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CONNECTING COVID-19 AND CLIMATE CHANGE IN THE ANTHROPOCENE

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ABSTRACT

1. MOTIVATION

RESEARCH GAP:

Research and policy overlook the influence of urban development in vulnerability to climate and health crises, increasing the unintended, unjust, and negative outcomes of adaptation (i.e. maladaptation).

RESEARCH QUESTION AND HYPOTHESIS:

Research question

- What is the system of connections between urbanisation and risk exposure in the Global South cities in the Anthropocene?
- Are there urban populations in SP (BR) vulnerable to both the COVID-19 pandemic and climate change? Which factors influence this vulnerability?

Hypothesis

- H1: Areas lacking human development include vulnerability factors that are common to climate change and COVID-19.
- H2: Urban hot spots of these factors coincide with greater COVID-19 fatality rates in a megalopolis of the Global South: São Paulo.

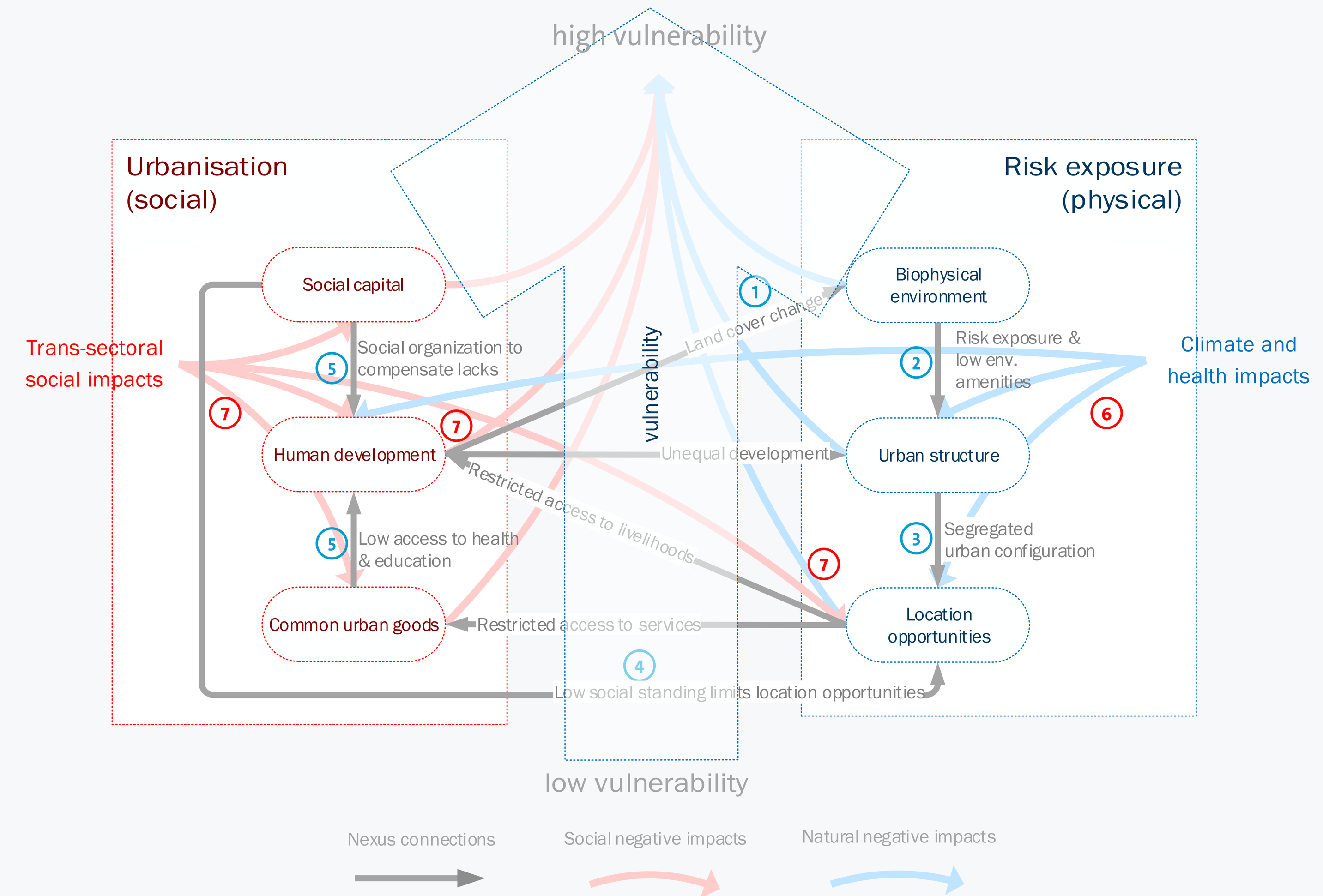
A NEXUS BETWEEN URBAN DEVELOPMENT AND RISK EXPOSURE

Urban development dynamics

1. Social demand drives urbanisation via the land market.
2. Unequal urban development.
3. Spatial opportunities with more/less exposure.
4. Segregated access to infrastructure, institutions, and services.
5. The cycle repeats, with feedback mechanisms (non-linearity).

Urbanisation interact with hazards:

6. Climate and health impacts interact with the unequal development: Vulnerability often matches exposure.
7. Location and human development are key to exposure.
8. Trans-sectoral impacts amplify and prolong effects.



2. METHODS

Mixed-methods approach:

- Thematic analysis (qualitative): seeks patterns comparing groups, adequate for mixing methods.
- Hot spot analysis (Getis-Ord Gi*, quantitative): spatial concentration of high/low values, iterative model returns confidence intervals of multiple specifications (ArcGIS Pro).
- Survival analysis (KME & Cox, quantitative): calculates probability of association over time with no other assumptions. Results validated with Cox proportional hazard model.
- Methods are mixed (quali > quanti > quanti) and analyses are trans-scalar (local > intra-urban > national to intra-urban).
- Mixing seeks robustness in detecting association between factors when the causation is ellusive.

Data:

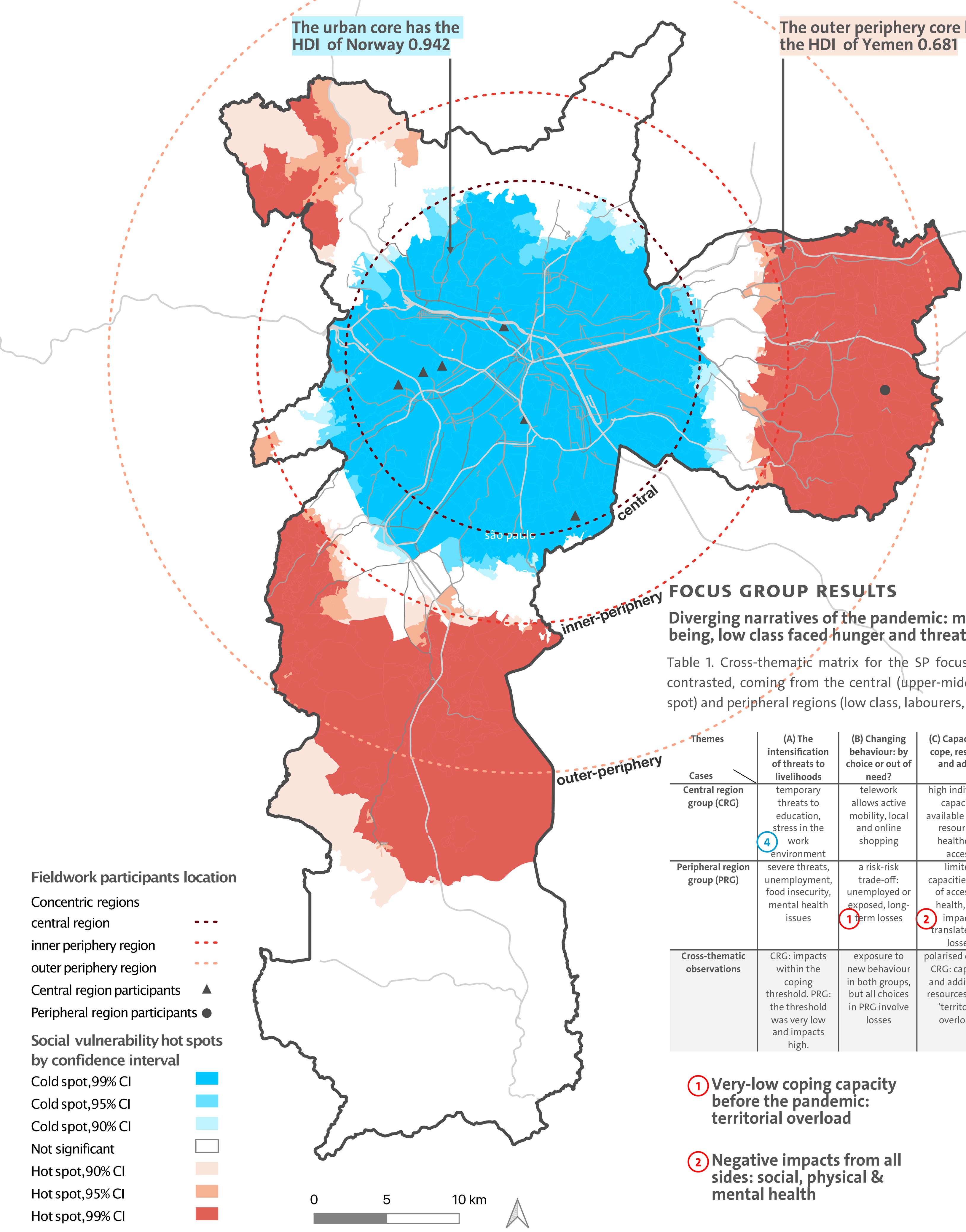
- Fieldwork in São Paulo (03.2022): 2 regions, 18 participants.
- Authoritative COVID-19 micro data (n = 1,948,601).
- Social vulnerability & Human Development Indices (IPEA, 2015).

www.covidgi.uni-hamburg.de
github.com/alexandrepereiraarq/urb_exposure_nexus
alexandre.pereira.santos@uni-hamburg.de
twitter.com/macuonline

3. RESULTS

SÃO PAULO: CITY OF RINGS

Figure 1. Social vulnerability hot (red) and cold (blue) spots in São Paulo (data from social vulnerability index based on the 2010 census). This map updates the famous "Bellndia" (Belgium+India) model by Edmar Bacha to "NorMen", showing the stark contrast of opportunities offered depending on where one lives. Place, in this case, associates social and environmental factors that couple higher exposure to lower resistive and recovery capacity to multiple hazards.



FOCUS GROUP RESULTS

Diverging narratives of the pandemic: middle class improved well-being, low class faced hunger and threat to their lives.

Table 1. Cross-thematic matrix for the SP focus groups. Focus group participants contrasted, coming from the central (upper-middle class, intellectual in a SVI cold spot) and peripheral regions (low class, labourers, in a SVI hot spot).

Themes / Cases	(A) The intensification of threats to livelihoods	(B) Changing behaviour: by choice or out of need?	(C) Capacity to cope, respond and adapt	(D) New opportunities/ factors of resilience	Cross-case observations
Central region group (CRG)	temporary threats to education, stress in the work environment (4)	telework allows active mobility, local and online shopping	high individual capacity, available family resources, healthcare access	new habits increase well-being, resources to seize opportunities (3)	Negative impacts were temporary, long-term improvement
Peripheral region group (PRG)	severe threats, unemployment, food insecurity, mental health issues	a risk-risk trade-off: unemployed or exposed, long-term losses (1)	limited capacities, lack of access to health, and impacts translate into losses (2)	reduced resilience, but community organisation is a (new) lifeline	Long-lasting adverse effects hinder the development
Cross-thematic observations	CRG: impacts within the coping threshold. PRG: the threshold was very low and impacts high.	exposure to new behaviour in both groups, but all choices in PRG involve losses	polarised coping, CRG: capacity and additional resources; PRG: 'territorial overload.'	seizing opportunities needs resources, leading to increasing inequality	

(1) **Very-low coping capacity before the pandemic: territorial overload**

(2) **Negative impacts from all sides: social, physical & mental health**

(3) **Changes provided opportunity to build-back better**

(4) **Problems were temporary, life improved overall**

KAPLAN-MEYER ESTIMATOR

Cross-scale analysis shows contradictions: COVID-19 variability in the intra-urban scale is not explained by SVI alone.

