A methodological proposal to Disaster Risk Indicators in Brazil

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ABSTRACT

This article provides a tool to help assess, visualise and communicate different levels of exposure, vulnerability and risk in Brazil. The Disaster Risk Index in Brazil may sensitise public and political decision-makers towards the important topic of disaster risk and climate change adaptation. This article aims to explore the feasibility and usefulness of such a national risk index that considers both natural hazard phenomena and social vulnerability. The results showed that the risk is strongly interwoven with social-economic and cultural conditions and normal everyday life, as well as with the performance of state institutions dealing with Disaster Risk Reduction and Disaster Risk Management, in other words, vulnerability. Spatial trends of disaster risk and vulnerability, products of this research, also have stressed the serious inequalities between and within regions of the country, which result in barriers to the development of the DRR and DRM in Brazil as a whole.

Keywords

Risk assessment; risk index; natural hazards; vulnerability; Brazil.

INTRODUCTION

This article aims to serve as a tool to help assess, visualise and communicate different levels of exposure, vulnerability and risk in Brazil. Furthermore, the index may sensitise public and political decision-makers towards the important topic of disaster risk and climate change adaptation.

The Disaster Risk Index in Brazil aims to explore the feasibility and usefulness of such a national risk index that considers both natural hazard phenomena and social vulnerability. The county comparison provides an initial ranking of exposure and vulnerability. In addition, specific analysis of coping and adaptation capacities also indicates that risk or vulnerability are not pre-defined conditions, but rather are constructed by societies exposed to natural hazards.

The information provided by the index highlights the need for preventive measures towards DRR and Climate Change Adaptation (CCA) in the country as a whole, but also at regional and local scales.

Concept

The concept of the index is based on the WorldRiskIndex (Birkmann et al, 2011;. Welle et al, 2012;. 2013), whose theoretical concepts and understanding of risk, within the framework of natural hazards and disaster risk community, state that disaster risk derives from a combination of physical hazards and vulnerability of exposed people (UNISDR, 2004; Wisner et al., 2004; Birkmann, 2006; IDEA, 2005; IPCC, 2012). A broad range of researchers who participated in preparing the IPCC-SREX agrees that a hazardous event is not the only driver of risk. These researchers are confident that the level of adverse consequences is largely determined by the vulnerability and exposure of societies and socio-ecological systems (Cardona et al, 2012).
Above all, the index aims to capture and measure four major components (figure 1): exposure to natural hazards; susceptibility of the exposed communities; coping capacities; adaptive capacities.

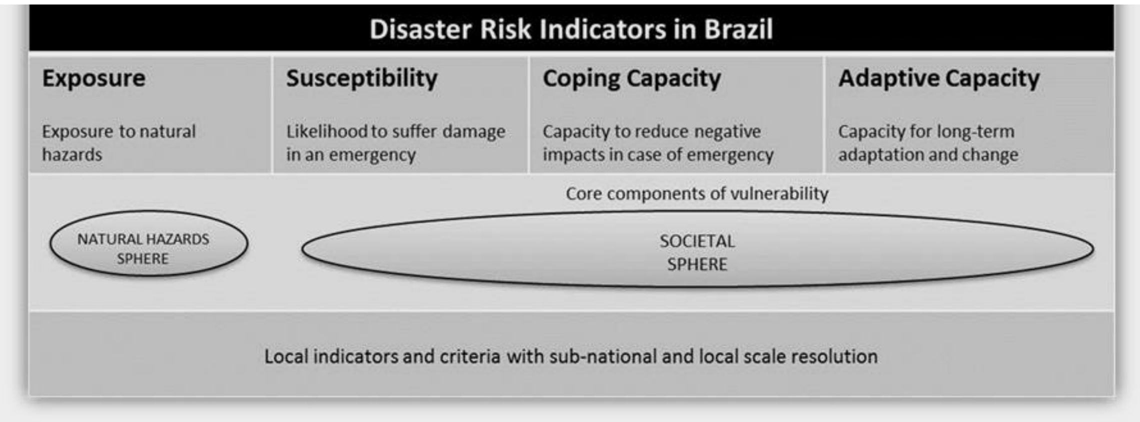

Figure 1: Structure of the Index and the Indicator System. Source: Almeida, 2015. The concept of index is based on WorldRiskIndex (Birkmann et al, 2011;. Welle et al, 2012;. 2013).

