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From federal transfers and local investments to a potential convergence of COVID-19 and climate change: The case study of São Paulo city

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1. Introduction

This paper highlights the importance of public transfers at national level to understand the way they are managed at subnational scale, identifying those aspects that ought to be considered to improve urban resilience in Brazil. The theme discussed acquire particular significance due to the limited resources allocated in disaster risk reduction (DRR) and to the role played by subnational governments in providing the infrastructure and the public services for which they are responsible. In the first moment, we conducted a survey of public investments among 45 municipalities most affected by disasters since 2008 to comprehend federal transfers and programs implemented through public investments at the subnational level. The main questions that inform this part of study are: (1) How has public transfers been allocated to DRR? (2) What are the main programs covered by subnational investments? In a second moment, we compared the geographic distribution of deaths caused by COVID-19 with maps on flood susceptibility and warmer surfaces to understand the materialization of processes arising from government measures at national and municipal scales. The objective was to understand the relationship between the populations most affected by COVID-19 and those affected by climate change. The main questions that inform the second part of study are: (3) Can different phenomena such as the pandemic and climate change be interrelated? (4) How are they related to urban investments and decision processes?

The purpose of this study is not to prove a correlation between federal transfers, municipal investments, and the vulnerability caused by COVID-19 and climate change. A significant amount of data would be needed to prove such correlation, from the continuous monitoring of measures implemented by municipalities with extensive questionnaires, which is incipient in Brazil. The idea is to sensitize different communities about the importance of federal coordination to designate investments in DRR, including during the pandemic emergence. Achieving responsiveness involves changing the way the development planning process is viewed and how it incorporates DRR. However, one of the difficulties in combining these perspectives lies in attempts to develop ways to measure the impact of efforts to support DRR. As we shall see, most of the processes described point to different dominant aspects that are more characteristically emphasized on some scales than on others. Recognizing this aspect, we consider different municipalities to compare the national and subnational interventions to finally focus on local scales that are related to more specific levels of urban system. The analysis on municipalities supports the examination of needs for projects and
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programs in areas with disabilities that should have been included through national coordination. Unfortunately, there is a lack of integrated data to compare municipal actions and the distribution of COVID-19, as the lack of coordination by the Ministry of Health has led to diffuse actions since each municipality decides and discloses what it considers relevant without standardization. For this reason, the last two questions are assessed through São Paulo case study that aims to provide a better understanding of policy decisions and, at the same time, promote critical thinking about DRR investments that affect the social and environmental dimensions of urban management. The case of São Paulo is opportune because the city has an institutional structure that provides data on local investments as well as on COVID-19 spatial distribution. Besides, it was published climate risk maps almost ten years before (Young, 2013), which allows a comparison.

In view of the current multiple hazards situation, with growing vulnerabilities exacerbated by COVID-19, we conclude that the planning process requires metrics and indicators to measure progress in responsiveness, which is a challenge because DRR-related metrics aligned with investments do not make part of national statistical systems yet. In this sense, our conclusion was summarized in four main issues that cities will face in becoming years: (1) infrastructure investment will be even more critical after COVID-19, requiring a shift in commitment of political sphere; (2) the spatial distribution of urban facilities needs to be shaped so that the urban structure can be egalitarian; (3) DRR investments cannot be considered only from an emergency perspective, that is, prevention and contingency must be considered; (4) climate change concerns and the proper use of all aspects of sustainability interfaces need to be effectively addressed otherwise responsiveness will be compromised.

2. Background

Sustainable public investment refers to long-term, financing-oriented strategies (Li et al., 2019) that integrate environmental, social and governance factors for effective management with successful results and lower risks (Boffo & Patalano, 2020). COVID-19 has reinforced the sustainability premiss (Sharma et al., 2021) and the interdependence of social and economic systems (van Barneveld et al., 2020, Nicola et al., 2020). However, the efficient management of national and subnational investments is need not only to the current situation but also to give legitimacy to decisions that will impact the future (Shetty, 2020). Local investment is a significant component of responsiveness and most developing countries are suffering severe losses due to deficient structures and lack of investments in infrastructure that affect from informal markets to extensive supply chains (United Nations, 2020; Heggen et al., 2020; Ferrannini et al., 2021).

National and sub-national governments are at the forefront of reaction and the pandemic is an excellent opportunity to show the interconnection between public investments and vulnerability (Bong et al., 2020; Newell & Dalle, 2020; Weible et al., 2020). The pandemic has become a constant concern due to its unfolding (Sannigrahi et al., 2020), bringing up socio-spatial aspects (Liu et al., 2019; Connolly et al., 2020) related to poor living conditions (Das et al., 2021; Herrero and Thornton, 2020; Viezzer and Biondi, 2021) which play a crucial role in the numbers of positive cases and deaths worldwide (Sannigrahi et al., 2020). For example, in Santiago of Chile, poor communities were most affected due to lack of health care, crowded households and inability to work from home during lockdown (Gonzalo et al., 2021). Living conditions and housing precariousness were also predictors of death in Chicago (USA), which disproportionately affected the Afro-Americans (Kim & Bostwick, 2020). In China, city size, population density, healthcare among other factors has a significant impact on pandemic recovery (Chen et al., 2021a). Particularly in Brazil, more than 40% of households do not have access to sewage treatment, 15% (or more than 30 million people) do not have access to treated water (Kuwajima et al., 2020), and the infrastructure stock has a deficit of 61% (Costa & Carrasco, 2020). In the last two decades, public resources have been directed to federal spending at the expense of public investments (Cavalcanlde & Souza Junior, 2018). From 2001 to 2016, we invested around 2% of GDP in infrastructure per year with projects that started and stopped. However, estimates suggest that it was necessary to continuously invest 4% for 25 years to try to get closer of emerging
countries (Frischtak & Mourão, 2018 a,b). In 2020, investment was very low, with only 0.5% of GDP (Costa & Carrasco, 2020), and in 2021, federal government investments reached close to 0.1% of GDP (Karpowitz, Góes, & Garcia-Escrivano, 2018). Due to COVID-19, a gap in accounts will reach a high level with emergency measures spending around $115 billion between 2020 and 2021 (Russi, 2021); despite reporting more than 21,427,073 cases and 596,749 deaths so far (SEADE, 2021d).