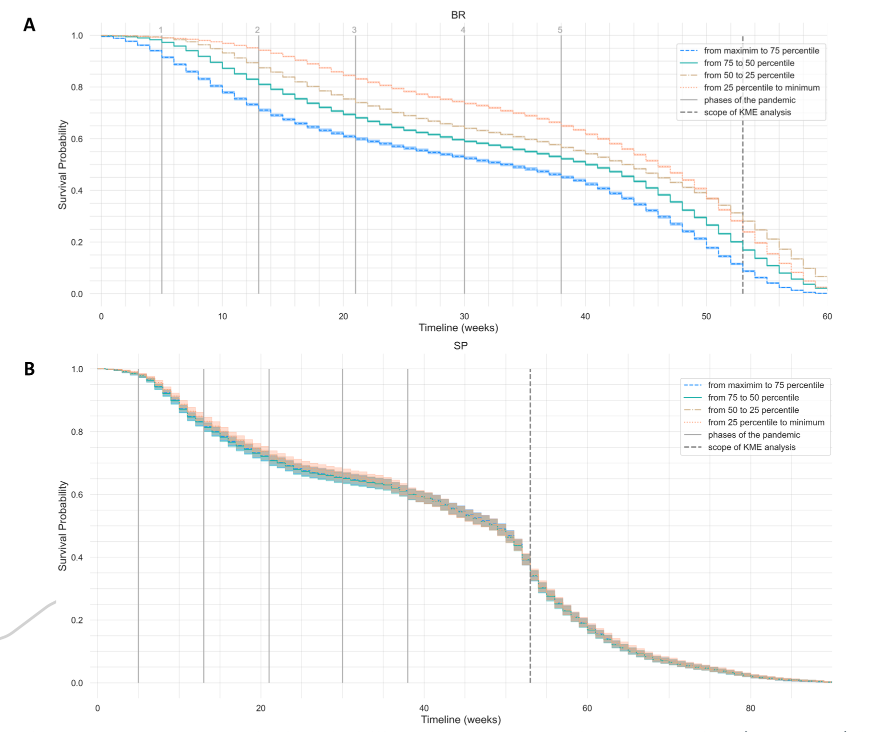


Figure 2. COVID-19 survival probability curves, grouped by SVI quartiles (60 weeks) for (A) 5,570 Brazilian cities; and (B) 5,970 census districts in São Paulo. Survival probability is lower in high-vulnerability cities (A), with no clear pattern at the intraurban scale (B), showing complexity and spatial unit problems (MAUP). Source: authors; data: IPEA (2015), Brasil.io (2021).

SPATIAL COINCIDENCE OF COVID-19 AND SVI

COVID-19 deaths peak first and stay more concentrated in the outer periphery. The core-periphery pattern partially explains fatalities.

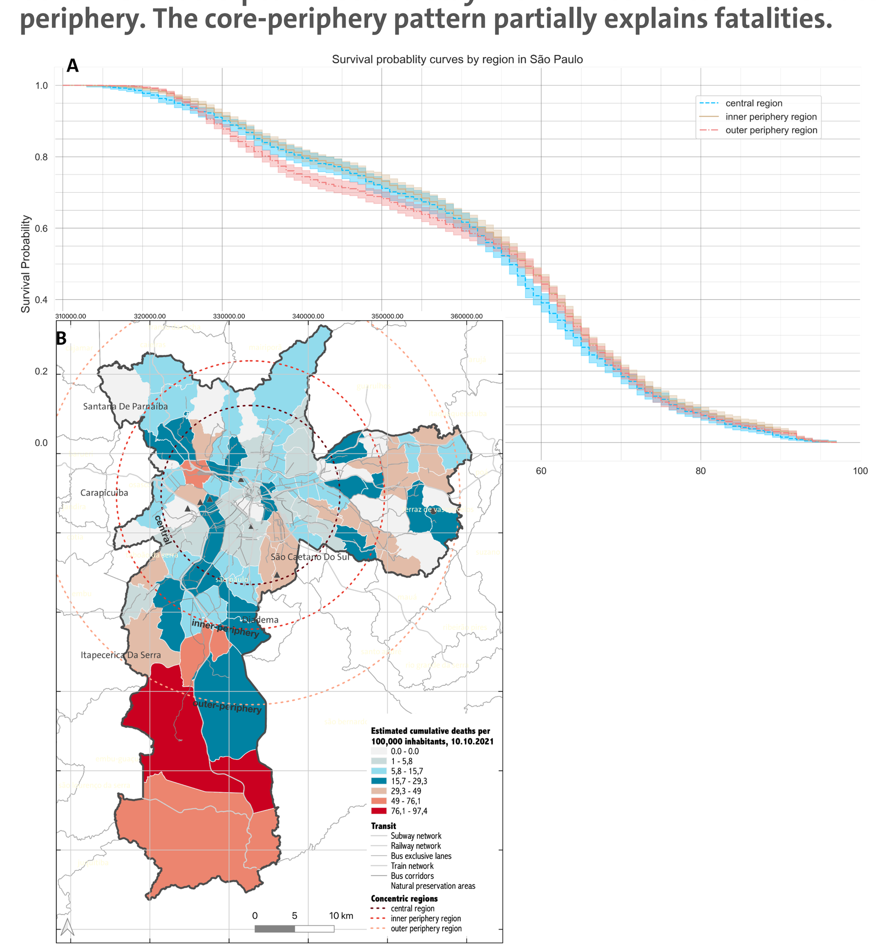


Figure 3. (A) Survival probability curves for 5,970 census districts grouped by the rings from Fig. 1 and (B) COVID-19 cumulative deaths per 100.000 inhabitants in the SP census districts on 10.10.2021

4. DISCUSSION

- Evidence for H1 in the qualitative common factors between health & climate crises and H2 in hot spots & KME, as high-vulnerability areas had more fatalities.
- This interdisciplinary approach demonstrates the nexus components (e.g. human development, urban structure) & the nexus connections (e.g. unequal development, access to common goods).

LIMITATIONS

- The nexus is not fully mapped. Interaction lacks hierarchy and quantification of influences.
- Methods do not exclude alternative explanations nor uncertainty.
- The mixing of methods should be evaluated more systematically.

However, multiple analytical scales, spatio-temporal data, and interdisciplinary combinations of evidence avoid 'monolithic assumptions' and improve robustness.

INNOVATIONS & INSIGHTS

- Widening gap in resilience (urban core versus peripheral group).
- Social status and location choice converge – exposure and response capacity match and increase vulnerability.
- Geographic differences in COVID-19 deaths aligned with social determinants of health (SDOH) and social vulnerability.
- Need for research: deviant patterns in KME (e.g. MAUP, or behaviour).

MAIN REFERENCES

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- Cinner, J. E., et al. (2018). Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change*, 8(2).
- De Koning, K., & Filatova, T. (2020). Repetitive floods intensify outmigration and climate gentrification in coastal cities. *Environmental Research Letters*, 15(3).
- Pelling, M. (2003). *The vulnerability of cities: natural disasters and social resilience*. Earthscan.

5. CONCLUSIONS

- Intersectoral and social consequences from systemic crises disproportionately affect the most vulnerable.
- Crises may interact, overlapping responses and adaptation. Under limited resources, they may widen social and vulnerability gaps.
- Health and climate adaptation need to account for contextual, societal and subjective factors and avoid over-generalisation and 'one-size-fits-all' measures to minimize maladaptation.

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CONNECTING COVID-19 AND CLIMATE CHANGE IN THE ANTHROPOCENE

EVIDENCE FROM URBAN VULNERABILITY IN SÃO PAULO

EGU session *Climate Extremes & Risk: impacts, nature-based disaster risk reduction and climate adaptation*
on-site poster X3.79 | EGU23-17315

Alexandre Pereira Santos
Prof. Dr. Jurgen Scheffran
Dr. Juan Miguel Rodriguez

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CITIES IN THE
ANTHROPOCENE

Research gap:

- Research and policy overlook the influence of urban development dynamics in vulnerability factors to climate and health crises.
- This increases the unintended negative outcomes of adaptation (i.e. maladaptation).

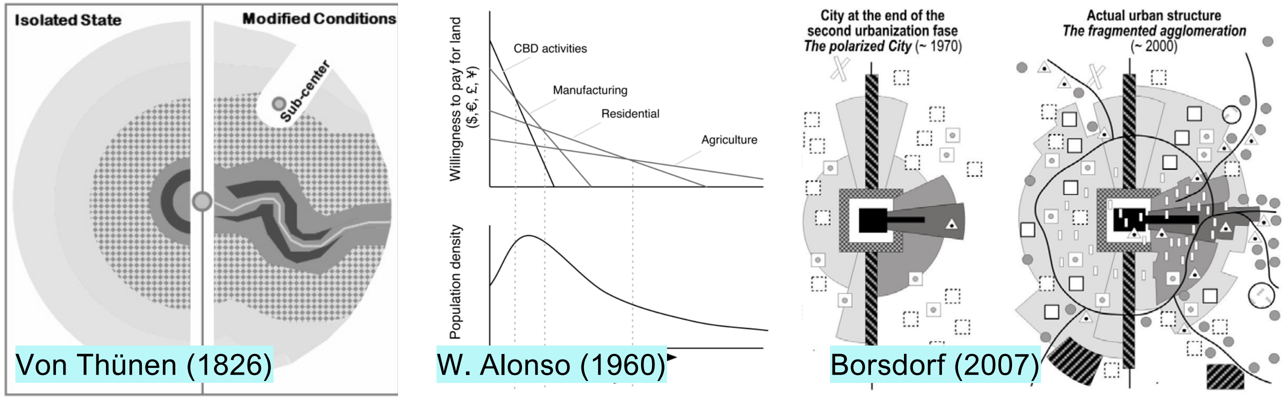
Unequal urban development interacts with hazards directly (e.g. exposure) and indirectly (e.g. access to services and support).

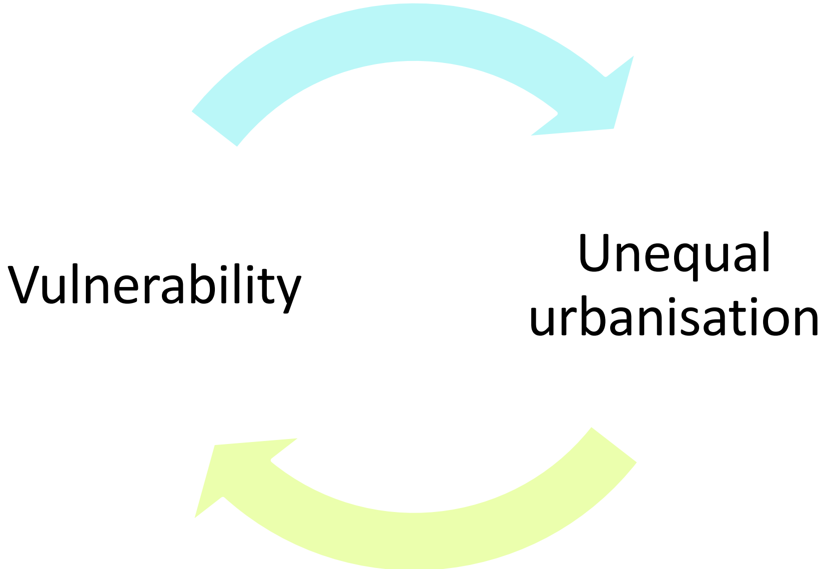
CITIES IN THE ANTHROPOCENE

- Vulnerability is the incapacity to avoid or cope with the harmful effects from a hazard.
- Urbanisation dynamics or urban development dynamics are the processes of urban expansion, densification, verticalization, and reconstruction.

CITIES IN THE ANTHROPOCENE

- Unequal development
  - Urban expansion, verticalization, and redevelopment follow market interests.
  - Advantages of agglomeration and social inequality lead to segregated distribution of jobs, wealth, and infrastructure.
- Why Brazil?
  - Highly urbanised & unequal
  - LAC may offer lessons to African or Asian cities





Sources: Abramo, 2012; Bógus, & Taschner, 1999; Borsdorf, Hidalgo, Sánchez, 2007; Gilbert & Gugler, 1984; Harvey, 2006, Pereira, et al. 2020.

Urban development and compound effects of hazards

- Unequal spatial development patterns interact with the biophysical environment in which it takes shape.
- Power asymmetries, social norms, and political relations skew infrastructure and adaptation measures distribution.
- More affluent households buy access to safe locations, pushing prices and excluding the socially vulnerable to exposed areas.
- Informal settlements combine high exposure with social or ethnic exclusion, low-quality or non-existent infrastructure, little tenure security, and restricted access to resources and services.

References: Cinner et al., 2018; Henrique & Tschakert, 2021; De Koning & Filatova, 2020; Harvey, 2006; Pelling, 2003.

Risk response motivation and capacity is a key driver of response, but not the only one:

- Empirical evidence of settling in exposed locations contradicts perfectly rational decision making based on risk perception.
- Location choice may be influenced by accessibility to economic opportunities, relative tenure stability, and strong social and family ties, for instance.
- Risk–risk trade-off: either accept risk to improve access to jobs and services or seek locations far enough to be cheap but risk social exclusion.
- Risk perception is necessary for response, but response capacity largely determines the choices available and the perceived efficacy.

Reference : Harvey, 2006; Janoschka, 2002; Wheaton, 1982; Abramo, 2012; Barros, 2012; Gilbert & Gugler, 1984; Bubeck et al., 2012; Lo et al., 2015.