In accordance with United Nations Development Programme (UNDP, 2004), exposure defines risky elements, those artefacts and people who are exposed to a hazard, that is, elements located in an area within which hazardous events can occur (Cardona, 1999; UNISDR, 2004, 2009b). Therefore, if a population and its resources are not located in (exposed to) potentially hazardous spaces, no disaster risk problem exists. Exposure is a necessary but not exclusive determinant of risk. It is possible to be exposed but not vulnerable. However, to be vulnerable to an extreme event, it is necessary to also be exposed (Cardona et al., 2013).
The index clearly prioritises hazards widely distributed in Brazil that account for serious harm to people and their properties in terms of losses and numbers of deaths and people affected. For the period 1991-2012, the most frequent and devastating natural hazards officially reported in Brazil, were droughts, floods and storms, accounting for 91.07% of the total records (UFSC.CEPED, 2013). In terms of number of deaths, focus is placed on flash floods, landslides, and gradual floods which caused 87.15% of all disaster-related deaths in Brazil in that period. In addition, emerging hazards in the context of climate change, in the case of sea level rise, were taken into consideration in the elaboration of the final index. In this context, the four following natural hazards were investigated in the research: floods, landslides, droughts, sea level rise.
Susceptibility is another component of the index and refers to exposed communities or other exposed elements (infrastructure, ecosystems etc.) that make them more likely to experience damage and be adversely affected by a natural hazard or by climate change. Whereas this component is closely related to structural characteristics such as infrastructure, economic capacity, and nutrition, it can provide basic evidence of the specific vulnerabilities of society (Welle et al., 2013).
Therefore, susceptibility can be understood as the probability of suffering damage or injury caused by a hazardous phenomenon, that is, a natural hazard. As in the WorldRiskIndex, the susceptibility component was divided into five sub-categories for assessing social exclusion, conditions of habitation, and public infrastructure of those social groups exposed to hazards. The five categories are: economic capacity and income, poverty and dependencies, nutrition (no data are available, appropriate to the scale of the research), housing conditions, public infrastructure.

Coping capacity is the ability of a group or society, organisation and systems, using available tools and resources, to face and manage emergencies, disasters, or adverse conditions that could lead to a harmful process caused by a hazardous phenomenon. (UNISDR, 2009). The coping capacity of populations affected by natural disasters is a key concept in vulnerability assessment (Billing and Madengruber, 2005).

This component can be measured on different scales and this requires different approaches. This important aspect of the evaluation of risk and vulnerability is a fundamental element for a full understanding of the overall risk of disaster in a county (local scale).

In the index, adaptation covers capabilities, measures and strategies that enable communities to change and transform in order to deal with the negative consequences expected from natural hazards and climate change. Therefore, these capabilities focus on features that allow structural changes within society. The sub-categories used in the index to capture aspects of adaptation and adaptive capacities are: education and research, gender equity, environmental status/ecosystem protection, adaptation strategies, investments.

DATA AND METHODS

In developing index, various methodologies were used, such as statistical analysis (using Microsoft Excell and IBM SPSS) and spatial analysis using geographic information system (GIS). For the spatial analysis and mapping, the values of the calculated indices were divided into five classes, using quantile method, which is integrated into the ArcGIS 10 software. Hence, each class has an equal number of features and all calculated indices differ in their value ranges, but qualitative classification of 'very high – high – medium – low – very low' was established.

In this regard, the individual components of exposure and vulnerability are more relevant to communication and decision-making than the aggregate total index, since an aggregation always results in a loss of differentiation, as will be discussed later (see Birkmann et al., 2011).

Indicators

The index was calculated based on 36 indicators, 4 of which refer to exposure to natural hazards, and 32 pertain to the societal vulnerability. The figure 2 (indicators-synthesis) displays these indicators, their respective components (exposure, susceptibility, coping capacity, adaptive capacity), and sub-categories. The three sub-categories – storms, nutrition, and social network, family and self-help – are mentioned although they could not be integrated into the calculation, but are recognised as important elements which should be in the concept.

The raw data of all selected indicators were extracted from various global and Brazilian official databases. For the index aggregation, all indicators have been transformed in dimensionless rank level between 0 and 1; that is, they can be read as percentage values for better comprehension. The indicators for calculating exposure are explained in the next section.

Exposure

The selection of natural hazards was based on two aspects: the natural hazards that occurred more frequently, and that caused more victims (people affected and deaths) between 1991 and 2012 (UFSC.CEPED, 2013). In this context, three selected natural hazards - floods, landslides, droughts - produced 85.8% of the disasters reported in Brazil in that period, accounting for 85.8% of people affected by disasters, and causing 94.72% of disaster-related deaths. Additionally, sea level rise was taken into account, since it is very likely that due to further climate change, sea level rise will affect many low-lying coastal zones and delta regions. In 2010, according to the Brazilian Institute of Geography and Statistics (IBGE) Census, 26.58% of the Brazilian population lived in cities located in the coastal zone.

Within the index, exposure was operationalised as physical exposure (figure 3), which means the potential annual average number of individuals exposed to floods, droughts, landslides and sea level rise in Brazil. The PREVIEW Global Risk Data Platform was used for the specific cases of exposure to floods, landslides. The PREVIEW Platform is a multi-agency effort to share spatial data on global risk related to natural hazards. In this scope, each set of hazard data represents an annual estimation of the exposed population. This includes a probabilistic component in the frequency of the respective hazard, and the information on population distribution based on Landscan TM Population Database (ESRI Grid population, 1 sq resolution for the year 2010)[1].

