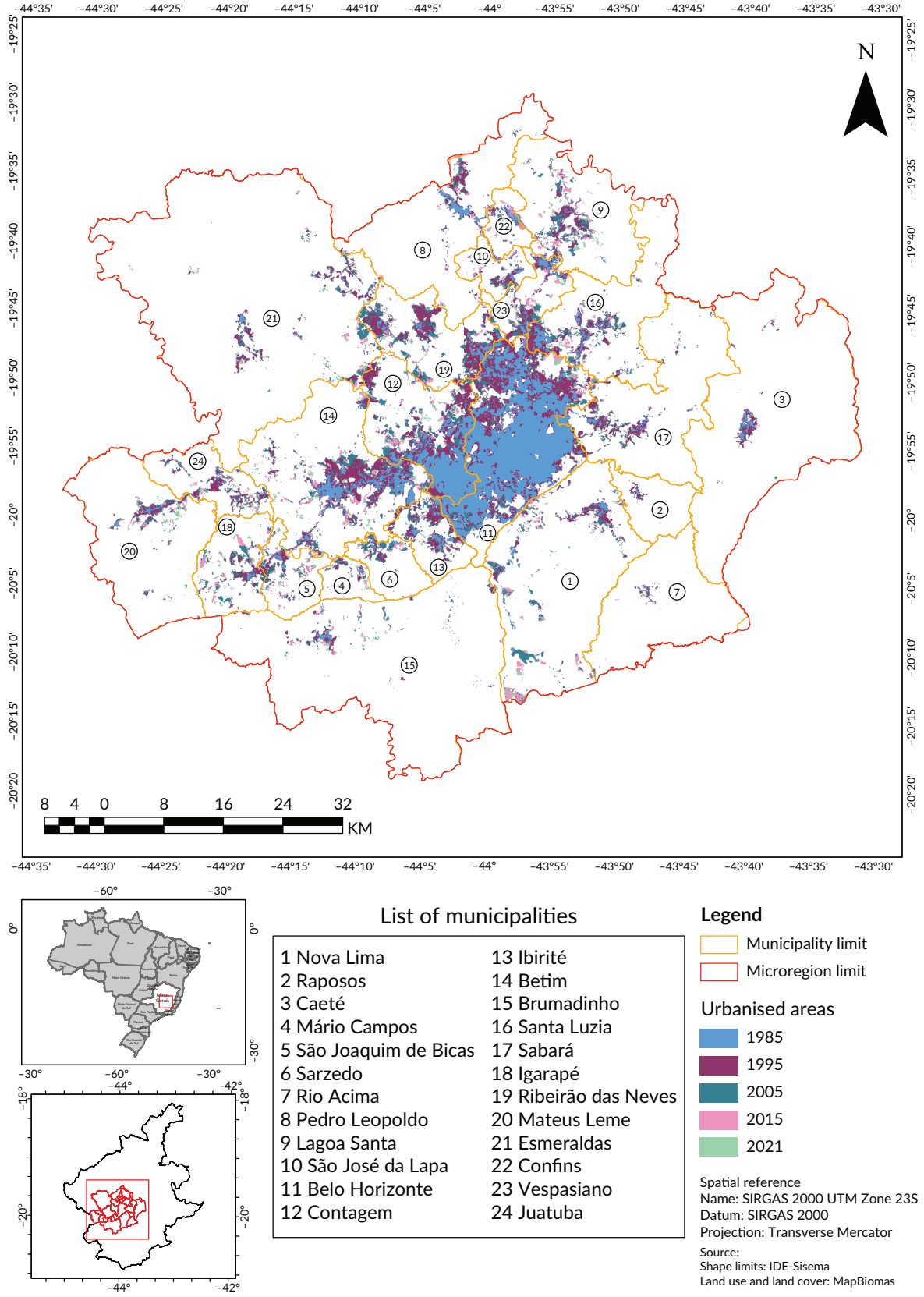

Figure 3. Urban expansion process in the cities of the BH microregion, 1985–2021. Source: Authors' work based on data from IBGE (2023a), IDE-Sisema (2023), and MapBiomas (Souza et al., 2020).

3.2. Variables and Methods of Analysis

To demonstrate the socio-spatial fissures in the three aspects of this study (generating and distributing wealth, availability of drinking water and sewage collection services, and capability to face hazards), open quantitative data, available in virtual databases of Brazilian public institutions, were collected and systematised covering a period of 15 years between 2006 and 2020. The variables described below were selected to analyse the evolution of each aspect of this study.

First, the economic aspect was analysed by the articulation between the variables: total population, GDP, average salary, and admissions and dismissals of formal work. The GDP and average salary were scaled with respect to the national minimum wage. Data for total population refer to the resident population estimate in Brazilian municipalities, produced by the IBGE (2021). Data for GDP are made available by IBGE, in its portal Cidades@ (IBGE, 2022), in partnership with State Statistical Agencies and State Government Secretariats. Data for average salary was also extracted from IBGE's Cidades@ portal, based on its Central Business Register (IBGE, 2023c). Data for the admissions and dismissals of formal work was extracted from the General Register of Employed and Unemployed (n.d.). The national minimum wage historical dataset is compiled by the Inter-Union Department of Statistics and Socio-Economic Studies (2024).

Second, the aspect of the provision of basic public services was analysed from the perspective of two variables: drinking water and sewage collection coverage. The data related to the total and urban population coverage were extracted from the National Sanitation Information System (2023). From the difference between the two, it was possible to calculate the data for the non-urban population coverage. Such information is provided by the drinking water and sewage collection companies (in the Brazilian context, they are institutionally referred to as sanitation companies) and may present significant gaps, particularly concerning sewage collection, which some municipalities have only recently started to inform. To avoid distortions, the analysis of this data is given as the number of informing municipalities in each water coverage/sewage collection level. The sewage collection data analysed here does not contemplate the existence or absence of wastewater treatment facilities in the municipalities.

Third, the aspect of susceptibility to hazards was analysed using data from municipal emergency decrees, sourced from the Integrated Disaster Information System (2023). These decrees, which detail the number and types of associated hazards, offer valuable insights into societal responses to local hazards. Notably, for this study, emergency decrees related to the global Covid-19 pandemic were excluded to focus solely on localised hazards. Emergency decrees serve as more than just legal and administrative tools; they represent significant indicators of societal responses to hazards. Firstly, they officially acknowledge the involvement of various social actors, including residents, businesses, and local administrations, in addressing susceptibility to hazards. Secondly, they signal the escalation of societal disruption, prompting government intervention and resource allocation beyond the conventional norms of democratic accountability. This may involve the imposition of temporary states of exception to expedite response and recovery efforts (Valencio et al., 2022). In Brazil, most emergency decrees pertain to the challenges municipalities face in dealing with hydrometeorological phenomena, such as floods and droughts. This study aims to investigate whether both the MG state and the BH microregion exhibit similar patterns in this regard. Following individual analyses of each aspect and visualisations of their evolution using descriptive plots, the multidimensional association between these aspects was explored.

After analysing each aspect individually, with descriptive plots of their evolution, the multidimensional association between the aspects above was investigated. Scatter plots were employed, with each municipality represented as a point, economic and water/sanitation variables on the x and y axes, and emergency decrees depicted by point colour. To identify clusters within this multidimensional dataset, unsupervised machine learning techniques—specifically Gaussian mixture models with centroids computed by K-means—were utilised (MacQueen, 1967; Reynolds, 2009), implemented using the Scikit-Learn library in Python. The graphical representation of clusters aids in discerning the presence of distinct groups within the data, which may not be immediately apparent from the scatter plot alone. Additionally, it facilitates comparison between cluster features through the centroids, shedding light on their unique characteristics or potential overlap.