The problem of poverty–vulnerability traps

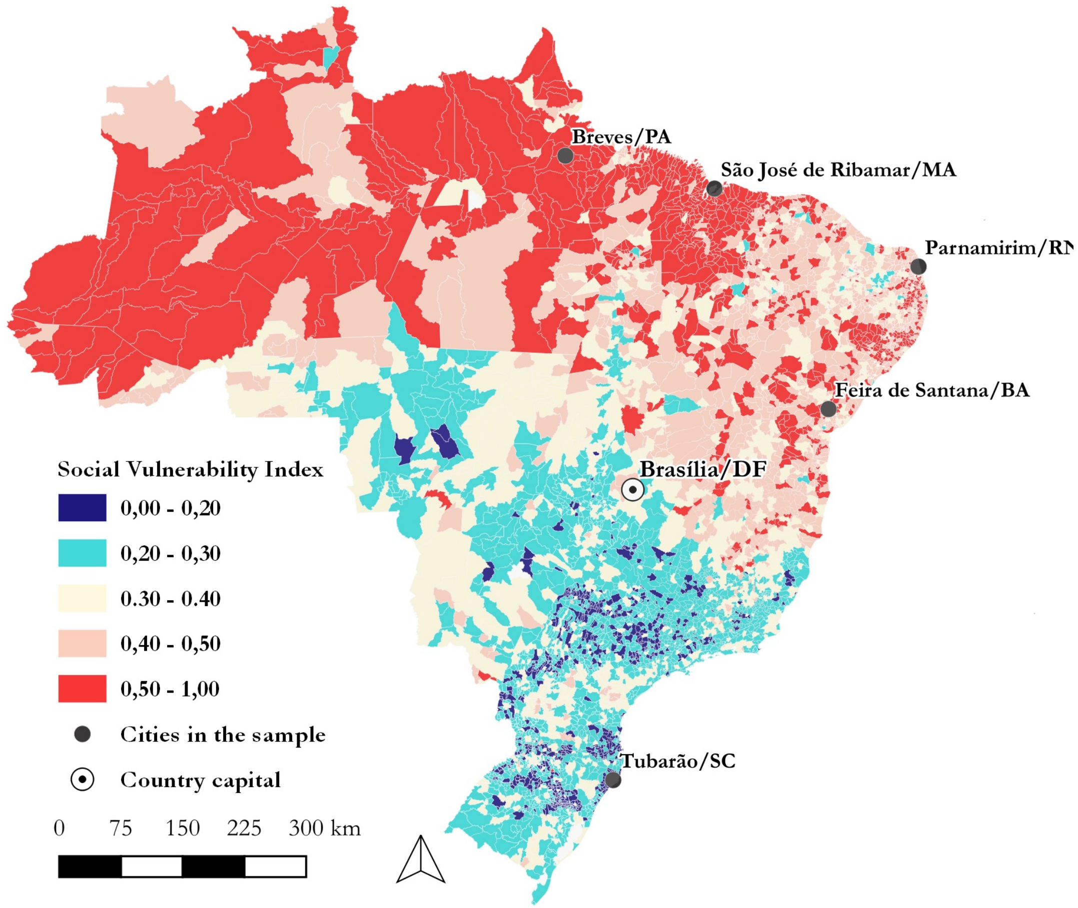
- Location choice may lead households to flood-prone areas.
- Tenure, kin relations, social networks, a familiar context, and economic opportunities are frequent factors.
- Evolving risk profiles may worsen exposure over time, offering an unfair trade-off between leaving (starting over) or staying under risk.
- Repeated hazards may sap resilience cyclically, impoverishing families, decreasing response capacity, and increasing vulnerability.
- Market regulation may lead to climate gentrification or poverty-vulnerability traps.

References: Hardoy & Pandiella, 2009; Hjälm, 2014; Penning-Rowsell et al., 2013; Abramo, 2012; Boubacar et al., 2017; Henrique & Tschakert, 2021; Pelling, 2003.

PREVIOUS RESEARCH & CONTEXT

COVID-19 and social vulnerability in Brazil:

- Brazil is highly unequal and hierarchical
- We use survival analysis to analyse the connection of COVID-19 fatalities and structural social vulnerability
  - Kaplan-Meier estimator.
  - Cities in the social vulnerability index (SVI) distribution.



Reference : Collet, 2003; Costa & Margutti, 2015; Brasil.IO, 2021; M. C. Castro et al., 2021; Nicolelis et al., 2021.

PREVIOUS RESEARCH & CONTEXT: *ONE YEAR OF THE COVID-19 PANDEMIC IN THE GLOBAL SOUTH: UNEVEN VULNERABILITIES IN BRAZILIAN CITIES*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Article details

One year of the COVID-19 pandemic in the Global South: Uneven vulnerabilities in Brazilian cities

Alexandre Pereira Santos, Juan Miguel Rodriguez Lopez, Katharina Heider, Laszlo Steinwärder, Jürgen Scheffran, Julio Celso Borello Vargas

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PREVIOUS RESEARCH & CONTEXT:

One year of the COVID-19 pandemic in the Global South

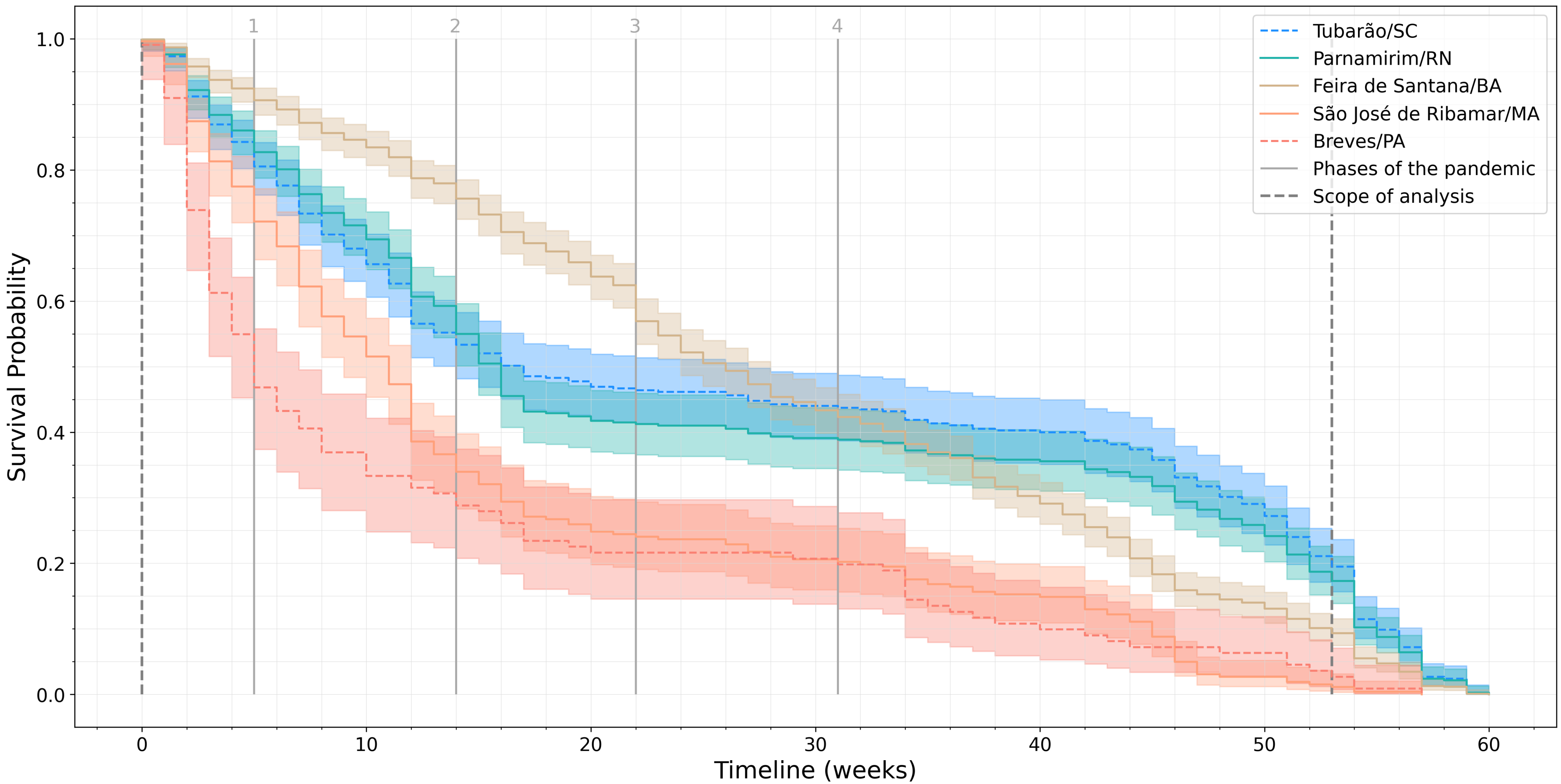
- Gap: COVID-19 vulnerability definitions come from the Global North, lacking contrast in socioeconomic factors (env. and demographic).
- Question: How do different degrees of vulnerability among Brazilian cities lead to varying survival probabilities of their populations in the COVID-19 pandemic?
- H: The population in more vulnerable cities had lower probabilities of surviving COVID-19 during the first year of the pandemic.

References: Nicolelis et al., 2021; Candido et al., 2020; M. C. Castro et al., 2021; S. L. Li et al., 2021.

Table 3-1. Descriptive statistics for the cities in the sample.
Source: authors, based on data from IPEA (2015).

City name/State	Population (2020)	SVI score	Approximate SVI quantile	Accumulated COVID-19 cases (24.02.2021)	Accumulated COVID-19 deaths (24.02.2021)
Tubarão/SC	106.422	0.121	Min. value	14,062	218
Parnamirim/RN[3]	267.036	0.247	25%	16,051	256
Feira de Santana/BA[3]	619.609	0.336	50%	29,106	498
São José de Ribamar/MA[3]	179.028	0.449	75%	1,748	151
Breves/PA[3]	103.497	0.603	Max. value	3,578	102
Brazil	211,707,713	0.326	Mean	10,438,360	253,372

PREVIOUS RESEARCH & CONTEXT
SURVIVAL PROBABILITIES FOR THE 5 CITIES



PREVIOUS RESEARCH & CONTEXT: PRELIMINARY TAKEAWAYS

- KME for the 5 Brazilian cities shows survival probability is inversely proportional to the city's vulnerability level.
- Results of log-rank test and Cox Proportional Hazard Model support the results from KME.
- Results do not reject hypothesis, showing correspondence between increasing vulnerability and the impacts of COVID-19.
- Small sample of cities and does not control for other alternative explanations (e.g. behaviour, politics, or individual char.).
- There is potential in considering SDOH and behaviour in multidimensional approaches to COVID-19.

References: Baggio et al., 2021; S. L. Li et al., 2021; Nicolelis et al., 2021; Pereira et al., 2021.

PREVIOUS RESEARCH & CONTEXT
PRELIMINARY TAKEAWAYS

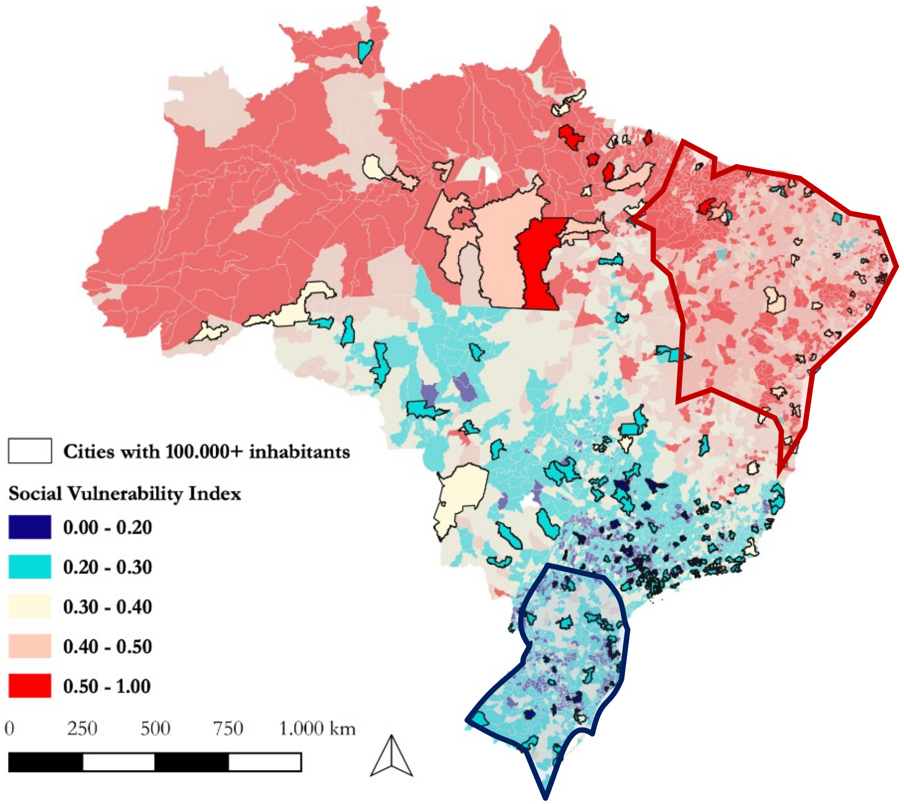
- Results show correspondence between vulnerability and COVID-19 fatalities (KME & Cox agree).
- Small sample of cities.
- Does not control for behaviour, politics, or individual characteristics.