At the same time, there is significant convergence between Covid-19 and climate change (Susskind & Vines, 2020). Actually, in few decades the impacts of climate change will be worse (Masson-Delmotte et al., 2021) than pandemic if we do not pay attention to climate-related disasters (Cole & Dodds, 2021). Some studies (Khavarian-Garmsir et al., 2020; Kim & Bostwick, 2020; Khato & Landau, 2020; Manzano & Manning, 2020; Huime, Lidskog, White, & Standring, 2020; Klenert et al., 2020; Thomas et al., 2020; Botzen, Duinjdam, & van Beukering, 2021; Hurliman, Moosavi, & Browne, 2021) have compared the impacts of pandemic with the effects of climate change through deep-rooted vulnerabilities caused by the inadequate urban structures (UCHOA, 2020) that permeate distinct territories (United Nations, 2020). Undoubtedly, cities must respond effectively (Wang, 2021) to anticipate disasters such as Covid-19 and climate change (Ribeiro & Gonçalves, 2019) with investments (Schwartzman et al., 2021) capable of providing mechanisms (Nicola et al., 2020) for prevention with effective technological innovation (Finn and Kobayashi, 2020), closer to what could be recognized as urban smartness (Ahvenniemi et al., 2017; Ahvenniemi and Huovila, 2019; Shorfuzzaman, Shamim Hossain, Mohammed, & Alhamid, 2021) for a more egalitarian framework (Ekenberg et al., 2021).

3. Methodological approach

3.1. People living in disaster-prone areas

We begin by outlining the number of disasters that occurred in Brazil since 2008. The most reasonable way to look at these numbers was considering them with the respective number of people living in disaster-prone areas through IBGE, 2017, IBGE - Instituto Brasileiro de Geografia e Estatística, 2020). It is important to emphasize that the available data were produced by agencies that did not always consider the same period of our analysis. This period was chosen because of the disasters that occurred in Santa Catarina in 2008, which led to some changes of federal policies and actions aimed at climate change and its impacts. Actually, we have many emergencies and calamities in Brazil, approximately 2000 decrees per year, with municipalities that are permanently in emergency situation (i.e., due to hydric stress and droughts). Due to the significant number of cities affected by disasters (i.e., floods, landslides and droughts), we focused on the Southeast and South region (Fig. 1) and selected 45 municipalities located in seven metropolitan regions that were affected by disasters over the past two decades. In addition, cities located in Região Serrana (RJ) and Zona da Mata (MG) were also considered due to events that occurred in 2011 and 2019 respectively.

3.2. Federal transfers and municipal programs

First, we searched and organized the total set of transfers from federal to each municipality. Then, we used ArcGIS to map the proportion of average investments since 2008 to compare the municipalities more and least favoured by disbursement. Although the proportion of investments in the last two years has not been significant, practically only civil defense receives financial resources continuously (i.e., until 2021), as this entity institutionally belongs to the municipal structures. The municipal governments have been taking a range of different measures at different speeds. It is essential to highlight that some projects have finished, some were suspended before the presidential elections (in 2017), and others after the elections (in 2019), which means that most of information finished in 2017 because the investments were not continuous, except for civil defense. Besides, the majority of the federal transfers for DRR occur through the submission of municipal projects (except in the case of emergency situations) which are included in the scope of other public policies. Therefore, we considered the amounts transferred for municipalities that can be classified in the scope of 67 types of actions such as civil defense operations, urban interventions, sanitation, drainage systems management, and others related to implemented policies, plans and projects of infrastructure based on Federal Law 12,983/2014 and the City Statute by Federal Law 10,257/2001.

We categorized these initiatives in nine categories based on Civil Defense operations, Master Plan, Organic Law, Inter-municipal Consortium, Social Zones of Interest, Observatory of Rivers, Atlantic Forest reforestation, Mangrove recovery and Save-Network. The data on mangroves and Atlantic Forests recovery were collected from National Institute for Space Research (INPE) and SOS Atlantic Forest Foundation. The civil defense categories are related to the ability to improve risk information, early warning, and mechanisms to address emergency needs at the community level. We also categorized the number of plans strengthening preparedness for response, emergency and contingency actions coordinated by National System of Civil Defense.