4. Results and Discussion

4.1. Economic Dynamics

In Brazil, in recent decades, the economic growth formulas adopted by governmental authorities stimulated private concentrated businesses, some of them through the leverage of the public sector, when considered strategic by the State (Schaeffer et al., 2003). This controversial partnership of the State with big for-profit actors has not always been reflected in an effective improvement in formal employment opportunities and workers' income. Technological innovations appeared in different sectors of the economy, and new forms of financial capitalisation were created that dispense human labour or absorb it through precarious work relations, as in the phenomena of outsourcing and uberisation. Even when there is a salary increase above inflation, the cost of living in the city tends to be onerous because the prices of public services (transport, energy, water, and communication), house financing or rent, food, and the like are readjusted at amounts not compatible with the income. For example, in terms of housing, Góes and Karpowicz (2019, p. 132) find that, in Brazil, "richer regions have higher price levels; conversely, poorer regions have lower price levels. Thus, adjusting for spatial price differences compressions nominal differences in incomes." Another indicative is the expressive degree of indebtedness of Brazilian families (78.3% in March 2023) or the level of default (29.4% in March 2023), according to a study by the National Confederation of Commerce of Goods, Services and Tourism (2024).

Examining the state's economic context, GDP per capita has been increasing in the municipalities, indicating a rhythm of prosperity. The number of impoverished municipalities (GDP per capita < 1.5 minimum wage) declined while the number of municipalities in the highest band increased (Figure 4a). In the BH microregion, the most economically dynamic, the impoverished municipalities also declined, as occurred on the MG state scale. The highest band stabilised in 2012, which was in tune with the national economic stagnation, corresponding to the prolonged economic crisis in the period (Figure 4b).

However, the GDP per capita of the BH microregion remained proportionally higher than the rest of the state, signalling the stabilisation of wealth concentrated in this space compared to the other state areas. Despite the GDP per capita growth, the average salary remains the same throughout the analysed period. The average salary level in the state is concentrated in the two lowest bands (i.e., less than two minimum wages; Figure 5a). Meanwhile, in the BH microregion, most municipalities have average salaries in the medium band, between two and three minimum wages (Figure 5b). However, the cost of living in the BH microregion is higher than in the rest of the MG state, so the citizens do not necessarily experience better conditions.

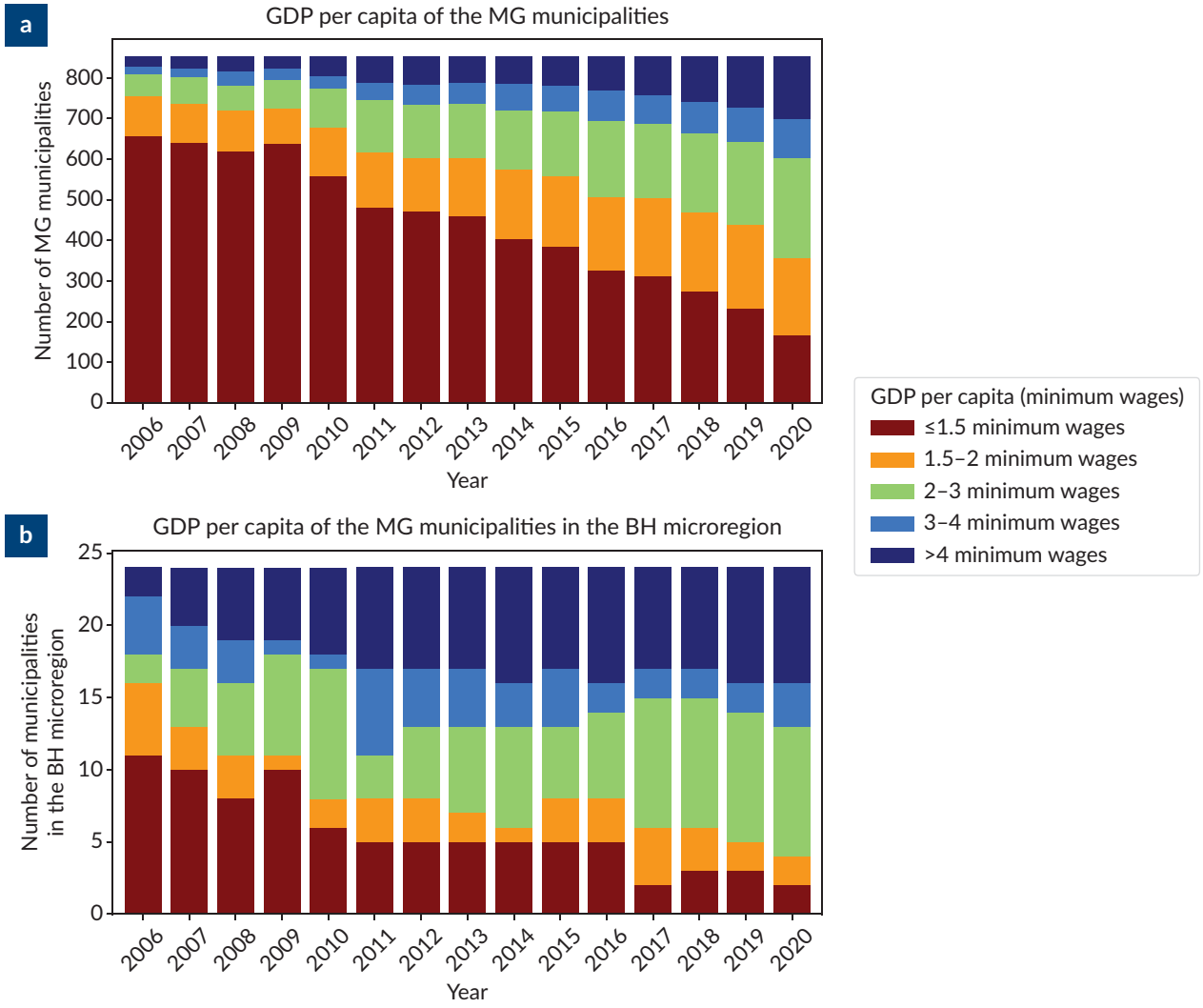

Figure 4. Evolution of the GDP per capita, in national minimum wages, in (a) the MG state and (b) the BH microregion, 2006–2020. Source: Authors' work based on data from IBGE (2022).

In association, Figures 4a, 4b, 5a, and 5b are the reflection of an economically expansionist context in several municipalities, indicating the *rurban* process, in which the cities are the dynamic core that subjects the rural areas, translated to the boundaries between the highly urbanised BH microregion as well as the (mostly rural) remainder of the state. It means that, although the economic boundary between the BH microregion and the remainder of the state exists, as given by the differences in GDP per capita and salaries of Figures 4 and 5, which are indicators of distinct economic dynamics, such boundaries are becoming more fluid, according to the time evolution. On the other hand, some municipalities may be receding in their growth ambitions, either because public finances are limited and unable to trigger policies to stimulate the economic agents constituted there or due to the administrators' lack of interest in attracting new investments to the locality.