1. Exposure	2. Susceptibility	3. Coping Capacity	4. Adaptive Capacity
EXPOSED POPULATION WITH REGARD TO A) Landslides B) Floods C) Droughts D) Storms E) Sea level rise	**PUBLIC INFRASTRUCTURE** A) % people in households with inadequate water supply and sanitation **HOUSING CONDITIONS** B) Share of population in irregular clusters (slums) C) % people in households with inadequate wall materials D) Degree of urbanization **NUTRITION** **POVERTY AND DEPENDENCIES** E) Dependency ratio F) % Vulnerable to poverty **ECONOMIC CAPACITY AND INCOME** G) Per capita income H) Gini index	**GOVERNMENT AND AUTHORITIES** A) Governmental corruption index **DISASTER PREPAREDNESS AND EARLY WARNING** B) Structural measures to reduce disaster risk C) Disaster risk management to Floods D) Disaster risk management to Landslides E) Vulnerable population to disasters (floods, landslides) is registered in housing programs F) Local structure for disaster response **MEDICAL SERVICES** G) Number of physicians per 1,000 inhabitants H) Number of hospital beds per 1,000 inhabitants **SOCIAL NETWORKS, FAMILY AND SELF-HELP** **MATERIAL COVERAGE** I) Coverage level of income-transfer program (Bolsa Familia, 2012)	**EDUCATION AND RESEARCH** A) Illiteracy rate - 15 years or more B) % 15-24 years in primary C) % 18-24 years in secondary D) % 15-17 years in terciary **GENDER EQUITY** E) Institution responsible for the formulation, coordination and implementation of policies for women with specific budget F) County has a Plan of Policies for Women G) % Of mothers household heads without complete primary, with children under 15 years **ENVIRONMENTAL STATUS / ECOSYSTEM PROTECTION** H) Specific policies and actions for the environment I) Share of deforestation J) Conservation areas L) Fire spots (2014) **ADAPTATION STRATEGIES** M) Legislation and Planning Instruments N) Specific planning tools to prevent disasters O) Commitments Schedule of the Millennium Development Goals - Manager joined the Agenda of Commitments **INVESTMENTS** P) Life expectancy at birth

Indicators underlined in grey: Indicators without existing data, limited data availability or without the possibility of validation.

Figure 2: Components with sub-categories and selected indicators for the index.

Source: own figure

The number of people exposed per hazard and per Brazilian county was derived by calculating the zonal statistics with ArcGIS 10. It should be noted that the global data for exposure are based on model calculations and thus some uncertainty in the calculation model has to be taken into account. Considering emerging risks posed by climate change, as well as the considerable population group that inhabits the coastal area in Brazil, it was decided, in accordance with the original methodology, to integrate exposure to sea level rise into the index. Since there was no information on physical exposure to sea level rise available in the PREVIEW Platform, this information was derived from the SRTM[2] image database from the EarthExplorer website (US Geological Service - USGS). The information was used to generate a relief contour of 1 meter, corresponding to sea level rise scenario. The area impacted by the projected sea level rise was then used to determine the exposed population, based on Brazil's population grid (mentioned above), combined with zonal statistics created using the ArcGIS 10. Nevertheless, the indicator for population exposed to sea level rise measures the population proportion currently (as of 2010) living in an area that may be affected by 1 meter sea level rise. This means there is a lack in terms of probabilistic component intrinsic to the other three hazards for estimating the exposed population.

The population exposed per county in Brazil was estimated through the zonal statistics calculation. However, to reduce the impact of sea level rise exposure on the overall exposure index, this indicator was weighted with 0.5, since it is a gradual process and lacks a probabilistic component. The same weighting (0.5) was applied to the population exposed to drought, given that this calculation and the data might overestimate the number of

[1] The use of population grid is justified by the fact that it is a raster image whose pixel represents the number of population in 1 km² area. Thus, this enables spatial distribution of the population and the application of GIS techniques with more accuracy of the spatial analysis. Other spacial units such as census sector of IBGE were not used because they do not hold a spatial and statistical regularity.

[2] *Shuttle Radar Topography Mission.*

exposed population, taking into account the complexity of this phenomenon and the less accurate data (Peduzzi et al ., 2009). Finally, the entire population exposed to hazard was calculated and divided by the total population of each county to obtain a single exposure index by county.