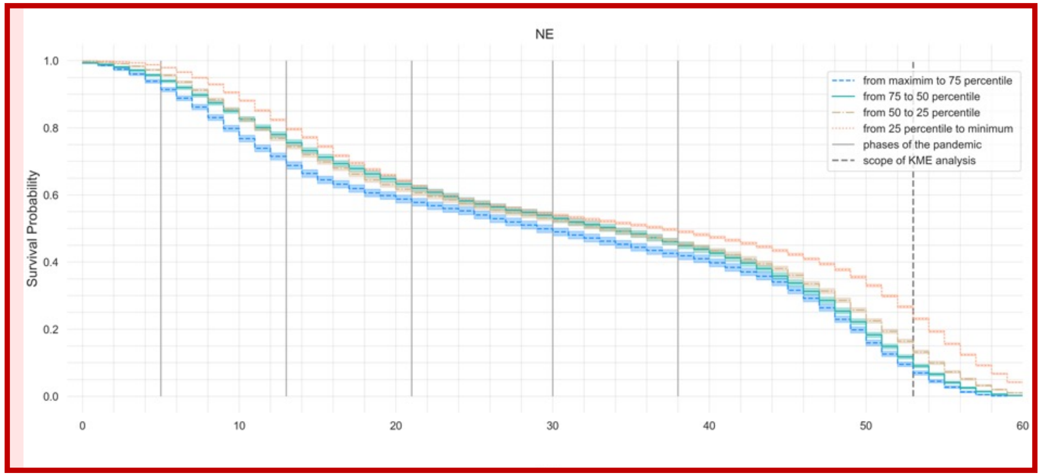
Nexus: human development and health (SDOH).

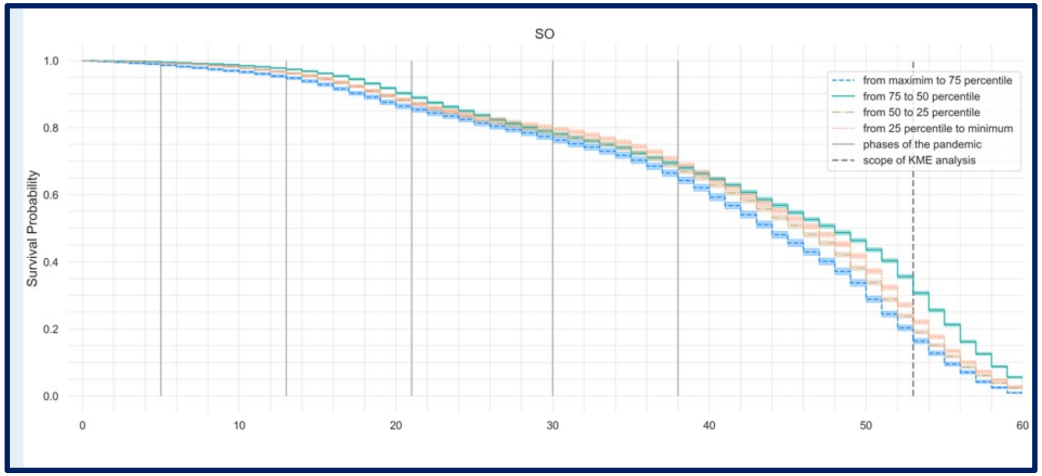
  - Socio-environmental vulnerability is associated with the impacts of health crises.
  - The role of human development and common urban goods.

THE URBANISATION-RISK EXPOSURE NEXUS

APPLYING KAPLAN-MEIER ESTIMATOR TO THE 5,570 MUNICIPALITIES IN BRAZIL: HIGH VULNERABILITY CITIES AND REGIONS HAVE LOWER SURVIVAL PROBABILITIES







NEXUS: RESEARCH QUESTION

- Gap: We know inequality fuels health and climate vulnerability, however we know little about how these vulnerabilities interact.
- Questions:
  - What is the system of connections between urbanisation and risk exposure in GS cities in the Anthropocene?
  - Are there urban populations in SP (BR) vulnerable to both the COVID-19 pandemic and climate change. Which factors influence this vulnerability?

- H1: Areas lacking human development include social and environmental vulnerability factors common to climate change and COVID-19.
- H2: Urban hot spots of these factors coincide with greater COVID-19 fatality rates.

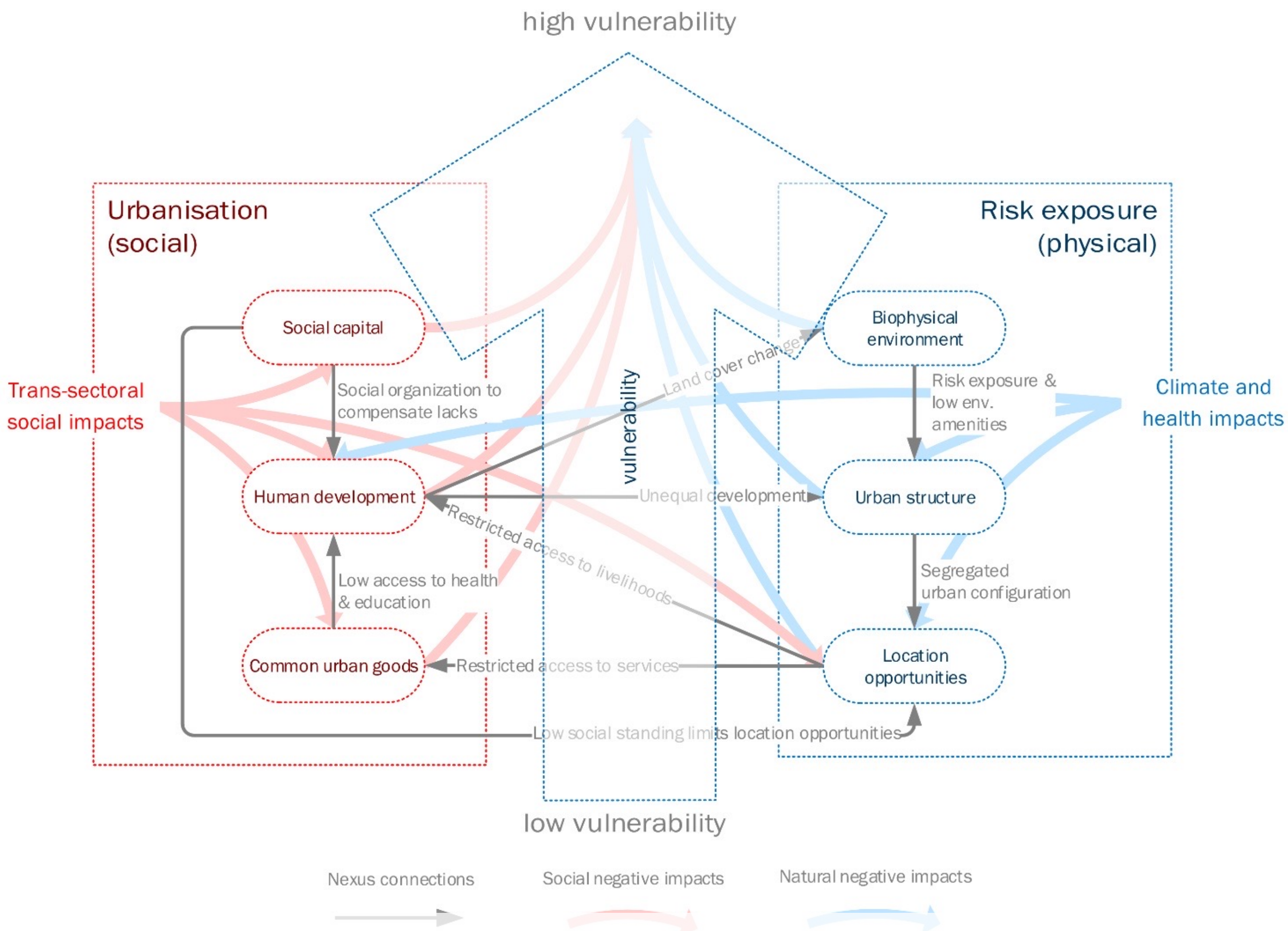
NEXUS:
LITERATURE REVIEW

Table 1-1: Select literature review results.

Literature bodies	Main insights	Sources
Vulnerability frameworks	- Vulnerability is a multidimensional, dynamic process that combines exposure, sociodemographic characteristics, access to assets, livelihoods and social capital - Vulnerability is contextual and trans-scalar, involving the individual, family and society scales - Vulnerability is not anonymous; it has race, class and ethnicity.	Adger, 2006; Bolin & Kurtz, 2018; Cutter, 1995; Cutter & Emrich, 2006; Salgado et al., 2020; Pelling, 2003; 2010; Satterfield et al., 2004
Multiple stressors	- Climate change shows increasing temporal and spatial overlap of stressors (e.g. heat waves, droughts and poor air quality) - Cities concentrate exposure - Cities provide economies of scale for resilience - Informal, low-income settlements often combine low well-being and high vulnerability - The poor often live on their resistive threshold, are more exposed and are less capable of coping - Stressors have environmental, technological and social origins	Corburn et al., 2020, Crutzen, 2002; Elmqvist et al., 2021; Gibbard et al., 2022; Watts et al., 2021
Compound risks or hazards	- Hazards may interact directly or through their secondary effects - Frequency of hazard impacts and resistance, resilience and recovery capacity - Systemic risks are unique; their outcomes cross system scales and affect multiple locations or sectors of society - Systemic risks have a greater possibility of interacting with other hazards and conflicts, tipping social systems beyond their resistive thresholds - Health and climate hazards may also interact directly or indirectly - Repeated impacts may lead to poverty–vulnerability traps	Cinner et al., 2018; Juhola et al., 2022; Sillman et al., 2022; Zscheischler et al., 2018

References: Sillmann et al., 2022 ; Revi et al., 2015; Adger, 2006; Pelling, 2003; Alberti et al., 2003; Elmqvist et al., 2021.

NEXUS:
THE FRAMEWORK

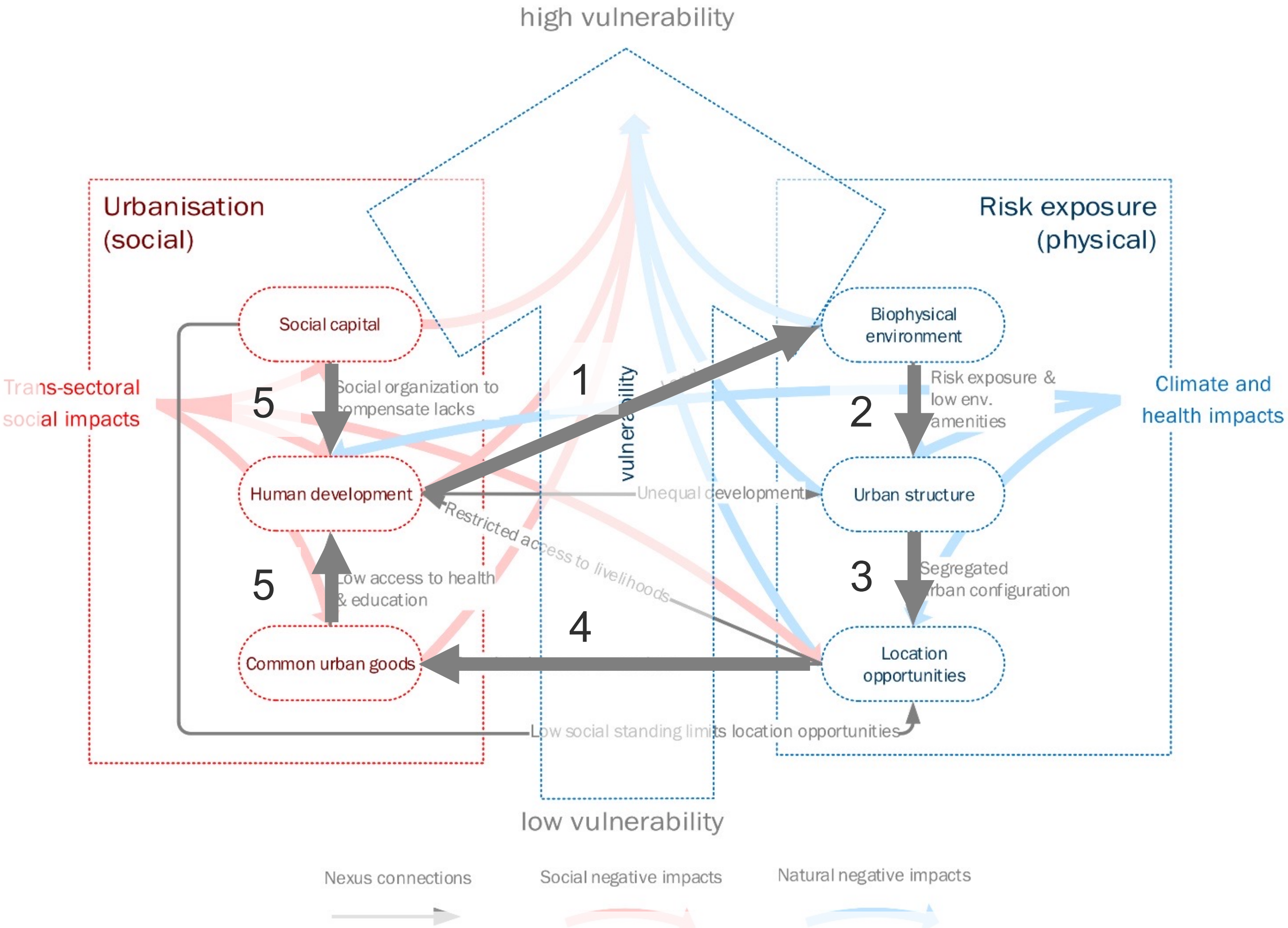


References: Sillmann et al., 2022 ; Revi et al., 2015; Adger, 2006; Pelling, 2003; Alberti et al., 2003; Elmqvist et al., 2021.