Regarding employment levels, the BH microregion witnessed two processes. Until 2011, there was an increase in formal hiring. In 2012–2014, there was a relative hiring stagnation. In 2015–2017, there were more layoffs than hiring, marking a recessive rate. From 2018–2019, a recovery process began compared to the previous one, with more hires than layoffs (Figure 6). No official data has yet been provided after 2019 on a municipal

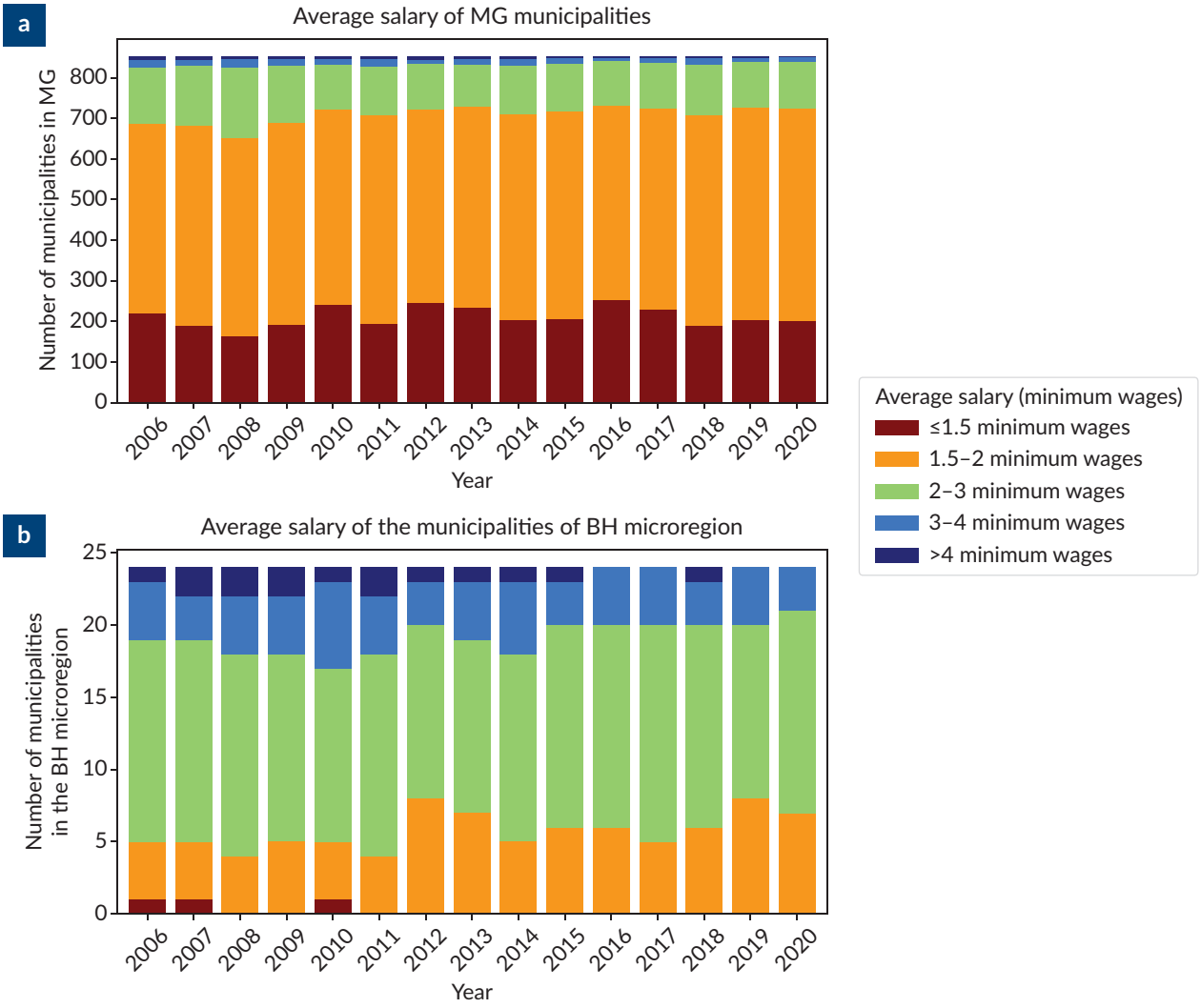

Figure 5. Evolution of the average salary, in national minimum wages, in (a) the MG state and (b) the BH microregion, 2006–2020. Source: Authors' work based on data from IBGE (2022).

scale, but it is assumed that the pandemic context had a negative impact on formal employability. Despite the economic activity level increasing, measured by the GDP per capita growth, this is not reflected in salaries or in local citizens' employment opportunities. However, any loss of momentum rapidly affects the workers through the termination of employment contracts. So, the workers' standard of living progressively declines because employment and wages do not evolve satisfactorily compared to a city that becomes more prosperous.

4.2. Provision of Infrastructure

The second aspect of this study problematises the public commitment to providing drinking water and sewage collection coverage (which, in Brazil, are designated as sanitation services). In this study, we are limited to investigating sewage collection, and not treatment, due to insufficient data on the latter. Regarding drinking water coverage, there is a sharp contrast in the public provision in the non-urban and urban areas of the MG state. While most of the urban population of the municipalities had over 90% of the provision of public water services, less than 50% of the non-urban population in these municipalities have

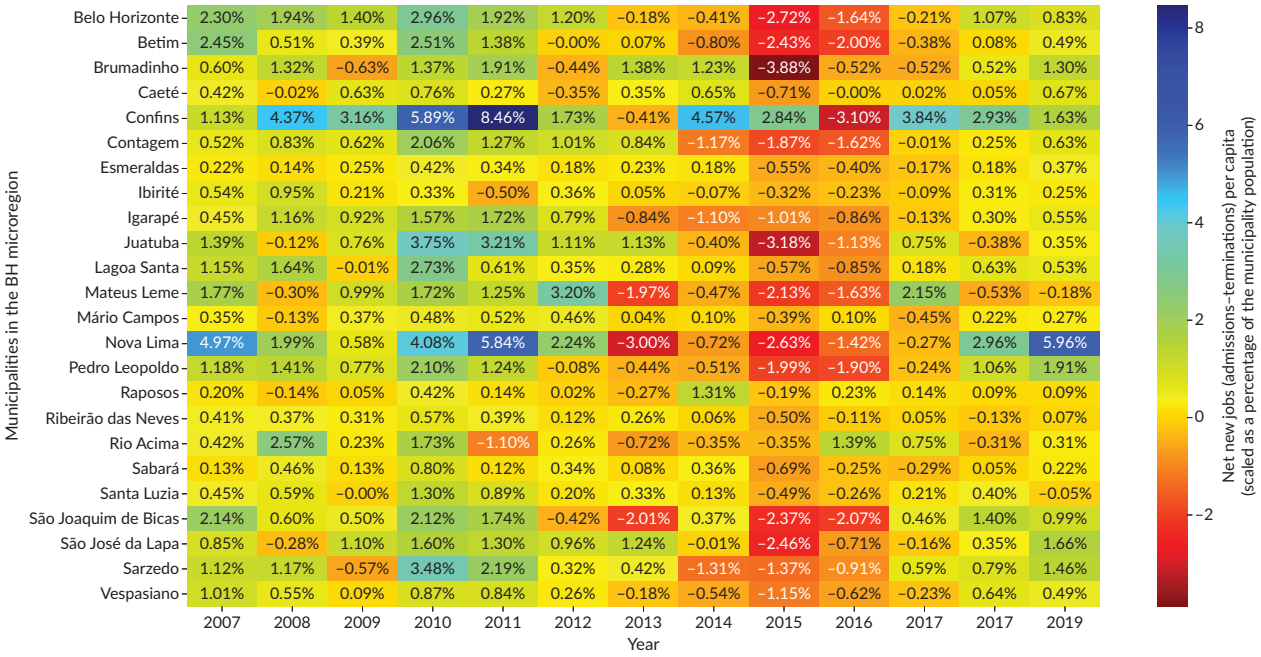

Figure 6. Net new jobs (admissions minus terminations), scaled as a percentage of the municipality population, BH microregion, 2007–2019. Source: Authors' work based on data from the General Register of Employed and Unemployed (n.d.).

access to this (Figures 7a and 7b). However, although small, there is an increasing trend in the water provision to the non-urban population in this state, characterised by the growing number of municipalities in the highest band of water provision to non-urban areas (Figure 7a). This is due to the implementation of local water capture and treatment solutions physically disconnected from the urban infrastructure but still maintained or supplied by the local government, such as artesian wells and water trucks. The same trend cannot be said of the urban population, where the drinking water provision has declined since 2015, with a reduction of the highest band and an increase in the middle bands of coverage (Figure 7b). Looking at the BH microregion, the contrast between a non-urban population with very low access to public drinking water and an urban population with almost total water services coverage is evident, like what is observed in the MG state (Figures 7c and 7d). From the sub-spaces in this microregion, there was also a decline in the water coverage for the urban population in 2015 (Figure 7d), but the increase in the coverage of non-urban areas is not observed (Figure 7c). As the BH microregion is strongly urbanised, the proportion of the total population with access to drinking water is better than in the rest of the state. Still, once the border of the urban and the non-urban population is evidenced, the municipalities in this microregion perform even worse than their state counterparts in providing public water services.