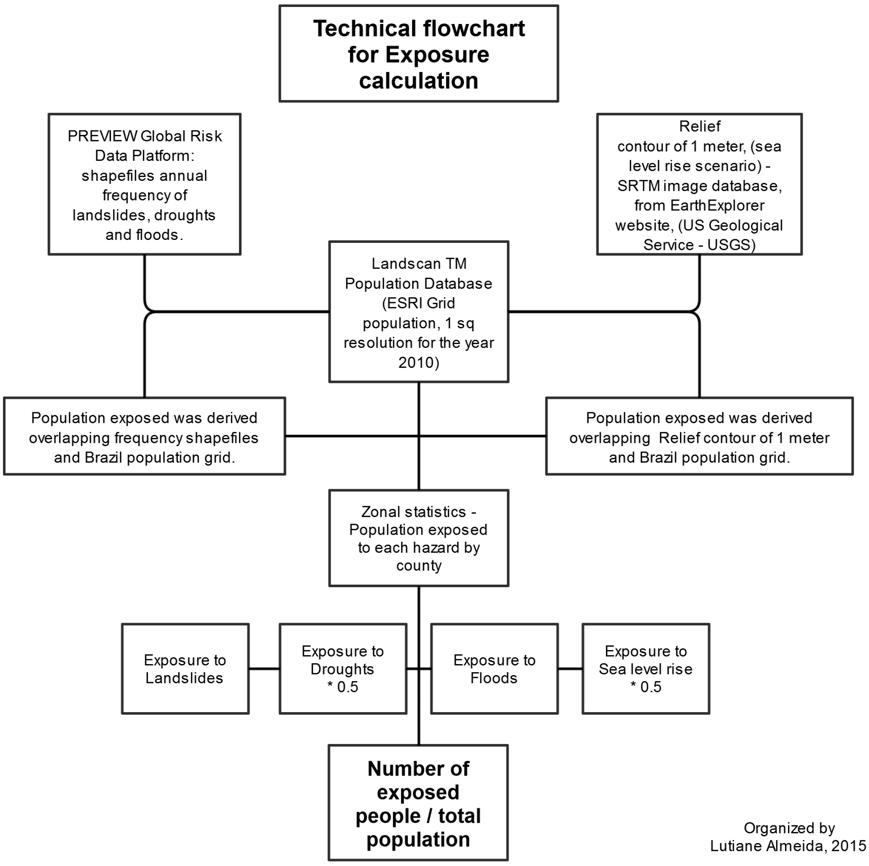

Figure 3: Technical flowchart for Exposure calculation.

Source: own figure

Susceptibility

The susceptibility index provides an overview of the indicators used to describe susceptibility of societies and social groups to natural hazards, at the local level (county) with local and regional comparison. This component comprises eight indicators distributed among four sub-categories: economic capacity and income, poverty and dependencies, housing conditions and public infrastructure. Nutrition data could not be integrated into the index aggregation, because data available are not suitable to the scale analysis of this research. The input data for susceptibility indicators (A-H) have been converted into non-dimensional ranks with values between 0 and 1. Hence, the susceptibility index is aggregated according to the stated weights, and their spatial information contained on the map.

Coping capacity

The coping capacity index was calculated based on several indicators that determine the capacity of a county to immediately manage or react to the impact of a hazardous process. This index captures the material conditions and resources used by a society in an emergency, such as material protection or medical services, as well as structures that could inhibit the coping of a county, such as corruption, weak governance, and lack of disaster preparedness. It is necessary to explain that the sub-category social networks, family and self-help could not be included due to insufficient data on the county level. For the aggregation of the index, the lack of coping capacities is included, since the overall sum of the vulnerability components will be a measure of deficiencies in societal capacities to deal with natural hazards and climate change impacts. In this respect, the value of each indicator is subtracted from 1 to compose the lack of coping capacities index, that is displayed in the map.

Adaptive capacity

Indicators for capturing characteristics of adaptive capacities of a county and its population seek to demonstrate the long-term response capacities to natural hazards and/or climate change. This component indicates the ability of a society/community to transform or adapt in an effort to reduce vulnerability to these changes and impacts. The adaptive capacity component contains five sub-categories: education and research, gender equity, environmental status/ecosystem protection, adaptation strategies and investments. As with the lack of coping capacities index calculation, adaptive capacity was also aggregated into the overall index referring to lack of adaptive capacities.

Calculation of the index

It was previously demonstrated that each component of the index – exposure, susceptibility, lack of coping capacities and lack of adaptive capacities – has been calculated separately. Intending to obtain an overview of vulnerability, the components susceptibility, lack of coping capacities and lack of adaptive capacities were aggregated into one vulnerability index that characterises societal conditions and processes essential to dealing with disaster risk in the context of climate change and natural hazards. Overall, the vulnerability index indicates whether a disaster may ensue if a natural hazard occurs. Ultimately, the vulnerability index is multiplied by exposure, comprising the magnitude and frequency of hazards, to obtain the risk. The fundamental hypothesis for the multiplication of exposure is, that if a vulnerable society is not exposed to a natural hazard, the level of risk will be zero (even if it is known that in practice there is no such thing as zero risk). The index results have been calculated with non-dimensional ranks with values between 0 and 1. The figure 4 displays the formula that outlines how the index was calculated including its weightings for components.