In the case of total federal transfers, we considered the data from National Treasury, which results from the Participation Fund of the states (FPE) and municipalities (FPFM) on the distribution of the Union’s revenue (Internal Revenue System); Royalties (ANP, PEA and FEP); on the Fund for the Maintenance and Development of Basic Education and the Valorisation of Education Professionals (FNDE and FUNDEB); Tax on Industrialized Products and Commercial Exports (adjusted by the Broad Consumer Price Index - IPCA). Information on the monitoring of federal spending on combating COVID-19 was also obtained from the National Treasury to understand how the total transfers are taking place. We compiled information on proportion of average investments comparing the data from IBGE, 2017, National Treasure (2021) and CGU (2021).

3.3. Local sphere: socio-spatial structure and its relationship with disasters

We considered the local approach in an attempt to articulate municipal investments with the effects of urban interventions to describe the physical and social processes that operate at this scale. We refer to São Paulo case to present some aspects about the convergence of pandemic and climate change. This study is a complement to the analysis carried out by Young (2013) from the perspective of federal transfers and municipal investments in DRR. In particular, the advent of COVID-19 stood out as an opportunity since it brought what should be considered the main focus when addressing the impacts of disasters, that is, its direct relationship with the socio-spatial structure. Thus, we considered the intra-urban scale to analyse the spatial structure and update the climate change information (i.e., flood and temperature rise events that can enhance the effects of drought and heat waves). We used ArcGIS to integrate the spatial information by interpolation of the spatial information such as hydrography, land use, topography, precipitation, temperature patterns, by which related known values were used to estimate scenarios based on known or potential situation. The hydrology tools were used to model the flow of water across surface and to identify the flood prone areas. The map of surface temperature was obtained by digital processing techniques of the thermal band of LANDSAT-8 satellite sensor that were obtained at National Institute for Space Research (INPE). The data about the spatial distribution of the apparent temperature was analysed considering the emissivity of the surface (i.e., digital numbers) and thermal contrasts between vegetated and non-vegetated areas. In addition, we obtained spatial clusters of social inequality such as favelas distribution, afro-decedent neighbourhoods, and vulnerability index from State Data Analysis System (SEADE) and Institute of Applied Economic Research (IPEA). The data on
Covid-19 such as number of confirmed cases and number of deaths were obtained from the General Directorate of Epidemiology of the Municipal Health Department. First, we geocoded the data to interpolate local information through the software ArcGIS. Then, we identified the population density (kernel density estimation for a geostatistical approach) for distinct zones through census tract where the surface of population density is estimated from total population counts in each zone. In the sequence, we overlapped the number of afro-descendants’ cases to distinguish the most affected (i.e., the variable related to population deaths were represented by dots and not as a continuous surface).

3.3.1. São Paulo case study

The city of São Paulo is the center of the metropolitan region that encompasses 39 municipalities and 21.9 million inhabitants (IBGE - Instituto Brasileiro de Geografia e Estatística, 2020). With 12,330 million inhabitants, São Paulo city is the largest municipal economy in Brazil. The São Paulo Metropolitan Area (SPMA) is the largest urban conglomeration in South America which consists of urban concentration surrounded by diverse municipalities and counties that are economically integrated by commuting flows. The region is located on the Atlantic Plateau and its elevation (about 800 m) gives it a more temperate climate characteristic. It has a monsoon-influenced humid subtropical climate, with a mild four-season cycle. Most of thunderstorms are associated to South Atlantic Convergence Zone (SACZ) and Intertropical Convergence Zone (ITCZ). During the summer, the city has a mean low/high temperature of about 17/28 °C, and in winter, temperatures tend to range from 11 to 23 °C. In general, the rainfall is abundant, averaging around 1454 mm annually. The metropolitan area consists mainly of functional labor markets, road infrastructure and transport systems with approximately 50% of the population of the state of São Paulo living in this territory (EMPLASA, 2014). During the first year of pandemic, the Gross Domestic Product (GDP) of São Paulo city has increased 0.4% corresponding to US$ 603.4 billion (i.e., 10.6% of national GDP) while the Brazilian GDP decreased 4.1% (SEADE, 2021a). Between 1960s and 1990s, the urban area (i.e., total occupation) has doubled - from 308,000 to 673,000 km². In 1973, it was established the SPMA (by Complementary Federal Law No. 14/73, disciplined by State Complementary Law No. 94/74). In the 1990s the SPMA comprised 1,217.36 km², in 2011 received the current denomination (by Complementary Law No. 1,139/11), and recently has comprised an area of 7,946.96 km² (EMPLASA, 2019). Fig. 2 shows the forecast of urban expansion to 2030 that considered an estimate based on the past growth rates.

4. Results

4.1. Population at risk

At this stage, it was important to observe the data compilation about the number of households and settlements at risk (Table 1). The most significant numbers are located in São Paulo, Rio de Janeiro and Belo Horizonte, which are cities extremely populous and concentrate the headquarters of large metropolitan areas. On the other hand, we can clearly distinguish that most of the less populated municipalities lack updated data, which make more difficult to evaluate the relationship between risks and coping capacities through government investments and local programs. In most cases, substantial prevention in the recent post-disaster period, such as COVID-19, takes place in an absolutely complex and chaotic environment, without adequate plans with anticipation and preparation. This finding gives even greater relevance to disaster prevention strategies because without sufficient data on the municipalities, it is difficult to prove their need.