Considering the provision of public sewage collection services, the data informed by sanitation companies presents a more significant number of gaps than in the case of water coverage, which is translated in the growing number of informing municipalities over the years in Figures 8a to 8d. Once again, on the state level, the non-urban population is mainly in the lowest band of public sewage collection coverage (less than 50%; Figure 8a), while the urban population is mainly in the highest band of public sewage coverage (over 90%; Figure 8b), although, in this case, a non-negligible proportion of the urban population is in the middle bands. Therefore, the divide between the urban and non-urban access to public sewage collection services is observed. Focusing on the BH microregion, the contrast between a non-urban population almost exclusively

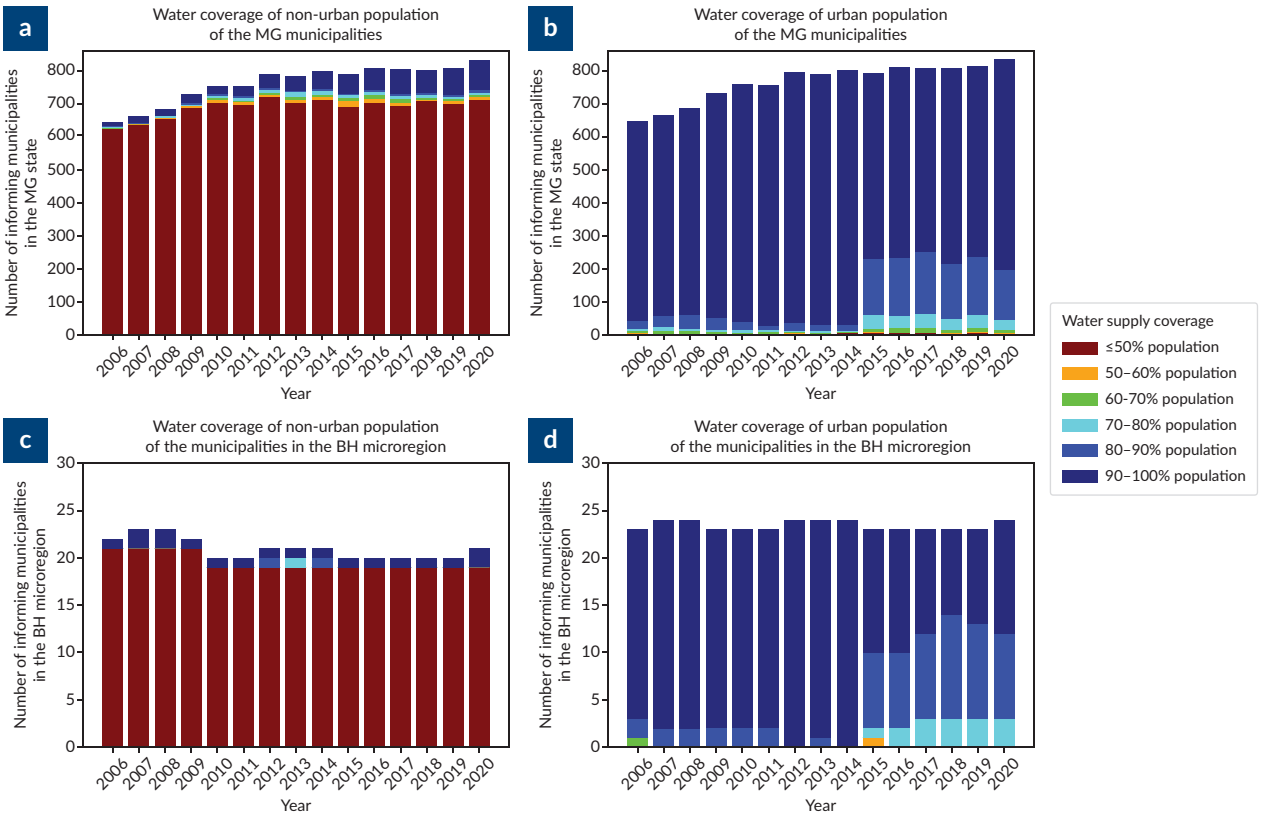

Figure 7. Evolution of public water supply coverage: (a) MG state non-urban population, (b) MG state urban population, (c) BH microregion non-urban population, and (d) BH microregion urban population, 2006–2020. Source: Authors' work based on data from the National Sanitation Information System (2023).

in the lowest band of access to public sewage collection services (Figure 8c) and the urban population with greater access (Figure 8d) is again verified. However, for sewage collection, the urban population in the BH microregion face greater difficulties in obtaining access to public sewage collection than water, with significant proportions in the middle and even in the lowest band of public sewage collection coverage (Figure 8d). This is especially evident after 2015 when an increase in BH microregion municipalities in the lowest band of public sewage collection provision to the urban population (less than 50%) was observed. In other words, water and sewage are important aspects to delimit which social groups, located at different spatial scales, are closer or further away from the human right to water and sanitation. In association, Figures 7 and 8 reflect the existence of an invisible boundary in the human right to water and sanitation between the urban and non-urban groups. From a multilateral perspective, this can be considered a serious violation of the State's obligations to meet the minimum well-being requirements of citizens who remain helpless, as it makes the various and necessary uses of water unfeasible and exposes these communities to aggravated health risks (Heller, 2022). Above all, the human right to water and sanitation must be constantly reaffirmed as derived from the right to a minimum standard of living, which requires not only that infrastructures and services are available to everyone, and at affordable prices, but that any type of existing barriers, such as those of a legal or bureaucratic nature, be eliminated. It is especially concerning to observe, in Figures 7 and 8, the increase in the municipalities at the middle-lower levels of water and sewage coverage in urban areas after 2012. It means that fragmented spaces of lack of access to such services are being born in the cities and an indication that there is a significant imbalance in the material conditions of the inhabitants to live with dignity there. This coincides with the onset time of the economic crisis that affected the country.