EXPLAINING THE NEXUS

Urban development dynamics:

1. Social demand for urbanisation (i.e. market led land-cover change)
2. Unequal urban development
3. Spatial opportunities with more/less exposure
4. Segregated access to infrastructure, institutions, and services
5. And so on…

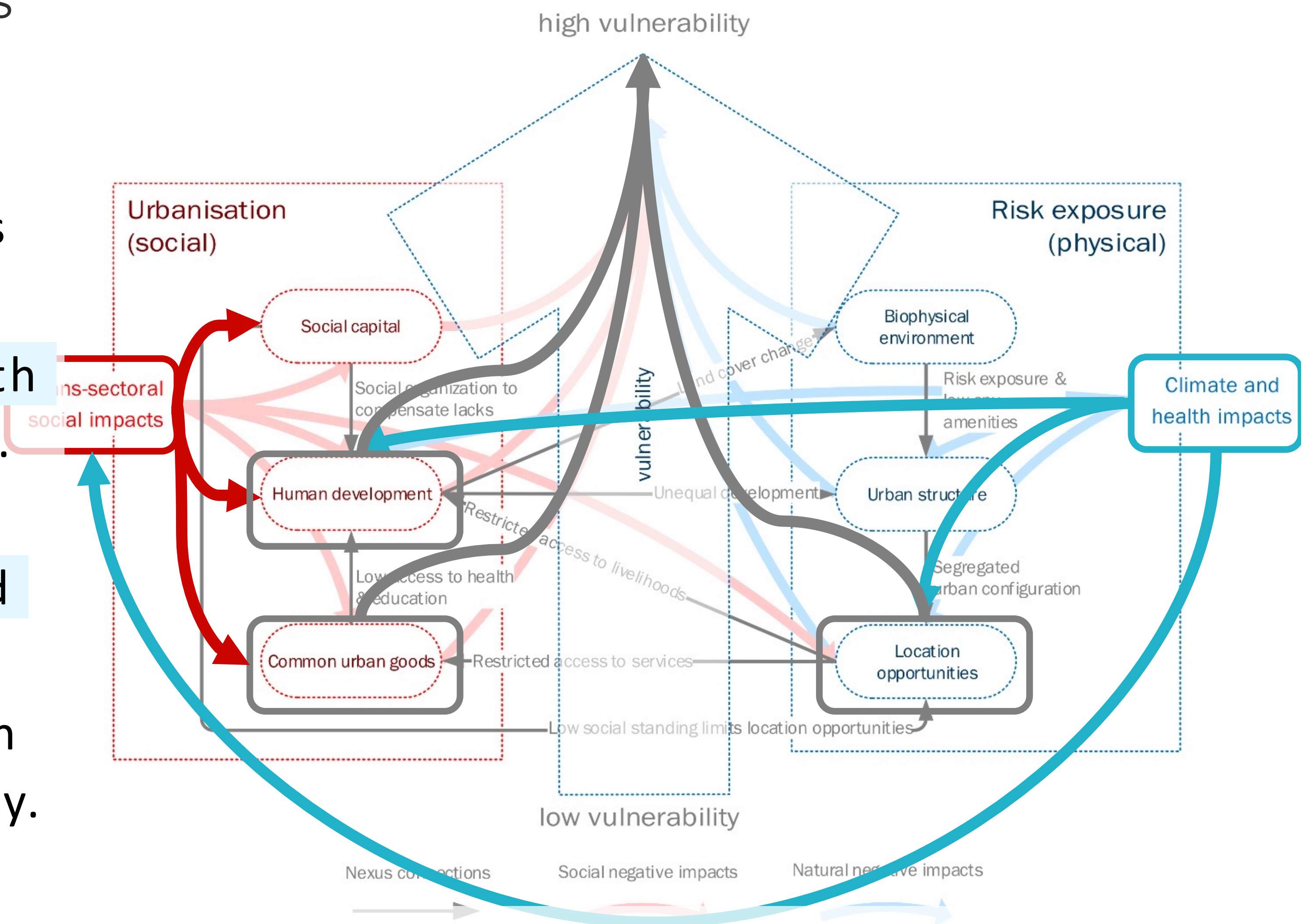


References: Sillmann et al., 2022 ; Revi et al., 2015; Adger, 2006; Pelling, 2003; Alberti et al., 2003; Elmqvist et al., 2021.

EXPLAINING THE NEXUS

Interact with hazards

1. Climate and health impacts interact with the unequal factors.
2. Trans-sectoral impacts amplify and prolong effects.
3. Location and human development are key.

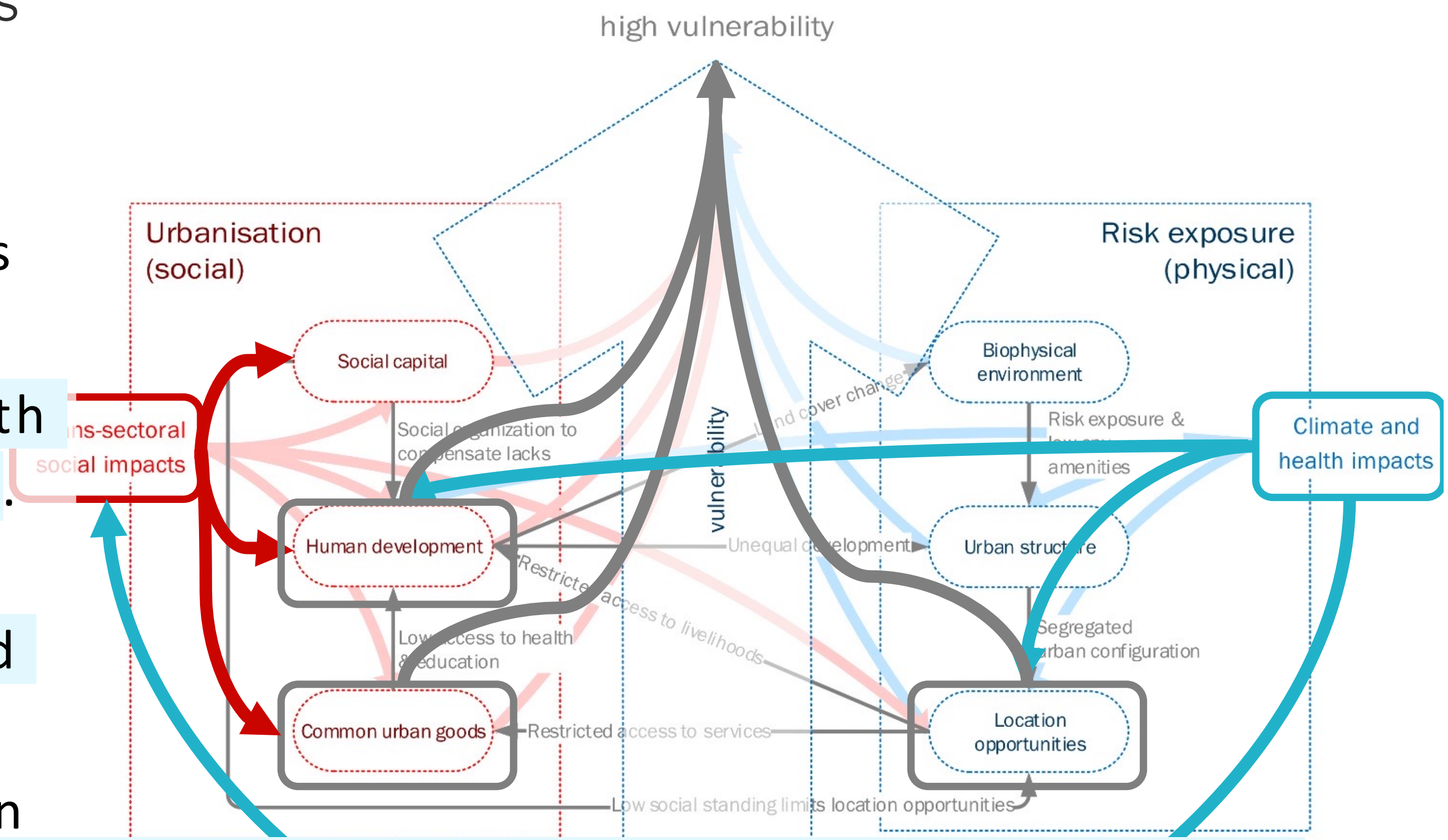


References: Sillmann et al., 2022 ; Revi et al., 2015; Adger, 2006; Pelling, 2003; Alberti et al., 2003; Elmqvist et al., 2021.

EXPLAINING THE NEXUS

Interact with hazards

1. Climate and health impacts interact with the unequal factors.
2. Trans-sectoral impacts amplify and prolong effects.
3. Location and human



Therefore:

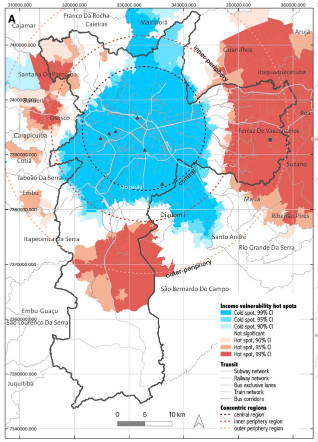
- vulnerable populations suffer more intense or lasting consequences from crises
- these populations have lower coping and adaptive capacities against impacts

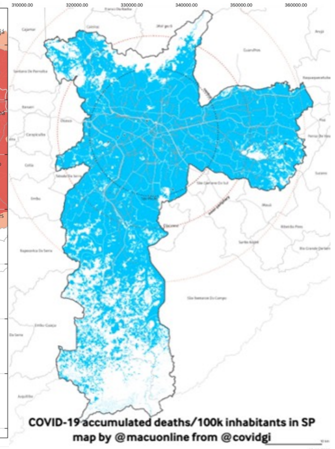
METHODS TO EXPLORE THE NEXUS

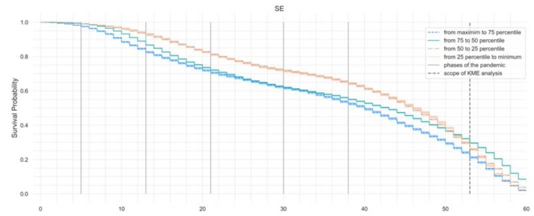
- Mixed-methods approach:
  - Thematic analysis.
  - Hot spot analysis (Getis-Ord Gi*).
  - Survival analysis (KME & Cox).
- Data:
  - SP Fieldwork (03.2022).
  - SP COVID-19 microdata (n = 1,948,601).
  - SVI & HDI.

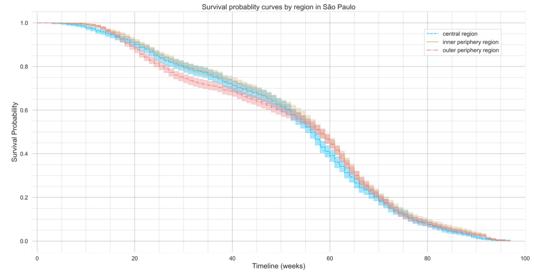
Table 5-3: cross-thematic matrix for the SP focus groups.