4.2. Federal transfers and investments in municipalities

The federal government’s priorities are shaped by the legislative and budgetary processes. Therefore, we initially considered the approved budgets of US$ 2 billion for DRR (from 2008 to 2014). After that, despite disaster losses totalling US$46,266,585,433.84 billion between 2014 and 2019, the transfers for disaster recovery (i.e., emergency) were around U
$948,144,952 million, and only a small part of it (US 94,814,495 million) was applied in prevention. In 2019, the amount approved by federal government was US 228,654,684 million, and in 2020, was around US 149,074,505 million, which represents the lowest approved value since 2008. Table 2 presents the total amounts transferred and the amounts invested by municipalities in projects related to DRR from 2008 to 2021. Not surprisingly, current investment varies significantly by municipality, normally based on factors like geographical extension (size), population density and consequent tax collection to revenue. However, some differences result from the willingness of the state to identify and fund needed investments. Overall, federal transfers have been declining as needs have risen and the most common practice relates to allocation of resources in the post-disaster (Montalvão, 2018).

Actually, the city of São Paulo was the only one that recently reported the amount received from 2009 to 2019 to face the impacts of flood events. The city received US 6,740,935 million from federal transfers and more US 4,612,219 million from Federal Growth Acceleration Program. In addition, the municipality has its own urban development fund (Fundurb) which invested a total of US 294,602,428 million divided into US 137,165,375 for urban infrastructure and US 157,437,053 for housing between 2014–2020 (Strobel et al., 2021). The São Paulo state investment was around US 8,869,652 million by transferring part of its state taxes (2%) to municipalities to curb deforestation in 2021 (Law 17,348/2021). The state of São Paulo also spent US 262,468,743 to combat the effects of the pandemic, and São Paulo city invested US 276,722,134 (2020-2021) for the same purpose. Overall, the federal budget and the total amount transferred to emergency response significantly decreased during the pandemic (Table 3).

It is noteworthy that the results in Tables 2 and 3 refer mainly to federal transfers to municipalities while the next sequence of maps refers to average proportion of resources allocated to the different plans, programs and projects implemented by them. The comparison of results highlight that municipalities are facing tight budgets and low financial support, which pose barriers to investment in DRR. The results also show the few projects and programs in disadvantaged areas that should be included through the national coordination and are not. For example, we compared the local investments achieved in different municipalities

### Table 1

| State | Municipality | Population | Population Density | Number of Household | Household at risk (municipal scale) | Population at risk (municipal scale) | Number of hotspots at risk on the intra-urban scale |
|-------|--------------|------------|--------------------|---------------------|-------------------------------------|---------------------------------------|---------------------------------------------------|
| SP    | Rio de Janeiro | 6,718,903 | 5,263              | 5,248,110           | 135,989                             | 444,893                               | 106                                               |
|       | Seropédica    | 82,312     | 276                | 24,772              |                                     |                                       |                                                   |
|       | Nova Iguaçu   | 821,128    | 1,527              | 248,321             |                                     |                                       |                                                   |
|       | Maringá       | 44,468     | 103                | 12                  |                                     |                                       |                                                   |
|       | Quixadá       | 130,319    | 1,822              | 42,241              |                                     |                                       |                                                   |
|       | Rio Branco    | 60,201     | 122                | 17,191              |                                     |                                       |                                                   |
|       | Mococa        | 176,103    | 4,310              | 53,117              |                                     |                                       |                                                   |
|       | Belford Roxo   | 510,906    | 6,031              | 145,743             | 16,655                              | 53,204                                | 44                                                |
|       | Duque de Caxias | 919,598  | 1,829              | 209,577             |                                     |                                       |                                                   |
|       | Niterói       | 513,584    | 3,646              | 169,331             | 11,347                              | 33,822                                | 97                                                |
|       | São Gonçalo   | 1,084,839  | 4,035              | 326,079             |                                     |                                       |                                                   |
|       | Itapevi       | 249,592    | 506                | 69,487              |                                     |                                       |                                                   |
|       | São João de Meriti | 472,406 | 13,024             | 147,516             | 27,165                              | 86,185                                | 87                                                |
|       | Magé          | 245,071    | 585                | 70,465              |                                     |                                       |                                                   |
| RJ    | Teresópolis   | 184,240    | 239,1              | 53,782              | 11,443                              | 45,772                                | 109                                               |
|       | Nova Friburgo | 190,651    | 203,8              | 53,530              | 8,415                               | 33,660                                | 109                                               |
|       | Niterói       | 162,485    | 8,117              | 50,535              |                                     |                                       |                                                   |
|          | Alto Capurú   | 5,847      | 51,1               | 17                  |                                     |                                       |                                                   |
|          | Alto Jequitibá | 8,317     | 54,6               | 2,7                 | 412                                | 1,212                                 | 4                                                 |
| MG    | Belo Horizonte | 2,512,070  | 7,167              | 762,752             | 112,335                             | 389,218                               | 216                                               |
|       | Beirã         | 1,493,340  | 1,102              | 122,693             | 236                                | 733                                   | 4                                                 |
|       | Guarapuava    | 663,855    | 3,066              | 185,046             | 3,859                              | 13,029                                | 48                                                |
|       | Itaí         | 180,204    | 2,190              | 46,285              |                                     |                                       |                                                   |
|       | Lusurgo       | 6,266      | 42,9               | 1,9                 |                                     |                                       |                                                   |
|       | Pedro Bonita  | 7,097      | 38,4               | 1,8                 |                                     |                                       |                                                   |
|       | Simõesia      | 19,633     | 37,6               | 5,4                 |                                     |                                       |                                                   |
| SC    | Florianópolis | 500,973    | 627                | 148                 | 6,780                               | 23,105                                | 22                                                |
|       | Camboriú      | 62,789     | 290                | 80                  | 592                                | 2,366                                 | 7                                                 |
|       | Beja           | 134,723    | 372                | 33                  | 1,939                              | 6,670                                 | 42                                                |
|       | Blumenau      | 357,199    | 595                | 101                 | 24,671                             | 78,371                                | 6                                                 |
|       | Balneário Camboriú | 142,295 | 2,309              | 39,297              | 213                                | 804                                   | 5                                                 |
|       | Içua          | 219,536    | 634                | 58                  | 2,138                              | 7,462                                 | 18                                                |
|       | Ilhota        | 14,184     | 48,8               | 5,8                 | 1,861                              | 6,085                                 | 27                                                |
|       | Jaraguá do Sul | 177,697   | 268,7              | 45,2                | 3,500                              | 12,551                                | 17                                                |
|       | Joinville     | 590,466    | 146,7              | 36,5                | 762                                | 2,555                                 | 22                                                |
|       | Luiz Alves    | 12,859     | 40,1               | 3,1                 | 26                                 | 68                                    | 17                                                |
|       | Navegantes    | 12,859     | 543,3               | 18,6              | 604                                | 2,059                                 | 2                                                 |