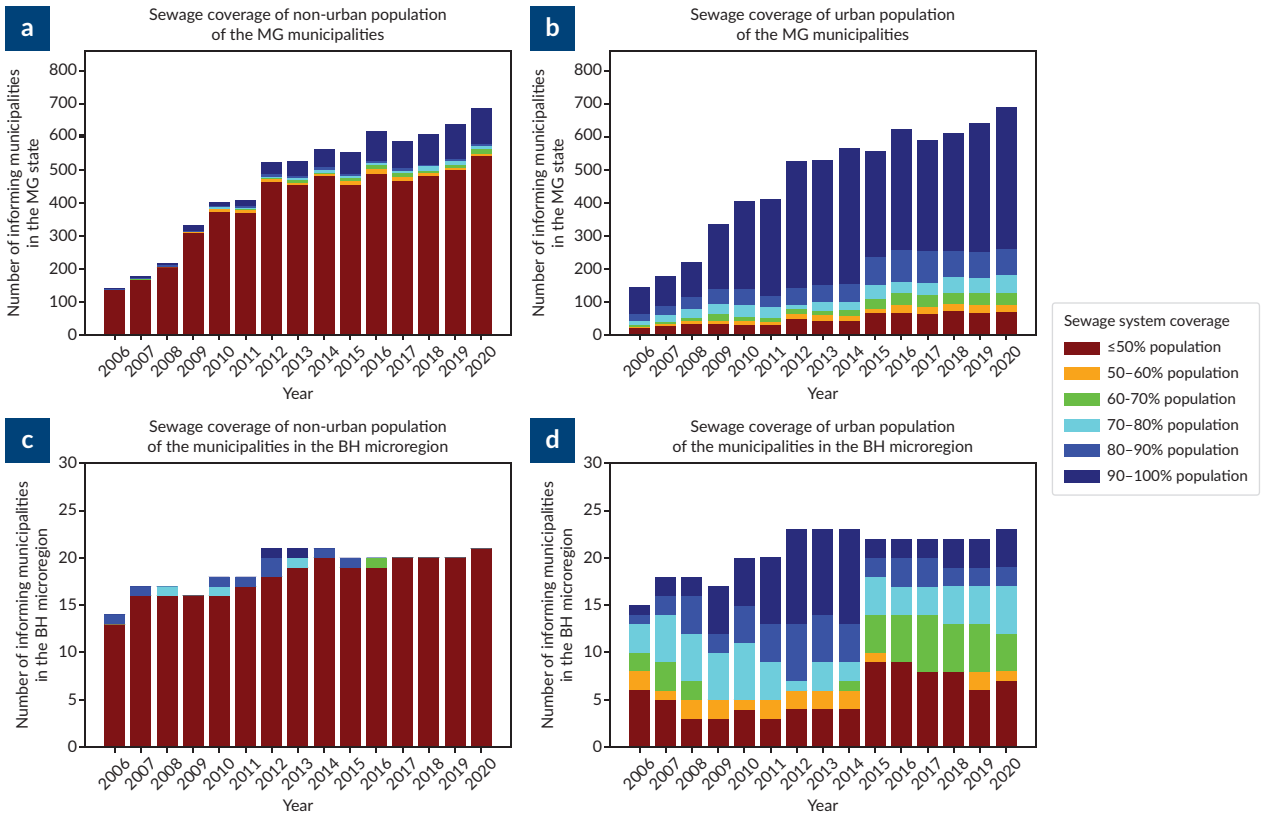

Figure 8. Evolution of public sewage system coverage: (a) MG state non-urban population, (b) MG state urban population, (c) BH microregion non-urban population, and (d) BH microregion urban population, 2006–2020. Source: Authors' work based on data from the National Sanitation Information System (2003).

4.3. Local Susceptibility to Hazards

The third aspect of this study is the characterisation of the local susceptibility to hazards, which is assessed by the evolution of emergency decrees. Regarding the type of hazard (Figure 9a), the most decrees in the MG state are associated with hydrometeorological phenomena, alternating between floods and droughts. This is the same as the national pattern (Valencio et al., 2022). The number of emergency decrees per year in this state oscillates between 100 and 467, which is considerably high for a state with 853 municipalities. An increased susceptibility is likely associated with the limited economic conditions of a municipality to cope with an occurrence, once the damage and losses might be greater than the institutional support capacity, leading to higher chances of emergency decreeing. To investigate this hypothesis, the evolution of the emergency decrees with the GDP per capita of the issuing municipalities has been compared. Indeed, between 2006 and 2019, it is observed that most decrees were concentrated in the lower two bands of GDP per capita (less than two minimum wages; Figure 9b). An outlier was observed in 2020, with a significant proportion of the higher bands of GDP per capita taking over most of the emergency decrees due to the floods in the BH microregion and southern MG state (Figures 9b, 9c, and 9d). The urbanised and economically dynamic BH microregion issued six or fewer emergency decrees in each year of the period, except for the 2020 flood event when 25 emergency decrees were issued (Figure 9c).

The data suggests that there is an invisible boundary between the BH microregion and the remainder of the state regarding susceptibility to disasters, as the first tends to have an emergency decree rate of about

0.12 decrees/municipality per year (excluding 2020), while the latter tends to have a rate of about 0.20 decrees/municipality per year. Unlike the state, the BH microregion shows no association between GDP per capita and the issuing of emergency decrees (Figure 9d), partially due to the close distance of these municipalities to the state capital and the ability to call the state institutional apparatus for support when facing a threat. When disasters happen, the prevailing governmental and media narratives focus on measures taken to rehabilitate the affected people—such as opening shelters and delivering food and clothes to them—and shy away from the improvement of recovery policy, reinforcing a mismatch between the institutional perceptions and the affected social groups' expectations (Schneider, 2008; Valencio & Valencio, 2018). The maintenance of high levels of emergency declaration across the state, often recurrences of the same hazards, indicates this institutional unpreparedness and mismatch with the population's needs and rights.

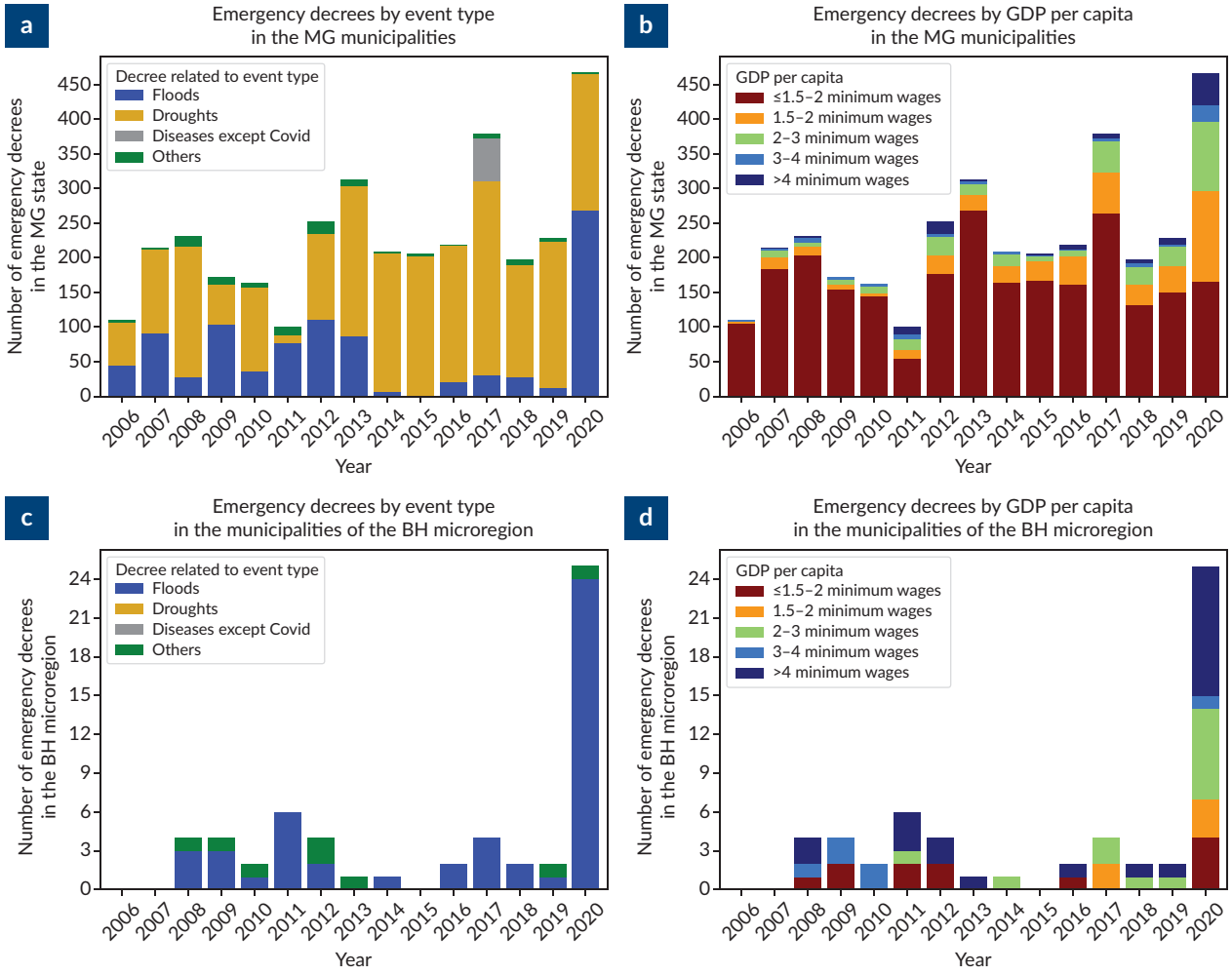

Figure 9. Evolution of emergency decrees evolution: (a) MG state by event type, (b) MG state by GDP of the municipalities declaring an emergency, (c) BH microregion by event type, and (d) BH microregion by GDP of the municipalities declaring an emergency, 2006–2020. Source: Authors' work based on data from Integrated Disaster Information System (2023).