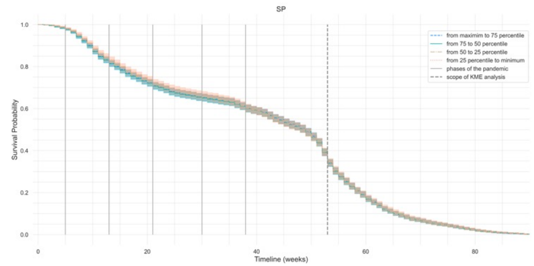
Themes / Cases	(a) The intensification of threats to livelihoods	(b) Changing behaviour: by choice or out of need?	(c) Capacity to cope, respond, and adapt	(d) New opportunities/ factors of resilience	**Cross-case observations**
Central region group (CRG)	temporary threats to education, stress in the work environment	telework allows active mobility, local and online shopping	high individual capacity, available family resources, healthcare access	new habits increase wellbeing, resources to seize opportunities	Negative impacts were temporary, long-term improvement
Peripheral region group (PRG)	severe threats, unemployment, food insecurity, mental health issues	a risk-risk trade-off: unemployed or exposed, long-term losses	limited capacities, lack of access to health, impacts translate into losses	reduced resilience, but community organization is a (new) lifeline	Long-lasting negative impacts hinder development
Cross-thematic observations	CRG: impacts within the coping threshold. PRG: the threshold was very low and impacts high.	exposure to new behaviour in both groups, but all choices in PRG involve losses	polarized coping, CRG: capacity and additional resources; PRG: "territorial overload"	seizing opportunities needs resources, lead to increasing inequality	











References: Braun & Clarke, 2012; Tashakkori & Teddlie, 2010; Kaplan & Meier, 1958; Getis & Ord, 1992; Costa & Margutti, 2015; UNDP, 2022.

METHODS TO EXPLORE THE NEXUS: MIXED METHODS

Mixed-methods research design that includes a thematic analysis of the material from two focus groups, geospatial analysis with hot spots methods, and survival analysis.

This research combined quantitative and qualitative methods using a sequential, iterative, and multi-sampling design (Tashakkori & Teddlie, 2010).

The qualitative data include two focus groups held in SP in March 2022, and we studied them using thematic analysis methods (Braun & Clarke, 2012). Quantitative data sources included the Social Vulnerability Index (SVI) (Costa & Margutti, 2015) and the COVID-19 fatalities data (Brasil.IO, 2021; SP Municipal Health Department, 2022).

References: Braun & Clarke, 2012; Tashakkori & Teddlie, 2010; Kaplan & Meier, 1958; Getis & Ord, 1992; Costa & Margutti, 2015; UNDP, 2022.

METHODS TO EXPLORE THE NEXUS: THEMATIC ANALYSIS

We obtained the qualitative data during fieldwork in two focus group sessions held on March 13 and 15 in the Benfica community (Guaianases neighbourhood) and the SP city centre. The lead author of this paper participated in the focus group sessions held in Portuguese. The research team recorded and transcribed the sessions and then coded the transcripts from a deductive, semantic, and realist approach to support thematic analysis (Braun & Clarke, 2006, 2012).

We analysed the coded content of the focus group sessions using thematic analysis methods (Braun & Clarke, 2006, 2012), which consists of identifying common and relevant themes across the cases to support the research question. We opted for these methods due to their flexibility and accessibility to non-experts in qualitative methods involved in mixed methods designs. Further detail on the fieldwork design, focus group implementation.

Coding available at our GitHub repository.

METHODS TO EXPLORE THE NEXUS: HOT SPOTS ANALYSIS

Using social vulnerability data, we implemented the Optimised Hot Spot Analysis tool in ArcGIS Pro 2.2.2 to answer the research question: Which populations are vulnerable to climate change and the COVID-19 pandemic? The assumption is that lower human development leads to higher impacts from COVID-19 in the form of higher fatality rates. We derive this assumption from the literature (Corburn et al., 2020; Levin et al., 2022; Lorenz et al., 2021) and prior research (Santos, Rodriguez Lopez, Heider, et al., 2022). The tool calculated the Getis-Ord Gi* statistic using multiple fixed-distance spatial relationships and automatically tested distances to discover the most significant statistical concentrations of high values (i.e. hot spots) or low values (cold spots). The tests sought to reject the null hypothesis (e.g. eliminating clusters that could be random). The results were the z-scores and p-values for each spatial feature, indicating confidence intervals of 90, 95, and 99% (ESRI, 2022).

METHODS TO EXPLORE THE NEXUS: SURVIVAL ANALYSIS

We implemented survival analysis using the Kaplan-Meier Estimator (KME). We employ the KME to analyse the survival probabilities of different populations over a predefined period (Kaplan & Meier, 1958). This method observes fatalities within a given time window for different population subgroups (also called 'reduced groups'), permitting the analysis of statistical differences between these groups without other assumptions.

We implement these models with the SP municipal COVID-19 fatalities geocoded microdata from January 2020 to November 2021 (SP Municipal Health Department, 2022). Data preparation included eliminating invalid records (e.g. without geographic references) and aggregating fatalities per epidemiological week and census district. We provide additional survival analysis with the Cox proportional hazard regression (Cleves et al., 2008) in 0. Data and the Python code feature in the supplementary materials.

Data & code available at our GitHub repository

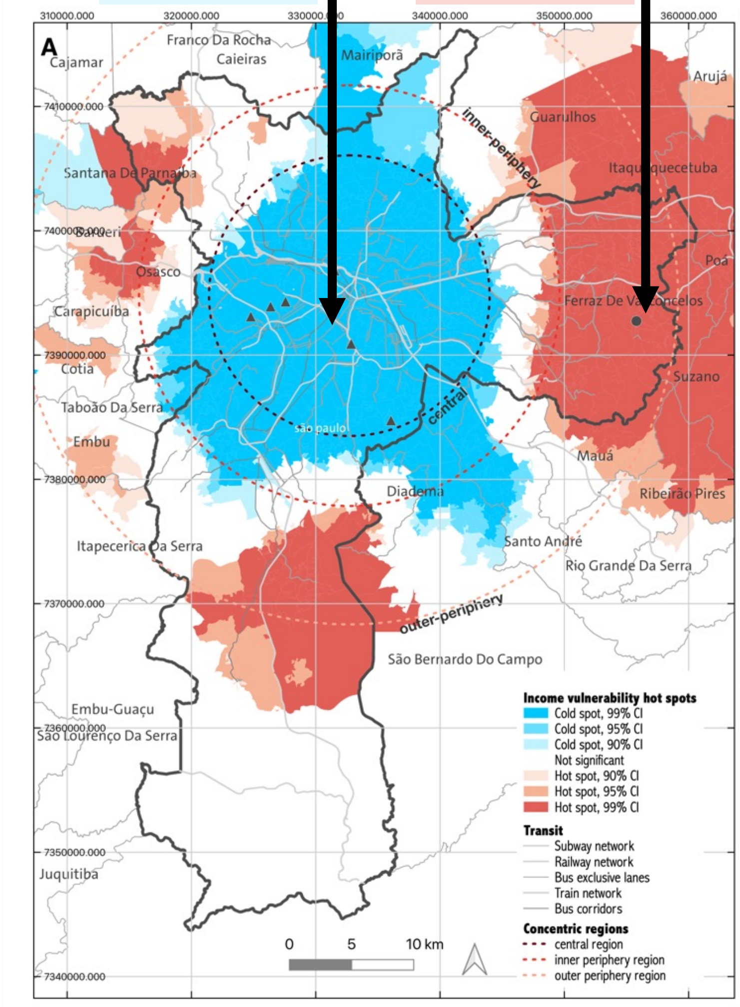
RESULTS – THEMATIC ANALYSIS

- 2 focus groups in contrasting contexts:
  - CRG: Centre
  - PRG: Benfica community
- 17 participants, convenience sample.
- Socioeconomic and ethnic diverse sample.

References: Braun & Clarke, 2006, 2012.«

Norway
HDI 0.942

Yemen
HDI 0.681



CRG: expanded Centre

7 participants (5F/2M), ages: 20 – 34y.

Self-dec. eth.: 1 Black/3 Pardo/3 White.

PRG: Benfica

10 participants (7F/3M), ages: 19 – 48y.

2 Black/6 Pardo/2 white.

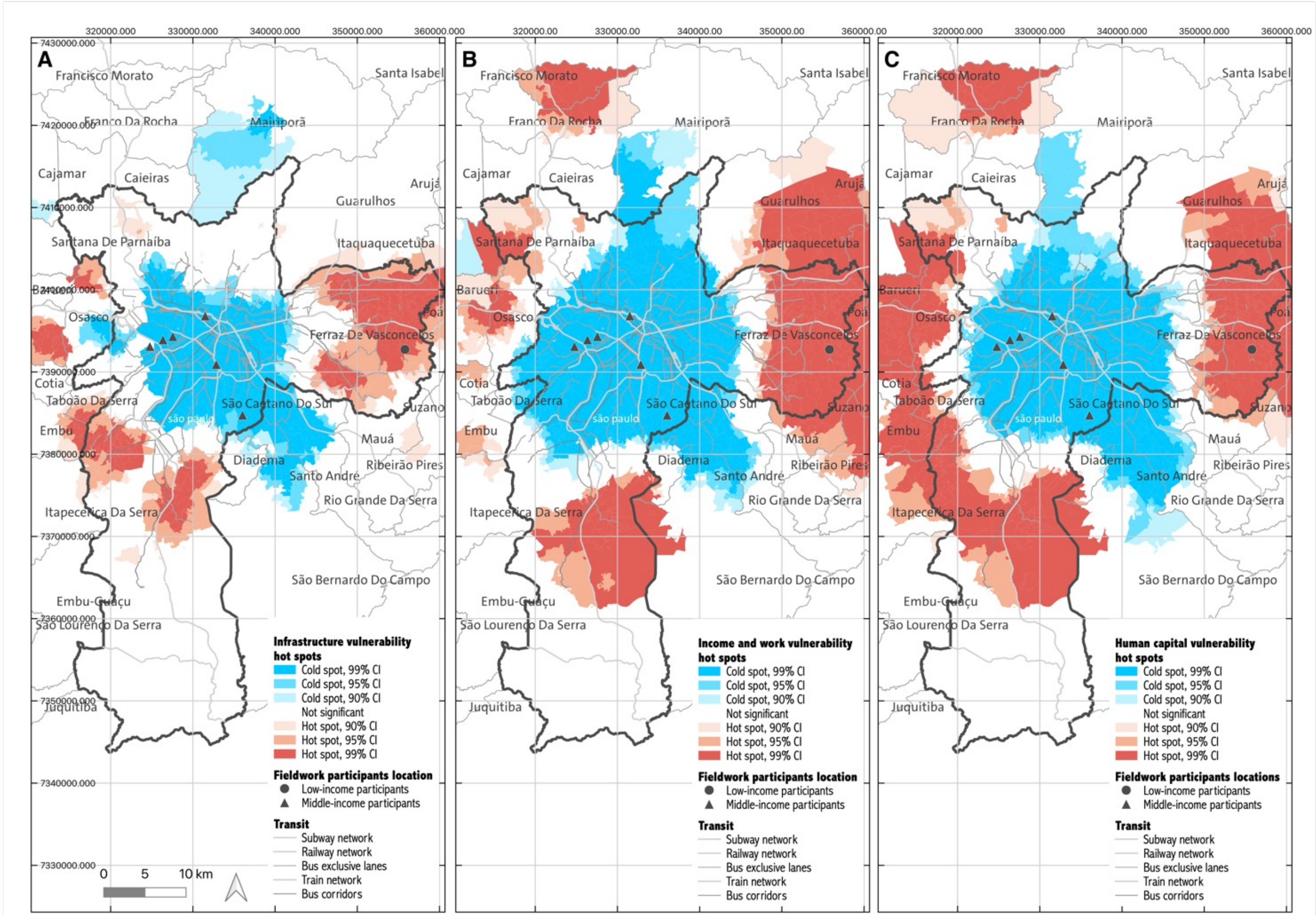
RESULTS – THEMATIC ANALYSIS

Table 5-2. cross-thematic matrix for the SP focus groups.