Source: IBGE - Instituto Brasileiro de Geografia e Estatística, 2020
Table 2
Summary of federal transfers to municipalities.

| States | Municipalities | Federal transfers based on IPCA from 2008 to 2021 (US$) | Municipal Investments from 2008 to 2021 (US$) |
|--------|----------------|--------------------------------------------------------|------------------------------------------------|
| SP     |                |                                                        |                                                |
|        | São Paulo      | 24,184,729,581                                          | 4,836,946                                      |
|        | São André      | 208,822,818                                              | 41,765                                         |
|        | São Bernardo do Campo | 268,509,994                       | 53,702                                         |
|        | São Caetano do Sol | 175,081,409                     | 35,016                                         |
|        | Santos          | 204,069,641                                              | 40,814                                         |
|        | Guarujá         | 193,228,062                                              | 38,646                                         |
|        | São Vicente     | 225,623,818                                              | 45,125                                         |
|        | Campinas        | 264,333,703                                              | 52,862                                         |
|        | Rio de Janeiro  | 22,065,059,345                                           | 4,412,612                                      |
|        | Senopólis       | 124,961,547                                              | 24,992                                         |
|        | Nova Iguaçu     | 274,762,685                                              | 54,952                                         |
|        | Maringá        | 154,971,890                                              | 30,994                                         |
|        | Queretaro       | 163,734,220                                              | 33,146                                         |
|        | Rio Bonito      | 95,241,120                                               | 19,248                                         |
|        | Maringá        | 191,392,573                                              | 38,278                                         |
|        | Belo Horizonte  | 250,468,195                                              | 46,093                                         |
|        | Rio de Janeiro  | 436,646,062                                              | 87,329                                         |
|        | Niterói         | 1,387,604,746                                            | 277,521                                        |
|        | Rio de Janeiro  | 260,126,376                                              | 52,025                                         |
|        | Itu             | 220,958,145                                              | 44,191                                         |
|        | São João de Meriti | 210,525,162                     | 42,105                                         |
|        | Magé            | 354,851,041                                              | 66,966                                         |
|        | Teresópolis      | 168,661,308                                              | 33,732                                         |
|        | Nova Friburgo  | 110,226,275                                              | 22,043                                         |
|        | Niterói         | 187,549,534                                              | 37,542                                         |
|        | Alto Caparé     | 20,723,250                                               | 4,144                                          |
|        | Alto Jacuí       | 20,551,606                                               | 4,111                                          |
|        | Belo Horizonte  | 1,631,991,215                                            | 326,398                                        |
|        | Belo Horizonte  | 351,998,043                                              | 70,399                                         |
| MG     | Corregem       | 339,514,094                                              | 67,902                                         |
|        | Barueri         | 219,222,775                                              | 43,844                                         |
|        | Itu             | 70,831,681                                               | 4,166                                          |
|        | Pedra Bonita    | 22,087,974                                               | 4,417                                          |
|        | Sinopónia       | 41,935,525                                               | 8,386                                          |
| SC     | Florianópolis   | 354,855,730                                              | 74,971                                         |
|        | Camboriú       | 90,669,563                                               | 18,134                                         |
|        | Itajaí          | 118,197,717                                              | 23,635                                         |
|        | Bauru           | 227,435,434                                              | 45,487                                         |
|        | Palmeário Camboriú | 354,180,818           | 74,856                                         |
|        | Itajaí          | 214,911,480                                              | 42,982                                         |
|        | Ilhota          | 28,182,609                                               | 5,636                                          |
|        | Itajaí          | 179,232,994                                              | 33,846                                         |
|        | Juquehy         | 309,514,306                                              | 61,903                                         |
|        | Itajaí          | 23,554,276                                               | 4,711                                          |
|        | Navegantes      | 74,353,643                                               | 18,870                                         |
|        | Total           | 56,797,030,671                                           | 11,359,406                                     |

Source: IBGE (2017); National Treasure (2021) and CGU (2021)

Table 3
Resources released by the federal government to pandemic emergency.