4.4. Relationship Between Economic Dynamics, Public Infrastructure Provision, and Susceptibility to Hazards in MG State

Finally, we investigate how the three aspects—economic dynamics, provision of public water and sewage services, and susceptibility to hazards—are associated in the MG state. Hence, we analyse the distributions through a scatter plot of average GDP per capita, mean total population with public water supply and sewage collection systems, and the total number of emergency decrees in the period (Figures 10a and 10b). Using Gaussian mixture models (Reynolds, 2009) with centroids computed by K-means (MacQueen, 1967), two clusters were identified from the data in both plots. These clusters were also plotted in Figures 10a and 10b,

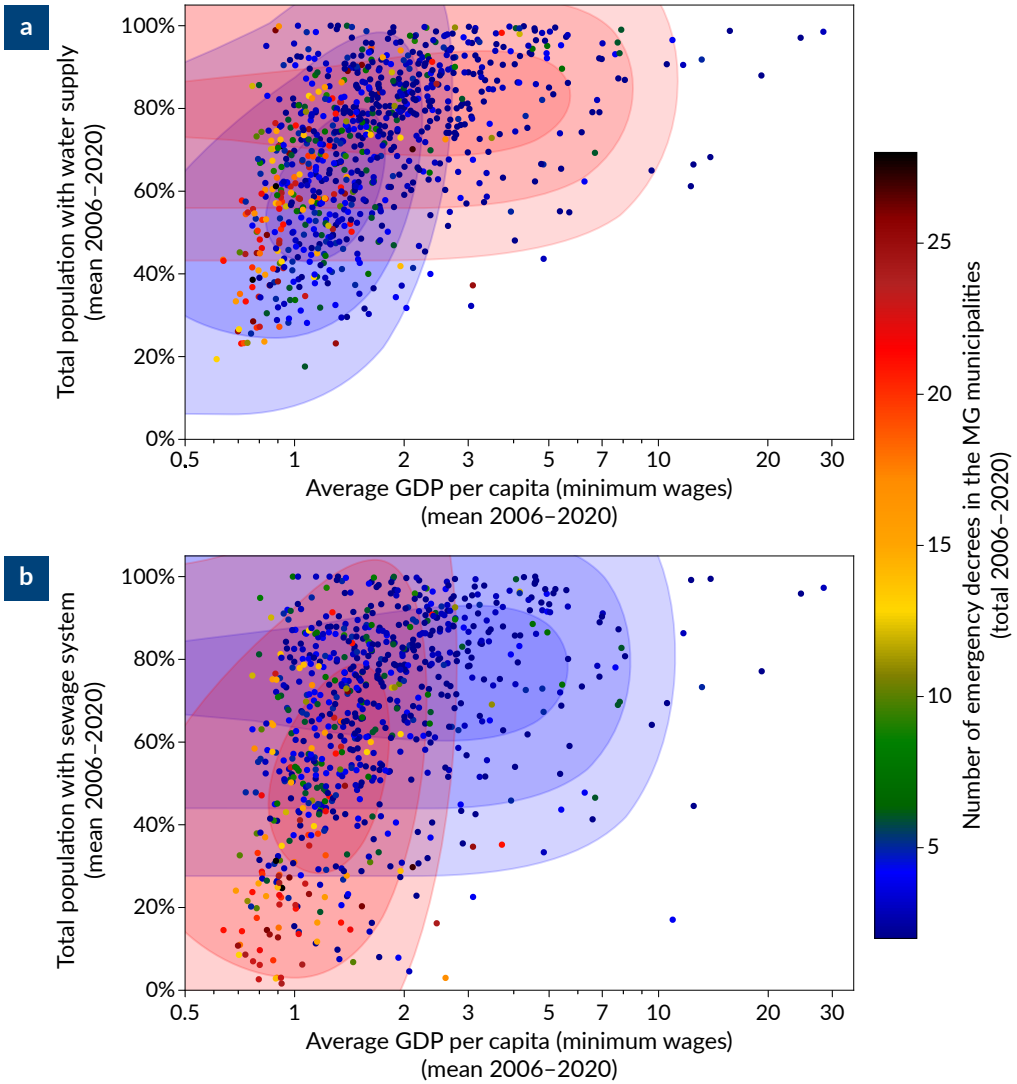

Figure 10. Scatter plots of (a) GDP per capita and public water supply coverage and (b) GDP per capita and public sewage system coverage, both colour-coded by the total number of emergency decrees in the municipality, 2020–2026. Note: The Gaussian mixture model method was applied to the three-variable data of the scatter plot, resulting in the identification of two clusters described by the blue shaded areas (low number of emergency decrees) and the red shaded areas (high number of emergency decrees). Source: Authors' work based on data from IBGE (2022), Integrated Disaster Information System (2023), and the National Sanitation Information System (2023).

with the red cluster being the one that primarily classifies the municipalities with a high number of emergency decrees and the blue cluster primarily classifying the municipalities with a low number of emergency decrees. The concentric rings in the clusters are a proportion of the variance the model considers. The centroid of the red cluster in the relation GDP–water–emergency (Figure 10a) is at [GDP per capita, total population with water, number emergency decrees] = [1.3, 61.5%, 8.9]. In contrast, the blue cluster has a centroid at [GDP per capita, total population with water, number emergency decrees] = [2.9, 81.2%, 2.7]. For the association GDP–sewage–emergency (Figure 10b), the red cluster centroid is at [GDP per capita, total population with water, number emergency decrees] = [1.3, 53.5%, 8.5] and the blue cluster centroid at [GDP per capita, total population with water, number emergency decrees] = [2.9, 76.7%, 2.8]. This means that a higher number of emergency decrees is associated with a lower GDP and a lower provision of public water and sewage collection infrastructure. In addition, the elongation of the red cluster along the y-axis and the blue cluster along the x-axis indicate that, while a higher number of emergency decreeing is more strongly associated with a lower GDP per capita, a lower number of emergency decreeing is more strongly associated with the provision of public water and sewage services. While two clusters with differing characteristics are observed, they superimpose in the low GDP and high water or sewage supply region. Such a combination has both municipalities with low and high emergency characteristics; distinguishing the groups is not trivial. Hence, the priorities of economics and infrastructure public policies should be combined.

The political-administrative borders represented by the MG state, the BH microregion, and its constituent municipalities are geographically well delimited, with territorial borders ensured by legal instruments, official cartography, and public institutional structures. Thus, they can be considered stable systems. Occasionally, there are territorial rearrangements. Contemporaneously, Brazil's and the MG state total areas have been stable, while the BH microregion has been malleable and attractive, tending to incorporate municipalities over the decades. Behind the state and microregional borders, there are environmental and economic *content forms* that operate as open systems, driven by trans-scale circuits related to the climate and the global market, delineating other borders and municipal sub-groups, such as between municipalities susceptible/resilient to disasters or prosperous/impoverished. Finally, water and sanitation infrastructures are material delimiters of the borders between urban and rural areas, but innovative technological and economic approaches could blur these edges in the future.

5. Conclusions

As public management normalises the disparities among sub-spaces across various scales—within municipalities, between urban and rural areas, between municipalities within the same metropolitan region, between microregions in the same state, and between states and the nation—urban borderlands are fortified against the promotion of collective well-being (Iossifova, 2013). This study examines whether variables related to economic dynamics, availability of drinking water and sewage infrastructure, and susceptibility to hazards delineate boundaries beyond territorial demarcations set by political-administrative structures. The conclusion is affirmative, as these variables, whether in isolation or combination, redefine municipalities and zones as spaces of exclusion and inclusion.