Themes / Cases	(A) The intensification of threats to livelihoods	(B) Changing behaviour: by choice or out of need?	(C) Capacity to cope, respond and adapt	(D) New opportunities/ factors of resilience	Cross-case observations
Central region group (CRG)	temporary threats to education, stress in the work environment	telework allows active mobility, local and online shopping	high individual capacity, available family resources, healthcare access	new habits increase well-being, resources to seize opportunities	Negative impacts were temporary, long-term improvement
Peripheral region group (PRG)	severe threats, unemployment, food insecurity, mental health issues	a risk-risk trade-off: unemployed or exposed, long-term losses	limited capacities, lack of access to health, and impacts translate into losses	reduced resilience, but community organisation is a (new) lifeline	Long-lasting adverse effects hinder the development
Cross-thematic observations	CRG: impacts within the coping threshold. PRG: the threshold was very low and impacts high.	exposure to new behaviour in both groups, but all choices in PRG involve losses	polarised coping, CRG: capacity and additional resources; PRG: 'territorial overload.'	seizing opportunities needs resources, leading to increasing inequality	

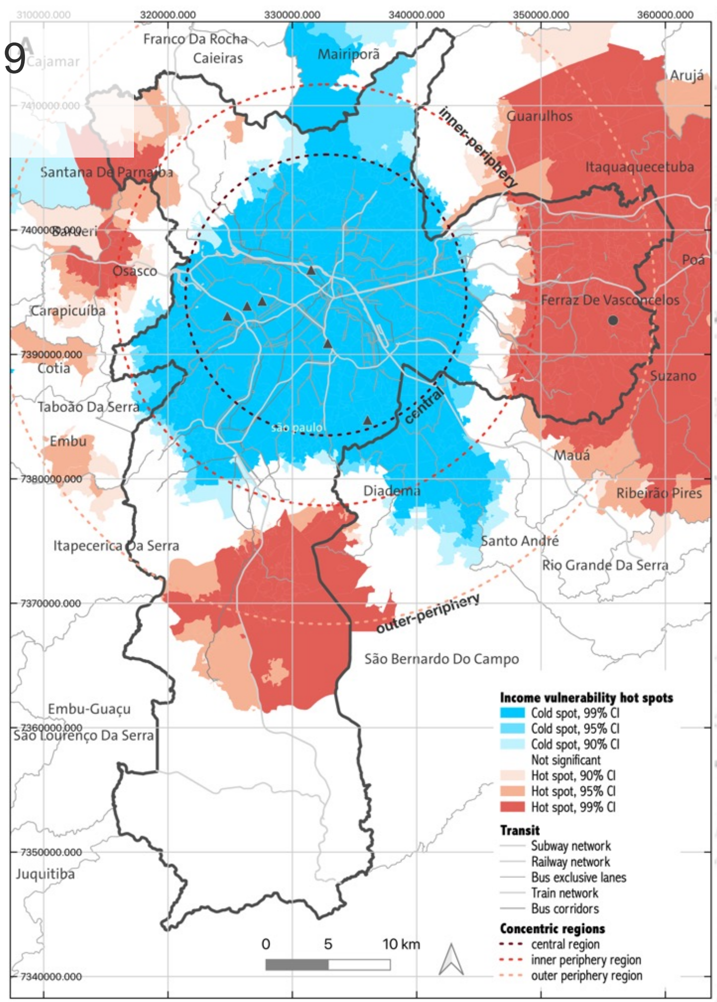
RESULTS:
HOT SPOTS ANALYSIS

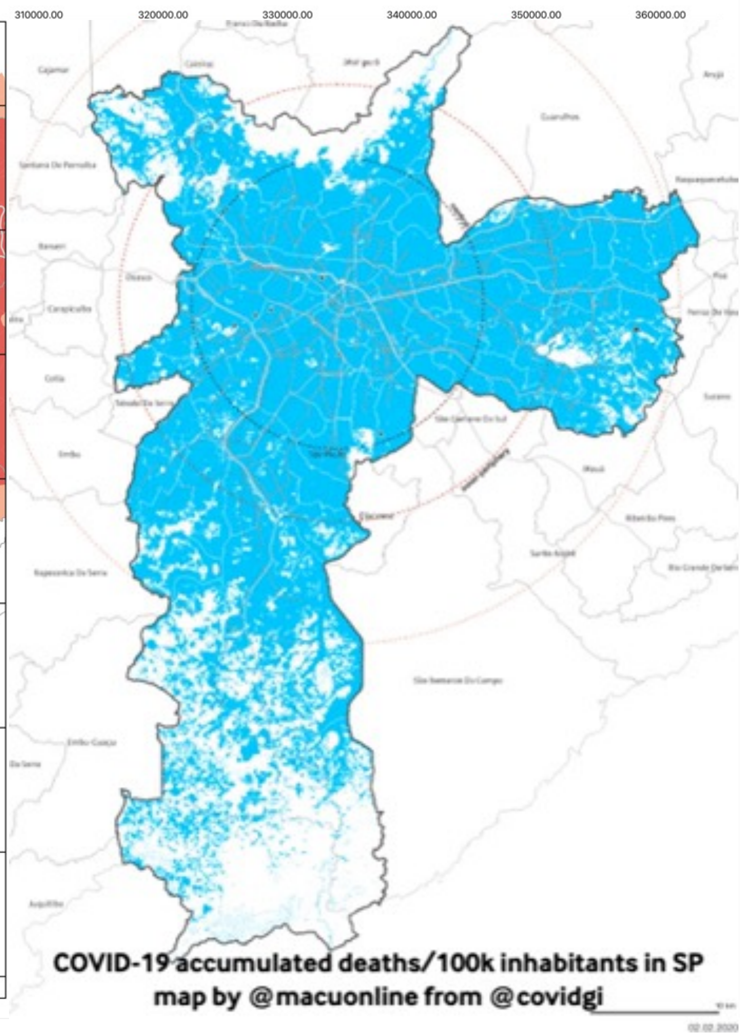
- All SVI components match the centre-periphery pattern
- Cold spots consistent in the central areas
- Hot spots consistent i the peripheral areas



RESULTS – HOT SPOTS VS. COVID-19 FATALITIES

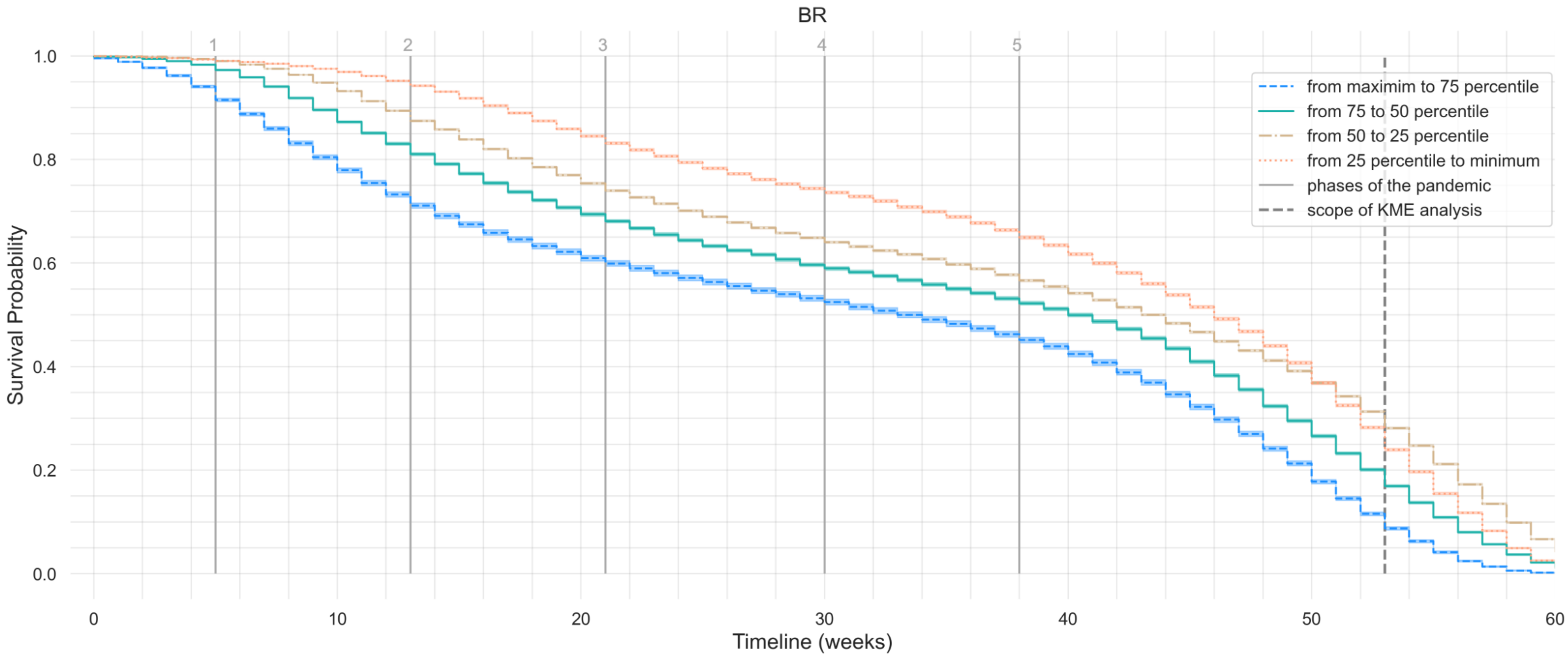
- Well-defined cold and hot spots: core-periphery.
- Periphery: infrastructure, income & work, and human capital hot spots.
- COVID-19 deaths concentrate in periphery.



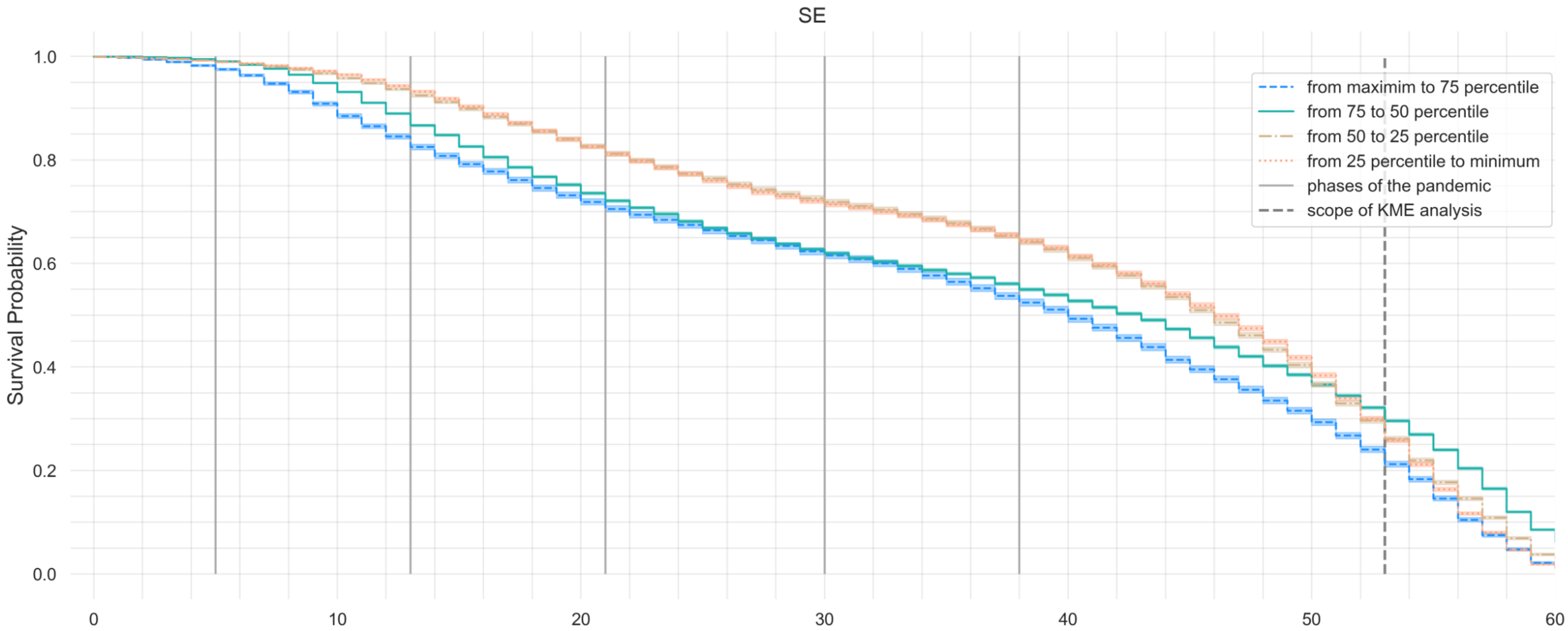


References: Bógus & Taschner, 1999; Feitosa et al., 2021.