| Emergency expenses with COVID-19 | 2020 | 2021 |
|----------------------------------|------|------|
|                                  | Budget | Paid | Budget | Paid |
| Emergency Assistance to Vulnerable People | 12,328,244,274 | 8,454,198,473 |
| Emergency Assistance Family Grant | 7,061,068 | 7,061,068 |
| Emergency Assistance Maintenance of Employment and Income | 2,227,099,236 | 1,440,839,694 |
| Financial Assistance to States and Municipalities | 14,933,206,106 |
| Granting of Financing Payroll | 1,299,618,320 | 1,299,618,320 |
| Transfer to Energy Development Account | 173,664,122 | 173,664,122 |
| Quota of Operation and Credit Guarantee Funds | 2,227,099,236 | 1,440,839,694 |
| Total | 15,112,595,419 | 14,933,206,106 |

Source: National Treasure (2021)
Fig. 3. Proportion of public investments in São Paulo state from 2008 to 2021.

Fig. 4. Proportion of public investments in Rio de Janeiro state from 2008 to 2021.
of São Paulo state (Fig. 3) and from public intervention perspective, the municipalities were considerably affected by investments in civil defense and emergency plans with less focus on contingency measures. In general, local authorities played an important role in implementing changes in master plans, prioritizing urban interventions with corresponding areas of social interest (e.g., through Growth Acceleration Program). The municipalities of São Paulo, Campinas, São Caetano and Santo André have accomplished large investments in urban drainage systems supervised by projects such as the Observatory of River. Likewise, Santo André, São Caetano do Sul and São Bernardo do Campo also made an effort to invest in infrastructure through an intermunicipal consortium as a way to meet the local demand for macro-drainage and solid waste management. Particularly, São Bernardo has implemented plans based on structural actions such as housing, sewage and drainage system that has been supervised by civil defense since 2013. In the same way, São Caetano updated its urban guidelines for improvement of social vulnerability in medium term (i.e., better social capital indicators, household income, and local infrastructure).

The municipalities of Baixada Santista Metropolitan Area such as Santos and São Vicente have consolidated policy frameworks and urban planning systems with focus on preparedness that are amongst the best of Brazil. Nevertheless, significant investment is needed to monitoring and evaluate the implemented actions. For example, heavy rains caused flooding, landslides, and deaths in March, 2020. About 17% of population is still living in favelas, and the situation is worse in Guarujá, where the most vulnerable populations live in landslide prone areas (about 30 hotspots). Despite the problems, this is one of the regions on the coast that has massively invested in the forest and mangrove recovery in the last 20 years. The reforestation processes in Santos and São Vicente on the coast, and São Bernardo on top of the mountain are related to forest recovery associate to preservation measures.

Fig. 4 shows the proportion of measures achieved by municipalities of Rio de Janeiro state. In this case, the municipalities were also considerably affected by investments in civil defense and emergency plans with less focus on contingency. On the other hand, projects such Save-network (developed by Rio de Janeiro state) appear in the list of most popular projects. The majority of municipalities has invested in master plans but with less emphasis on areas of social interest and drainage systems. For example, around 24% of the population of Rio de Janeiro still live in favelas without adequate sewage and water supply. The municipalities of Rio Bonito, Itaborai, Queimados, and Seropedica require specific drainage systems which further limit the prevention of disasters (i.e., most flood mitigation interventions are characterised by grey infrastructures that are inappropriate for heavy rains). Besides,
only two municipalities participate of intermunicipal consortium, and surprisingly, few municipalities invest in reforestation and mangrove recovery.

Fig. 5 summarizes the proportions of measures achieved by municipalities of Minas Gerais. In general, the municipalities present master plans and organic laws supporting the land use regulation. However, most of them have invested less in civil defense, emergency and contingency plans when we compare with previous states, which means that they can be less prepared to face disasters. Two municipalities participate in inter-municipal consortia but practically all municipalities do not seem to invest in forest recovery, including the municipalities located in the Zona da Mata.

Fig. 6 summarizes the proportion of measures achieved by municipalities of Santa Catarina. The maps highlight investments in civil defense and emergency but with less emphasis on contingency measures. Practically, all the observed municipalities present master plans with areas of social interest. We can see that Florianópolis, Blumenau and Itajaí are engaged in municipal consortium projects. In particular, the municipality of Joinville was involved in mangrove recovery as a measure to prevent sea level rise that would positively affect the estuary and interconnected rivers. Although during the period of analysis some municipalities appear on the maps as involved in forest restoration, the Atlantic Forest and mangrove recovery projects are outdated due to lack of funding.

4.3. Local-scale approach through COVID-19 distribution analysis

When we approach the local scale, the results about São Paulo city reveal that there is a long way for improving DRR. For instance, the poorest has faced significant challenges during the peak of the pandemic, which can be noted through urban living conditions and when we observe the numbers of Covid-19 cases. From March 11, 2020 to April 7, 2021, São Paulo city have registered 23,222 deaths and 642,322 confirmed cases, with a crude death rate around 188.34 deaths per 100 thousand inhabitants (SEADE, 2021b). It was one of the worst moments of pandemic (Kafruni, 2021; Watanabe, 2021) when the lethality rate among white people was 4.3% and among afro-descendants was 8.1%, showing that the curve of afro-descendants was markedly pronounced, especially among men (Fig. 7).