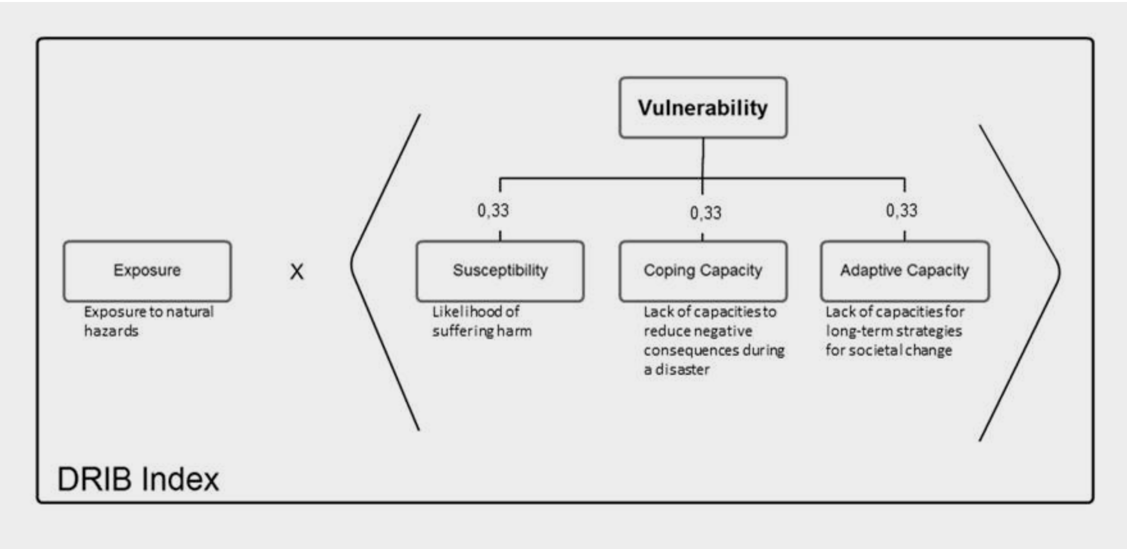

Figure 4: Calculation of the index.

RESULTS

Exposure

The map of exposure (figure 7) displays the potential exposure of individual counties to natural hazards, such as landslides, floods and droughts, as well as the exposure of populations to one-meter sea level rise for each county on the Brazilian coast (see exposure maps for each hazard type in the figures 5 and 6). It is clearly demonstrated that the main hotspot regions for exposure are counties located in the South Region; North Region, above all in the watershed of the Amazon river; counties in eastern coast of the Northeast Region (figure 7).

In absolute terms, the largest urban areas in Brazil have huge populations exposed to natural hazards, particularly the cities of Rio de Janeiro (more than 2 million people exposed to landslides); São Paulo and Porto Alegre (respectively, 3.6 million and more than 3 million people exposed to floods); Sao Paulo, Rio de Janeiro and Fortaleza (respectively, 1.12 million, almost 800,000 and more than 650,000 people exposed to drought). With regard to the consequences of climate change, major urban areas in Brazil have large populations potentially exposed to rising sea levels. The cities of Vila Velha and Vitória (Espírito Santo) and Salvador (Bahia) present high exposure to sea level rising, in both absolute and relative terms. In relative terms, 100% of the population of Madre de Deus (Bahia) is potentially exposed to sea level rise.

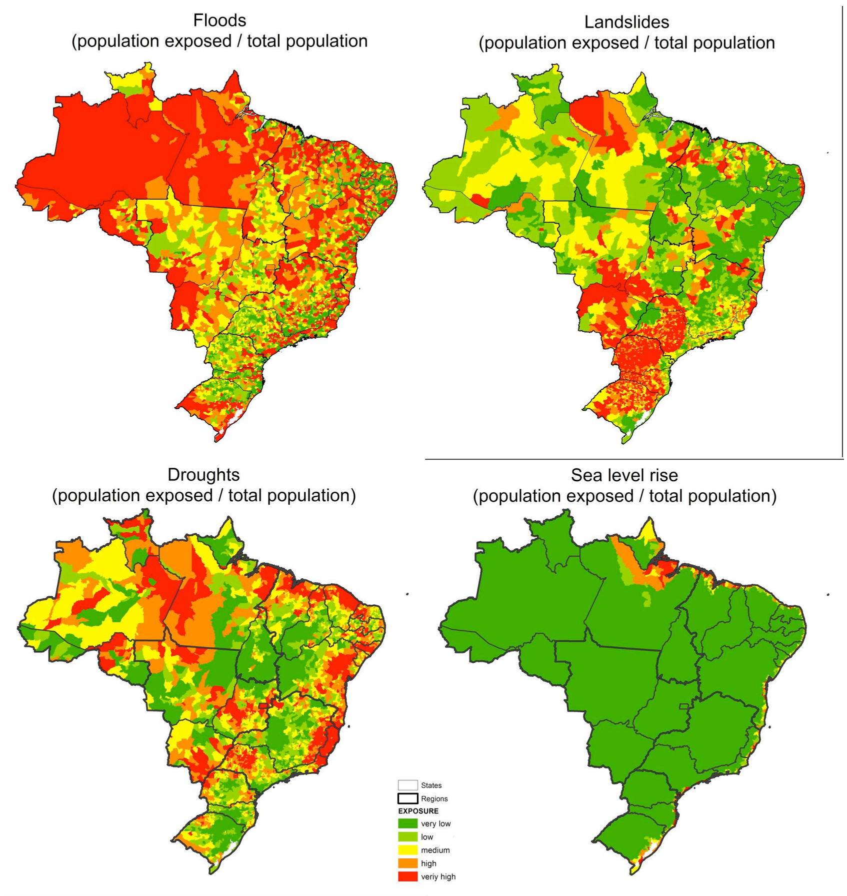

Figure 5: Exposure to natural hazards used in Index (by county).