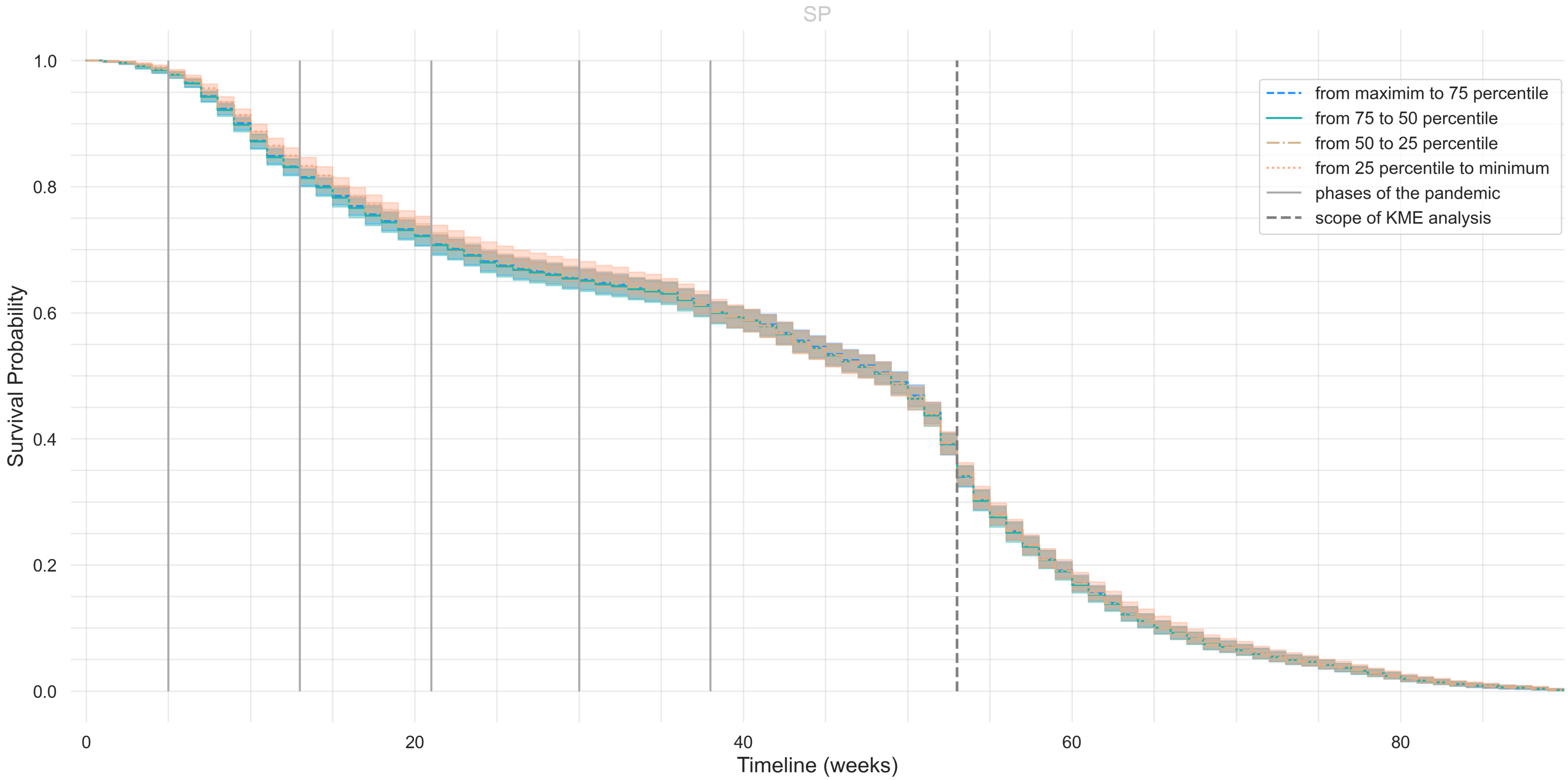
RESULTS – NATIONAL KME (N = 5,570 MUNICIPALITIES): VERY CLEAR TREND OF SURVIVAL PROBABILITY, NEGATIVE ASSOCIATION TO VULNERABILITY



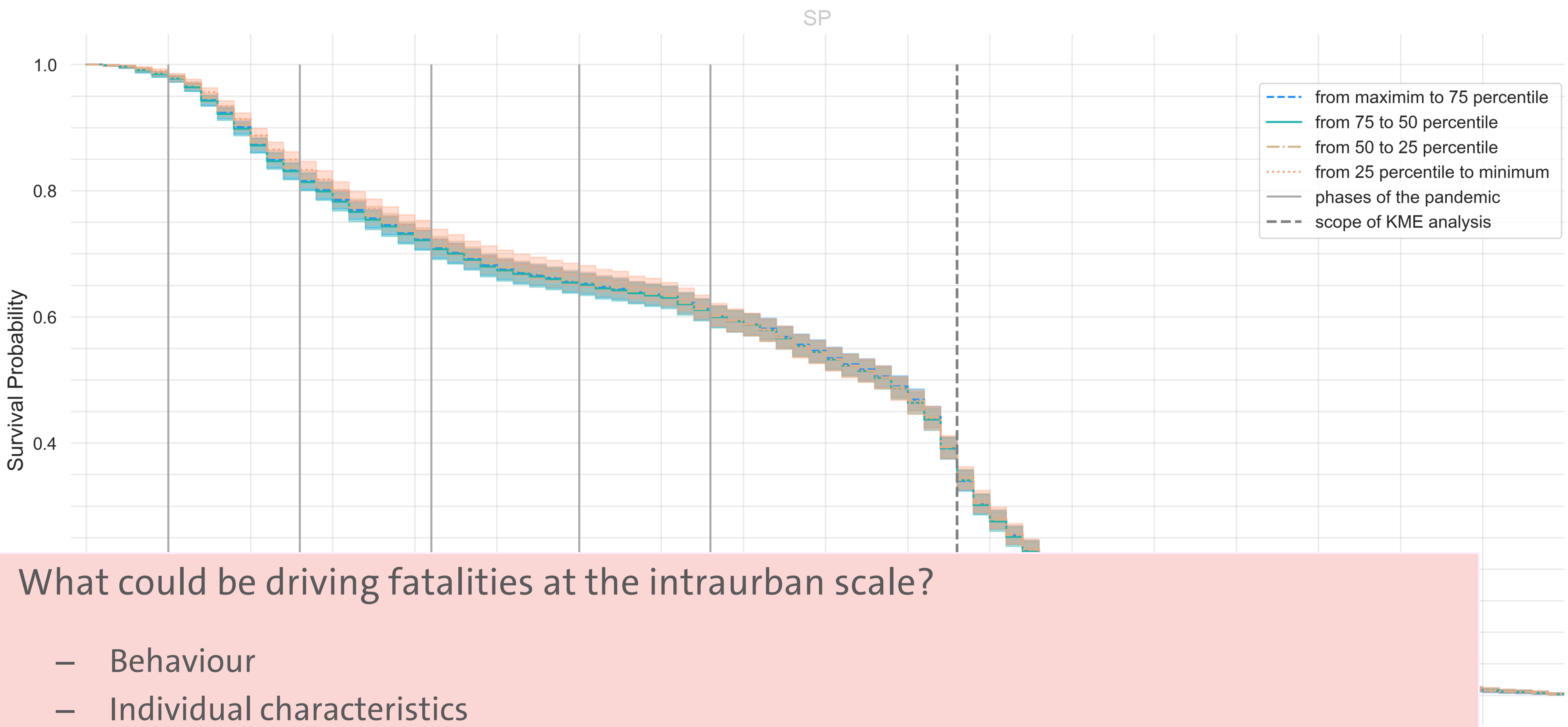
RESULTS – REGIONAL KME (N = 1,668 MUNICIPALITIES): CLEAR TREND OF SURVIVAL PROBABILITY, NEGATIVE ASSOCIATION TO VULNERABILITY



RESULTS – INTRAURBAN KME (N = 5,970 CENSUS DISTRICTS): NO CLEAR TREND, ALL SVI QUANTILES CROSS AND ERROR BARS OVERLAP

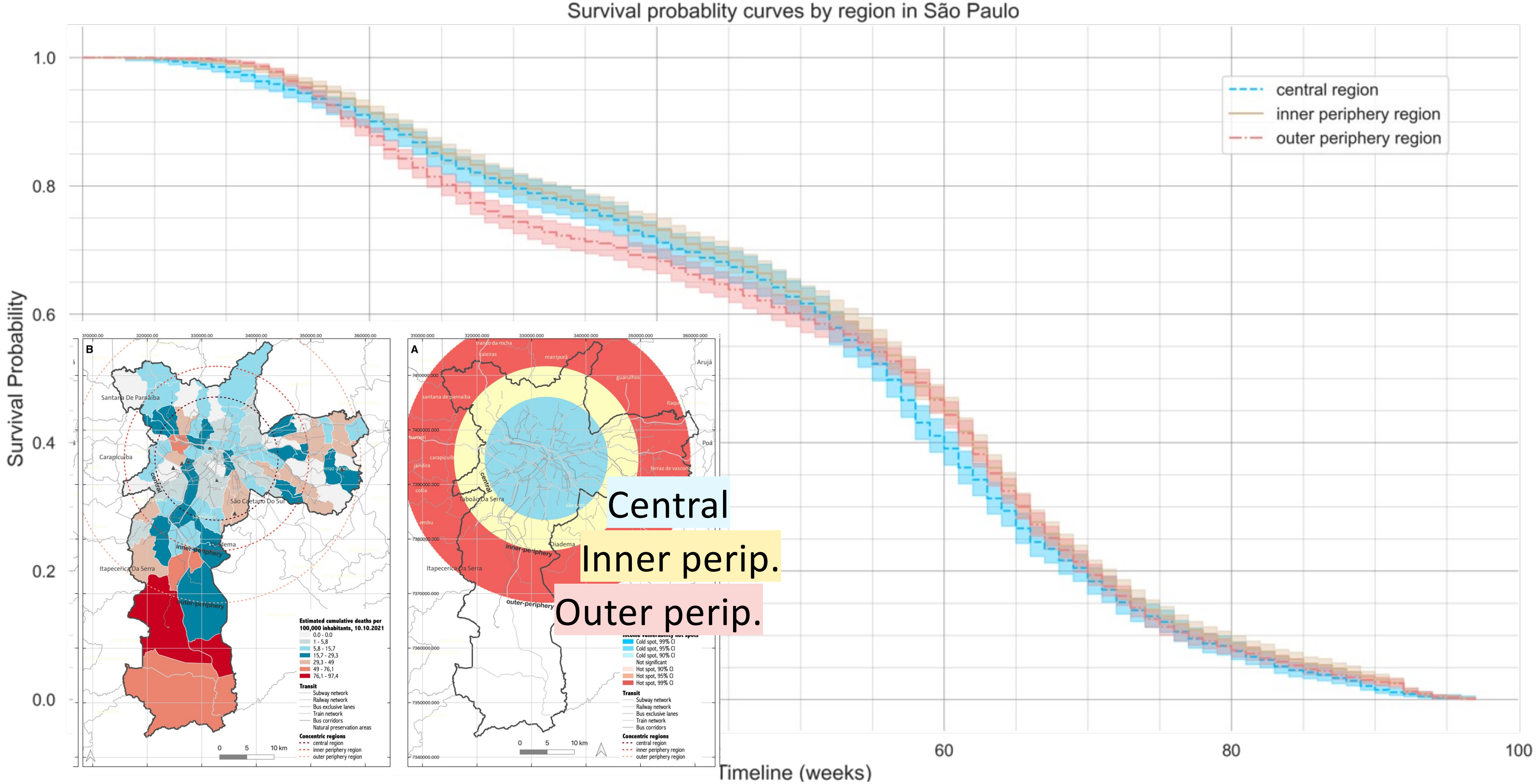


RESULTS – INTRAURBAN KME (N = 5,970 CENSUS DISTRICTS):



- What could be driving fatalities at the intraurban scale?
  - Behaviour
  - Individual characteristics
- Could long-term vulnerability play no role?

RESULTS – INTRAURBAN, BY REGION (N = 5,970 CENSUS DISTRICTS)



DISCUSSION

- Common factors between health & climate crises (qualitative evidence supports, H1)
  - Widening gap in resilience between the central and peripheral groups.
  - Social status and location choice converge – exposure and res. capacity.
- High-vulnerability areas had more fatalities (quantitative evidence, hot spots and KME, partially support H2).
  - Geographic differences in COVID-19 deaths aligned with SDOH and SV.
  - Need for research: deviant patterns in KME (e.g. MAUP, or behaviour).

References: Sillmann et al., 2022; Levin et al., 2022; Salgado et al., 2020;

DISCUSSION

- The nexus provides a systemic approach to a complex set of relationships.
- It demands empirical validation (beyond theory).
- Assumptions stemming from the nexus (for the ensuing work):
  1. unequal distribution of climate and health hazards in cities in the Anthropocene
  2. vulnerable populations suffer more intense or lasting consequences from climate and health crises
  3. vulnerable populations often have lower coping and adaptive capacities against these impacts
  4. urbanisation – a dynamic social process defined by social capital, human development and common urban goods
  5. exposure – the physical aspects of vulnerability, including the biophysical environment, urban structure and location opportunities.

LIMITATIONS

- The nexus is not fully mapped, interaction remains mostly theoretical, lacking hierarchy of factors and quantification of influences.
- Methods do not exhaust alternative explanations nor quantify uncertainty.
- Mixing of methods should be evaluated more systematically.
- The direct coupling of climate and health crises is hard to assess, may demand other techniques (e.g. modelling).

However, multiple scales, spatio-temporal data, and interdisciplinary combination of evidence avoid ’monolithic assumptions’ and improve robustness.

CONCLUSION AND OUTLOOK

1. Intersectoral and social consequences from systemic crises (climate change and COVID-19) disproportionately affect the most vulnerable.
2. Crises may interact, overlapping responses and adaptation.
   Under limited resources, the social and vulnerability gaps may widen.
3. Health and climate adaptation need to account for contextual, societal and subjective factors and avoid over-generalisation and ‘one-size-fits-all’ measures.

As our shared urban planet faces the Anthropocene, this research seeks to shine a light tinted by fairness onto future decisions.

CONCLUSION AND OUTLOOK

- The impacts of systemic risks are multidimensional. Many social dimensions are absent in measures (e.g. GDP or fatalities).
- Social & environmental factors significantly contribute to COVID-19 vulnerability.
- Unequal development patterns explain most socioeconomic vulnerability in SP and part of the COVID-19 fatality concentration in the period – increased exposure and reduced adaptive capacity.
- Local adaptation should be inclusive, context-sensitive, and counter inequality.
- Recommendations:
  - Regulate location opportunities equitably.
  - Support community organisation (instead of top-down interventions).
  - Correct historical bias toward adaptation where needed the least (e.g. in central areas).

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