The situation is particularly critical because São Paulo has a significant number of favelas, around 1715 locations registered by the Municipal Housing Secretariat, that is, one in six people live in the favela (SEHAB, 2017). They represent more than two million inhabitants, which is equivalent to 16.2% of total population. Half of residents live in precarious conditions and many houses do not have access to a continuous water supply and sanitation system (IBGE - Instituto Brasileiro de Geografia e Estatística, 2020). In fact, these settlements are home to large proportions of population, such as Paraisopolis (with 100,000 dwellers and 42,800 favelas), Heliopolis (200,000 dwellers and 41,100 favelas), Campo Limpo (216,098 dwellers and 59,483 favelas), M’Boi Mirim (216,098 dwellers and 42,350 favelas) and Cidade Ademar (248,215 dwellers and 25,468 favelas) in the south zone. The other
Fig. 7. Number of COVID-19 cases in the city of São Paulo in April 2021.

Fig. 8. Distributions of favelas, proportion of afro-descendants, and social vulnerability.
neighbourhoods are Sapopemba on the east side (with 296,042 dwellers and 18,273 favelas), Freguesia do Ó (264,000 dwellers and 1,915 favelas) and Brasiliândia (280,069 dwellers and 24,708 favelas) on the north side.

When we look at the number of favelas on the map (SEADE, 2021c) and the socio-environmental vulnerability based on the Atlas of Vulnerability (IPEA, 2016), we find out that the south and east zones of São Paulo coincide predominantly with afro-descendant neighbourhoods (Fig. 8). For example, the percentage of afro-descendants in Campo Limpo is 57.1% while in M’Boi Mirim is 56%, followed by Cidade Ademar (54%). Pinheiros and Vila Mariana, considered upper and upper middle class neighbourhoods, present 7.3% and 7.9% of afro-descendants.

In relation to population density (Fig. 9), around 2,162,368 people live in a territory of 30 square kilometres. Population density is higher on the outskirts of the city and gradually decreases towards the city centre (i.e., Sé square). In the southern zone, some areas have population densities that exceed 18,000 inhabitants/km². We observed that the number of afro-descendant deaths were high in denser and peripheral neighbourhoods (around 62%).

4.4. Climate change and COVID 19: an intrinsic spatial issue

The results showed that the areas susceptible to flood events (Fig. 10):
represent approximately 250 km$^2$. In fact, heavy summer rains are more concentrated causing flash floods, so that even when heavy rains reach the metropolis, little is absorbed because the urban spatial structure is completely sealed off. Most of these areas are located in neighbourhoods inhabited by the poorest populations which contain a significant number of afro-descendants. As we can see, there are interesting links between the areas normally affected by floods and Covid-19, especially when compared to the Afro-Brazilian death map.

Likewise, when compared to the hottest areas of the city (Fig. 11), they also have a close connection to COVID-19. During the urban expansion process, the areas located along the main rivers were transformed into road axes that became extremely occupied, sealed, and polluted because they constitute the main commuting links between the suburbs and central areas. Recently, the forecast point to a drought of great proportions (Voiland, 2020; Patel, 2021) which will affect several reservoirs in the Parana River basin connected to Tiete River located in the metropolitan area of São Paulo (MASP). The projections indicate a likely increase in the frequency occurrence of severe hydrological droughts and a likely reduction in the occurrences of wet hydrological years (Mello et al., 2021). With rainfall below the annual average, the possibility of Cantareira and Billings (the largest water reservoirs of MASP) drying up in early 2022, raises questions about what can still be done by the government in such a short period. Most of the measures that take time to complete depend on investments, especially in a scenario where droughts last longer due to climate change (Mello et al., 2021) and affect mainly and primarily the poorest areas.

5. Discussion

This study innovates by facing the challenge of drawing a quantitative overview of federal transfers to understand the principles and practices of DRR investments. Even more challenging was the attempt to identify, categorize and systematize the list of municipal investments since many projects start and end at different periods, and most projects that are still in progress do not undergo a review. As highlighted in the 2030 Agenda for Sustainable Development and the Sendai Framework, a sustainable urban process must specify the principles of integration by understanding the nature of disaster risk (Bello et al., 2021). This approach opens the way for new lines of research and planning before, during and after a disaster. In the study carried out ten years ago, we had no way of measuring DRR as there were no federal policies and investments. For this reason, we used GIS tools to improve accuracy and spatiotemporal resolution in order to identify disaster prone areas in MASP by analysing the interaction of urban expansion with environmental hazards (Young, 2013). Almost ten years later, the results show that the vulnerable areas are practically the same but now we have a potential convergence of multi-hazard disasters.

When we compare the social structure, spatial distribution of population, and disaster risks, a significant question arises: How the most exposed areas should be reassessed and reconsidered in the composition of federal transfers and public investments? COVID-19’s spatial effects analysis highlighted the critical nature of investments that did not consider responsiveness as an essential input to meet unexpected disasters. Particularly, urban planning based on outmoded perspectives, i.
e., poor infrastructure, lack of sewage, no equal water supply, and no egalitarian access to technological improvements along with social exclusion (racial, gender, indigenous rights) requires attention. There was no significant change in urban spatiality that could reverse socio-environmental vulnerability. For example, the logic established in the São Paulo master plan (from 2014) tended to favour the concentration of the population in dense areas called tertiary sector centralities where the road axes were already consolidated by the large flow of people (home-work-home) without significant changes in the mobility forms like walkable or bike-friendly cities (Fortes, Soares, Alves, & Giannotti, 2021). Although there has been an increase in civil defense and citizens participation in the master plans that reflected in transfers of resources to areas of social interest, the master plan has focused on identifying risk areas with less attention to prevention or contingency measures as a whole. The environmental sustainability is also less addressed (e.g., reforestation, observatory of river). As we observed, the São Paulo case is not unique as the implementation of DRR policy measures is critical, especially when federal transfers are scarce (Montalvão, 2018) and municipal investments take different forms that need continuous evaluation of their effectiveness (e.g., the redistribution of real estate gains acquired by the São Paulo Urban Development Fund through an onerous grant) (Strobel et al., 2021; Maglio, 2021).