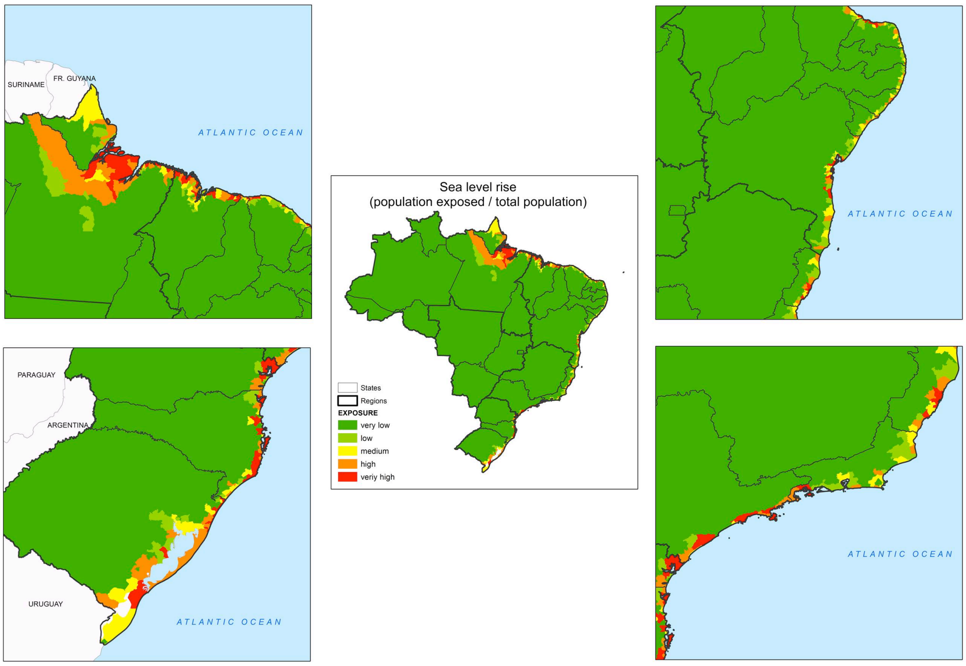

Figure 6: Exposure to sea level rise in Index (by county).

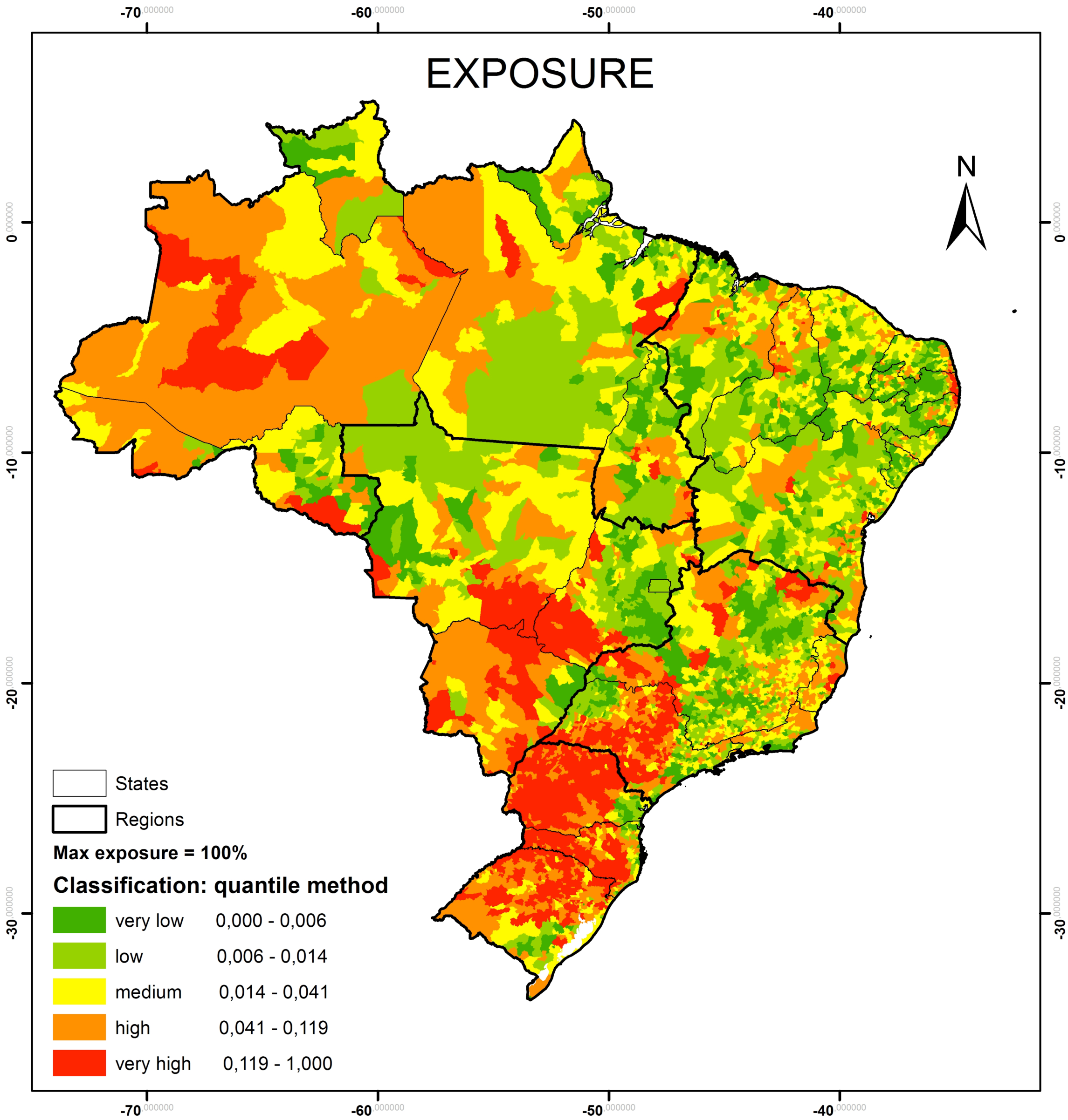

Figure 7: Exposure map (by county).