For economic dynamics (measured by GDP per capita and average salaries), a notable boundary emerges between the BH microregion (the state capital's location) and the rest of MG state. While significantly higher GDP levels in both areas indicate concentrated wealth and a more dynamic economy compared to surrounding

municipalities, higher salaries in these areas do not necessarily translate to better living conditions, given the elevated cost of living.

In terms of infrastructure, such as access to water and sewage systems, the observed boundary lies between urban and non-urban segments of municipalities, with rural populations often neglected in their right to access these services. Additionally, concerning susceptibility to hazards, distinctions arise based on municipal GDP levels (with lower GDP municipalities issuing more emergency decrees) and between the BH microregion (with fewer emergencies) and the rest of the state (with more emergencies). Examining these variables concurrently reaffirms the association between emergency decrees and GDP, while clarifying the inverse relationship with infrastructure; higher water and sewage supply levels correlate with fewer emergency decrees.

Therefore, essential public policies for disaster prevention should prioritise investments in universal water and sanitation infrastructure and services. This necessitates critical scrutiny of the prevailing government view that privatising this sector is advantageous. Given the inequities in wealth distribution across different scales, for-profit entities in this sector and the residents of these spaces often do not align, given the former's profit motives and the latter's rights. Even state-owned enterprises, like Copasa, are under policies that include permissions for tariff adjustments above inflation in order to incorporate economic-financial compensations and incentives (Regulatory Agency of Water Supply and Sewage Collection Services of Minas Gerais, 2022), aggravating residents' purchasing power decline if there are biases in the consumer payments calculation.

The composite analysis of these variables suggests a potentially vicious cycle for municipalities: Fragile economies hinder public policies' ability to create resilient spaces, especially in the face of known hazards, resulting in setbacks to local development aspirations when disasters occur. This translates to a multidimensional obstacle on the road to sustainable development.

These findings underscore the need to address three objectives—economic development with equitable wealth distribution, expanded provision of water and sewage services, and reduced susceptibility to hazards—through a convergence of policymakers' efforts. This requires a shift from sector-specific approaches to integrated public planning policies, transcending technical boundaries and power dynamics across operational levels (e.g., local administrations, microregions, states, or river basin committees). Synchronised commitments are necessary to achieve associated SDGs and elucidate their interconnections. Since access to water and sanitation is fundamental to dignified living (human right to water and sanitation), prioritising these rights should be the cornerstone of policy discussions, empowering river basin committees and fostering conciliation. Assessing the feasibility of this integrative effort warrants further investigation in future studies.

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

Municipal population estimates were produced by IBGE (https://www.ibge.gov.br/estatisticas/sociais/populacao/9103-estimativas-de-populacao.html). GDP data were made available by IBGE in partnership with state statistical agencies and state government secretariats in its portal Cidades@ (https://cidades.ibge.gov.br). Average salaries data were also extracted from the IBGE Cidades@ portal, using the central business register (https://www.ibge.gov.br/estatisticas/economicas/comercio/9016-estatisticas-do-cadastro-central-de-empresas.html?=&t=downloads). Employment statistics data were extracted from the General Register of Employed and Unemployed of the Ministry of Labour (https://bi.mte.gov.br/bgcaged/caged_perfil_municipio/index.php). The national minimum wage historical dataset was compiled by the Inter-Union Department of Statistics and Socio-Economic Studies (https://www.dieese.org.br/analisecestabasica/salarioMinimo.html). The National Sanitation Information System, with municipal data on water and sanitation provision, is available at http://app4.mdr.gov.br/serieHistorica. The Integrated Disaster Information System, with the municipal records of emergency decrees, is available at https://s2id.mi.gov.br.

References

Arrojo-Agudo, P. (2021). *Risks and impacts of the commodification and financialization of water on the human rights to safe drinking water and sanitation* (Thematic Report No. A/76/159). United Nations. https://www.ohchr.org/en/documents/thematic-reports/a76159-risks-and-impacts-commodification-and-financialization-water

Bourdieu, P. (2014). *Sobre o estado: Cursos no Collège de France (1989–92)*. Companhia das Letras.

Brazilian Institute of Geography and Statistics. (1990). *Divisão do Brasil em mesorregiões e microrregiões geográficas*. https://biblioteca.ibge.gov.br/visualizacao/livros/liv2269_1.pdf

Brazilian Institute of Geography and Statistics. (2017). *Divisão regional do Brasil em regiões geográficas imediatas e regiões geográficas intermediárias—2017*. https://www.ibge.gov.br/geociencias/cartas-e-mapas/redes-geograficas/15778-divisoes-regionais-do-brasil.html?=&t=sobre

Brazilian Institute of Geography and Statistics. (2019). *Biomas e sistema costeiro-marinho do Brasil*. https://www.ibge.gov.br/geociencias/cartas-e-mapas/informacoes-ambientais/15842-biomas.html?=&t=sobre

Brazilian Institute of Geography and Statistics. (2021). *Estimativas da população*. https://www.ibge.gov.br/estatisticas/sociais/populacao/9103-estimativas-de-populacao.html

Brazilian Institute of Geography and Statistics. (2022). *Cidades e estados do Brasil—Cidades@*. https://cidades.ibge.gov.br

Brazilian Institute of Geography and Statistics. (2023a). *Malhas territoriais*. https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html

Brazilian Institute of Geography and Statistics. (2023b). *Proposta metodológica para classificação dos espaços do rural, do urbano e da natureza no Brasil*. https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=2102019

Brazilian Institute of Geography and Statistics. (2023c). *Estatísticas do cadastro central de empresas—CEMPRE*. https://www.ibge.gov.br/estatisticas/economicas/comercio/9016-estatisticas-do-cadastro-central-de-empresas.html

Brito, T. M. A. (2008). A metamorfose do conceito de região: Leituras de Milton Santos. *GEOgraphia*, *10*(20), 74–105. https://doi.org/10.22409/GEOgraphia2008.v.v10i20.a13563

Fahel, M., & Teles, L. R. (2018). Measuring multidimensional poverty in the state of Minas Gerais, Brazil: Looking beyond income. *Revista de Administração Pública*, *52*(3), 386–416. http://dx.doi.org/10.1590/0034-7612154852

Falkenmark, M., & Folke, C. (2002). The ethics of socio-ecohydrological catchment management: Towards hydrosolidarity. *Hydrology and Earth System Sciences*, *6*(1), 1–10. https://doi.org/10.5194/hess-6-1-2002

Gabardo, E., Brepohl, M., & Gonçalves, M. (2021). Authoritarian setback in the current crisis of Brazilian democracy. *Tempo & Argumento*, *13*(34), 1–48. https://www.revistas.udesc.br/index.php/tempo/article/download/2175180313342021e0304/13736/81359

General Register of Employed and Unemployed. (n.d.). *Perfil do município*. https://bi.mte.gov.br/bgcaged/caged_perfil_municipio/index.php

Gobetti, S. W. (2024). *Concentração de renda no topo: Novas revelações pelos dados do IRPF*. FGV-IBRE. https://observatorio-politica-fiscal.ibre.fgv.br/politica-economica/pesquisa-academica/concentracao-de-renda-no-topo-novas-revelacoes-pelos-dados-do

Góes, C., & Karpowicz, I. (2019). Inequality in Brazil: A closer look at the evolution in states. In A. Spilimbergo & K. Srinivasan (Eds.), *Brazil: Boom, bust, and the road to recovery* (pp. 127–137). International Monetary Fund. https://doi.org/10.5089/9781484339749.071

Haesbaert, R. (2009). Região, diversidade territorial e globalização. *GEOgraphia*, *1*(1), 15–39. https://doi.org/10.22409/GEOgraphia1999.v1i1.a13361

Haesbaert, R. (2013). De espaço e território, estrutura e processo. *Economía, Sociedad y Territorio*, *13*(43), 805–815. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-84212013000300011&lng=es&tlng=pt

Heller, L. (2020). *Direitos humanos e a privatização dos serviços de água e esgotamento sanitário. Relatório do relator especial sobre os direitos humanos à água potável e ao esgotamento sanitário* (Report No. A/75/208). United Nations. https://www.ohchr.org/sites/default/files/Documents/Issues/Water/annual-reports/Privatization-pt.docx

Heller, L. (2022). *The human rights to water and sanitation*. Cambridge University Press.