More than ever, we need to adjust each of the interventions to the appropriate level (Chen et al., 2021b), otherwise we will make even bigger mistakes as poverty increases with the pandemic (Martin et al., 2020) and with climate change (Kienert et al., 2020). Actually, by maintaining spatial standards based on the real estate market and not focusing investments on disaster prevention (Montalvão, 2018) the plans end up being a potential source of vulnerability as existing inequalities increase (Asayama et al., 2021). The study breaks new ground by pointing that the effects of the pandemic and climate change can increase threats with the potential to break support boundaries, which can lead to cascading collapse. The collapse of health system can be aggravated by drought and hospitals can become overwhelmed again (e.g., new strains can evolve together with respiratory diseases). The lack of water and energy can also affect the performance of the health system and paralyze the industrial production, including the food chain. In fact, we must recognize that there can be a leap in the scale of the problems with even greater loss of jobs and income with people being evicted on the streets. Both effects are risk multipliers because threats such as food insecurity and inflated prices can appear quickly. Furthermore, both effects depend on up-to-date data (Sharifi et al., 2021) as time series are insufficient and the occurrence distributions change rapidly as problems increase.

Actually, the threat of a long period of drought in southeastern region (Mello et al., 2021) comes at distinguished time, when demand for more urban smartness advances (Ahvenniemi and Huovila, 2019) and nature-based solutions (Young et al., 2019; Shorfuzzaman, Shamim Hossain, Mohammed, & Alhamid, 2021) is increasingly expanding (Solecki et al., 2019). This demand requires additional attention to DRR to meet investment (Solecki et al., 2019; Bello et al., 2021). It was distressing to think about the financial support that Brazilian hospitals needed during the peak of the pandemic and did not receive from the federal government (Alves, 2021). More frightening is thinking about
the lack of federal support to prevent the forest fires that proliferate in Brazilian regions (Pivello et al., 2021), including São Paulo and Minas Gerais states. Indeed, the state of São Paulo is urgently transferring part of its state taxes to municipalities to curb deforestation since March (Law 17,348/2021). However, even if the summer rains are heavy, investments will be insufficient to avoid water stress next year as the absorption of rain has been compromised by the absence of vegetation (Mello et al., 2021). This pointed to a tension between short-term and long-term measures since the current situation will not be reversed with isolated and immediate measures as the federal sphere insists.

6. Conclusion

As we could verify, there are policy space for urban smart development if we consider where infrastructure can play a significant role to reduce vulnerability spatial distribution. The Brazilian DRR measures and the potential convergence of COVID-19 with climate change can lead São Paulo city to face many challenges. Urban density itself is not a good health predictor but it can be when associated with poverty, poor sanitation conditions, limited access to work/education and lack of medical care. When physical space is limited due to the spatial mode of production with an uneven development structure, total infections and mortality tend to be higher because social distance becomes impossible.

In this sense, contingency projects can be a way to incorporate uncertainties into plans, anticipating demand and providing flexibility for municipalities to adapt quickly in stressful times. This can be also useful tool to address with disastrous events, avoiding disruption of supply chains and facilitating access to essential services and goods. The links between organization, management and performance with urban smartness can be transferable to urban planning if they are carefully evaluated and understood but any planning process requires indicators to measure progress toward specific goals. Besides, the evaluation of DRR measures by standardization and control of undesirable variation in both quality and cost of alternatives can facilitate access to investments, encouraging new forms of services and creating new job positions at a time that there are great uncertainties about the trends for the coming years.

We need to act quickly as the instability caused by the pandemic has increased the constraints on the government’s own financial capacity, which has been aggravated by the continued fragmentation between the national and subnational spheres that is leading to the erosion of responsiveness. The idea that the risks posed by climate change seem too far away to matter is wrong. There is no justification for reducing investments in contingency, prevention, and adaptation measures as climate impacts will be far more far-reaching than the pandemic. Nevertheless, capturing these opportunities will require a shift in long-term socioeconomic strategies without underestimating climate risks and without forgetting that vulnerability is dynamic. For instance, the lack of resilience metrics and indicators; the distorted configuration of responsiveness; diluted funding with a lack of systematic and ongoing programs to enforce standards, measure costs, and ensure quality through a network of integrated digital platforms; have resulted in a lack of systematic and ongoing long-term measures since the current situation will not be reversed with isolated and immediate measures as the federal sphere insists.

Declaration of Competing Interest

The author(s) declare(s) that they have no competing interests and all authors have approved the manuscript for submission”. We also confirm that the content of the manuscript has not been published or submitted for publication elsewhere. All data generated or analysed materials (including its supplementary information files) are included in the article.

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