Susceptibility

There is a distinctive division north-south division with regard to susceptibility in Brazil. Most counties in the North Region (253 counties, 56% of all counties in the region) have very high levels of susceptibility. Another area with very high levels of susceptibility is the Northeast Region, with 791 counties (44.1% of all counties in the region). Thus, 93.71% of the counties of very high susceptibility group are concentrated in the North and Northeast Regions (figure 8). In the Northeast Region, the state that showed most counties with very high susceptibility levels is the Maranhão (86.18% of all counties in this state). Of the 20 most susceptible counties, most are located in the state of Amazonas (15 counties).

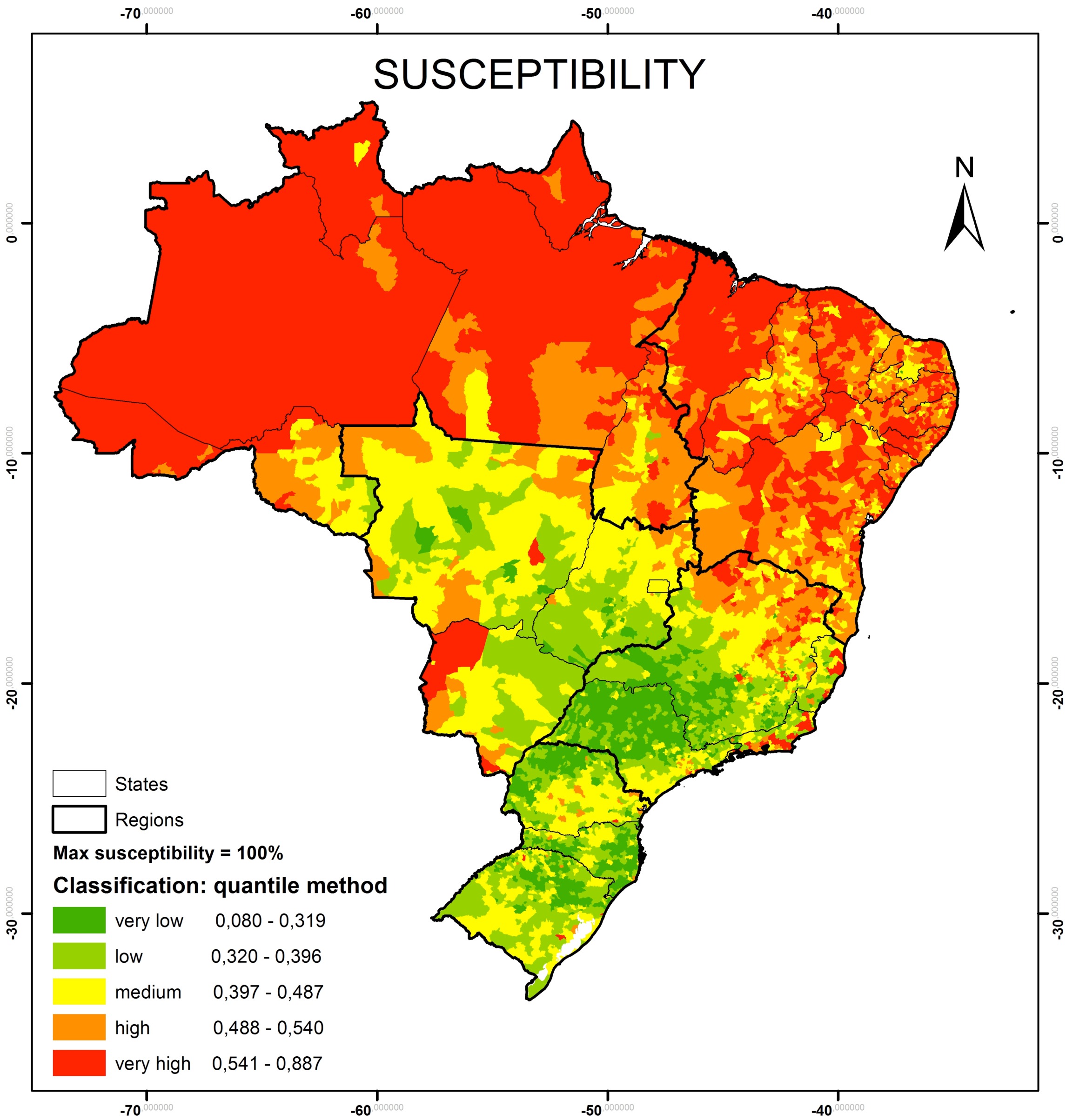

Figure 8: Susceptibility map (by county).