IDE-Sisema. (2023). *Infraestrutura de dados espaciais do sistema estadual de meio ambiente e recursos hídricos—Limites*. https://idesisema.meioambiente.mg.gov.br

Institute of Applied Economics Research. (2012). *Situação social nos estados: Minas Gerais*. https://www.ipea.gov.br/portal/images/stories/PDFs/120210_relatorio_situacaosocial_mg.pdf

Integrated Disaster Information System. (2023). *Sistema integrado de informações de desastres*. https://s2id.mi.gov.br

Inter-Union Department of Statistics and Socio-Economic Studies. (2024). *Pesquisa nacional da cesta básica de alimentos*. https://www.dieese.org.br/analisecestabasica/salarioMinimo.html

Iossifova, D. (2013). Searching for common ground: Urban borderlands in a world of borders and boundaries. *Cities*, *34*, 1–5. https://doi.org/10.1016/j.cities.2013.01.006

Iossifova, D., Bhide, A., Lazo, D. L., Valencio, N., Dong, N., & Gasparatos, A. (2020). Desigualdades infraestructurales en ciudades fragmentadas. Transformando infra-sistemas para la salud pública. In G. C. D. Ramos & D. L. Ramos (Eds.), *Las ciudades ante el Covid-19: Nuevas direcciones para la investigación urbana y las políticas públicas* (pp. 78–89). Plataforma de Conocimiento para la Transformación Urbana. https://observatorylatinamerica.org/es/las-ciudades-ante-el-covid-19-nuevas-direcciones-para-la-investigacion-urbana-y-las-politicas-publicas

Jedd, T., & Smith, K. H. (2022). Drought-stricken U.S. states have more comprehensive water-related hazard planning. *Water Resources Management*, *37*, 601–617. https://doi.org/10.1007/s11269-022-03390-z

Lefebvre, H. (1974). *La production de l'espace*. Anthropos.

Lefebvre, H. (2016). *Espaço e política: O direito à cidade* (Vol. 2). Editora da UFMG.

MacQueen, J. (1967). Some methods for classification and analysis of multivariate observations. In L. M. Le Cam & J. Neyman (Eds.), *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability* (Vol. 1, pp. 281–297). University of California Press.

Marston, S. A. (2000). The social construction of scale. *Progress in Human Geography*, *24*(2), 219–242. https://doi.org/10.1191/030913200674086272

Martins, J. S. (1985). *A militarização da questão agrária no Brasil*. Vozes.

Martins, J. S. (1996). *O cativeiro da terra*. Hucitec.

National Confederation of Commerce of Goods, Services and Tourism. (2024). *Pesquisa de endividamento e inadimplência do consumidor (PEIC): Perfil do endividamento anual 2023*. https://portaldocomercio.org.br/publicacoes_posts/pesquisa-de-endividamento-e-inadimplencia-do-consumidor-peic-perfil-do-endividamento-anual-2023/

National Sanitation Information System. (2023). *SNIS—Série histórica*. http://app4.mdr.gov.br/serieHistorica

Regulatory Agency of Water Supply and Sewage Collection Services of Minas Gerais. (2022). *Detalhamento do reajuste tarifário de 2022 da Companhia de Saneamento de Minas Gerais (Copasa MG)* (Report GRT No. 01/2022). http://www.arsae.mg.gov.br/wp-content/uploads/2022/06/NT_GRT_01_2022_Reajuste_Copasa_2022.pdf

Reynolds, D. (2009). Gaussian mixture models. In S. Z. Li & A. Jain (Eds.), *Encyclopedia of biometrics* (pp. 659–663). Springer.

Santos, M. (1985). *Espaço e método*. Hucitec.

Santos, M. (1996). *Metaformoses do espaço habitado*. Hucitec.

Schaeffer, R., Cohen, C., Almeida, M. A., Achão, C. C., & Cima, F. M. (2003). *Energia e pobreza: Problemas de desenvolvimento energético e grupos sociais marginais em áreas rurais e urbanas no Brasil*. CEPAL.

Schneider, S. (2008). Who's to blame: (Mis)perceptions of the intergovernmental response to disasters. *The Journal of Federalism*, *38*(4), 715–738. https://doi.org/10.1093/puplius/pjn019

Silva, J. G., del Grossi, M., & Campanhola, C. (2002). O que há de realmente novo no rural brasileiro. *Cadernos de Ciência & Tecnologia*, *19*(1), 37–67. https://seer.sct.embrapa.br/index.php/cct/article/view/8795/4938

Siqueira, D., & Osório, R. (2001). O conceito de rural. In N. Giarraca (Ed.), *Una nueva ruralidad en América Latina?* (pp. 67–79). CLACSO. https://core.ac.uk/download/pdf/35157225.pdf

Souza, C. M., Jr., Shimbo, J. Z., Rosa, M. R., Parente, L. L., Alencar, A. A., Rudorff, B. F. T., Hasenack, H., Matsumoto, M., G. Ferreira, L., Souza-Filho, P. W. M., Oliveira, S. W., Rocha, W. F., Fonseca, A. V., Marques, C. B., Diniz, C. G., Costa, D., Monteiro, D., Rosa, E. R., Vélez-Martin, E., . . . Azevedo, T. (2020). Reconstructing three decades of land use and land cover changes in Brazilian biomes with Landsat archive and earth engine. *Remote Sensing*, *12*(17), Article 2735. https://doi.org/10.3390/rs12172735

Teodoro, V. L. I., Teixeira, D., Costa, D. J. L., & Fuller, B. D. (2007). O conceito de bacia hidrográfica e a importânica da caracterização morfométrica para o entendimento da dinâmica ambiental local. *Revista Brasileira Multidisciplinar*, *11*(1), 137–156. https://revistarebram.com/index.php/revistauniara/article/view/236

Tundisi, J. G., & Matsumura-Tundisi, T. (2010). Impactos potenciais das alterações do Código Florestal nos recursos hídricos. *Biota Neotropica*, *10*(4), 67–76. https://doi.org/10.1590/S1676-06032010000400010

Valencio, N., & Valencio, A. (2018). Media coverage of the "UK flooding crisis": A social panorama. *Disasters*, *42*(3), 407–431. https://doi.org/10.1111/disa.12255

Valencio, N., Valencio, A., & Baptista, M. S. (2022). What lies behind the acute crises: The social and infrasystems links with disasters in Brazil. In D. Iossifova, A. Gasparatos, S. Zavos, Y. Gamal, & Y. Long (Eds.), *Urban infrastructuring: Reconfigurations, transformations and sustainability in the Global South* (pp. 35–52). Springer. https://doi.org/10.1007/978-981-16-8352-7_3

Vis, B. N. (2018). *Cities made of boundaries: Mapping social life in urban forms*. UCL Press.

Wolf, J., Johnston, R. B., Ambelu, A., Arnold, B. F., Bain, R., Brauer, M., Brown, J., Caruso, B. A., Clasen, T., Colford, J. M., Jr., Mills, J. E., Evans, B., Freeman, M. C., Gordon, B., Kang, G., Lanata, C. F., Medlicott, K., Prüss-Ustün, A., Troeger, C., . . . Cumming, O. (2023). Burden of disease attributable to unsafe drinking water, sanitation, and hygiene in domestic settings: A global analysis for selected adverse health outcomes. *The Lancet*, *401*(10393), 2060–2071. https://doi.org/10.1016/s0140-6736(23)00458-0

World Health Organization. (2019). *Safer water, better health*. https://iris.who.int/bitstream/handle/10665/329905/9789241516891-eng.pdf?sequence=1

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