Lack of Coping Capacities

Among Brazil's 5,565 counties, 1,114 (20.02%) present a high level of lack of coping capacities, which simply means that 1 in 5 counties has serious weaknesses with regard to the ability to react immediately or to manage impacts of a disaster. Overall, there is no apparent spatial pattern (figure 9), as there was with susceptibility, but the lack of coping capacities in Brazil is rather widespread. Counties in the states of Minas Gerais (6 counties), São Paulo (4 counties) and Maranhão (3 counties - Brejo de Areia is the county that had the higher level of lack of coping capacity) are among the 20 higher level counties in terms of lack of capacities for coping with adverse events or disasters. Among the 100 counties of higher level of lack of coping capacities, the result is similar to the previous: 20 counties in São Paulo and 38 in Minas Gerais.

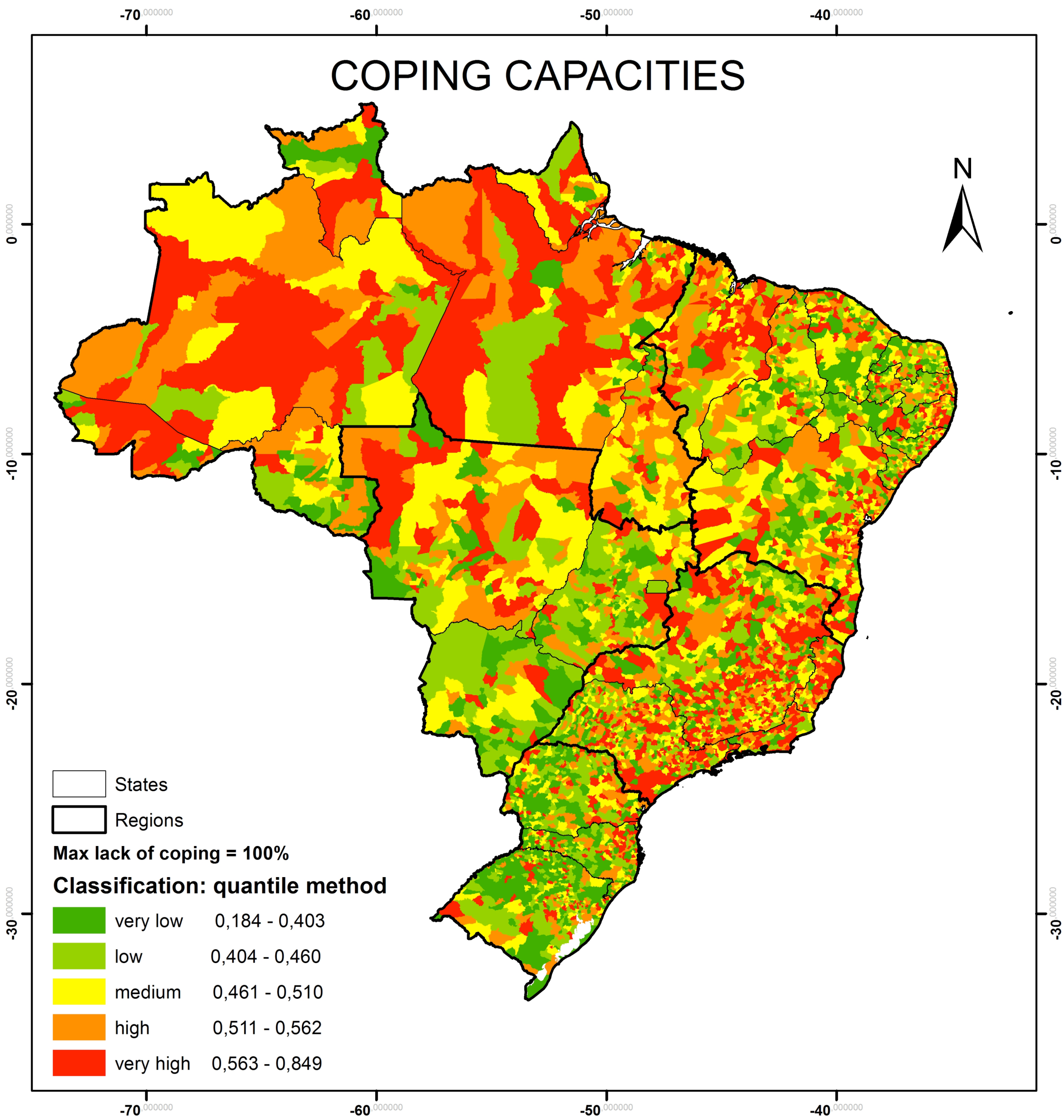

Figure 9: Lack of Coping Capacities map (by county).

Lack of Adaptive Capacities

Lack of adaptive capacities hotspots can be clearly seen in the states of Piauí and Maranhão; counties that are part of the arc of deforestation in the Amazon rainforest (Acre, RO, northern MT, TO, PA and MA); agreste region of the states of RN, PB, PE, AL, SE; BA Sertão; Northern and Southeastern MG; west and Ribeira Valley in SP (figure 10). Of the 100 counties with the most severe lack of adaptive capacities, 75 are located in the Northeast Region of the country, including 22 counties in Maranhão and 22 in Piauí. Among the top 20 counties in this category, it is possible once again to highlight the states of Maranhão (4 counties) and Piauí (4 counties).

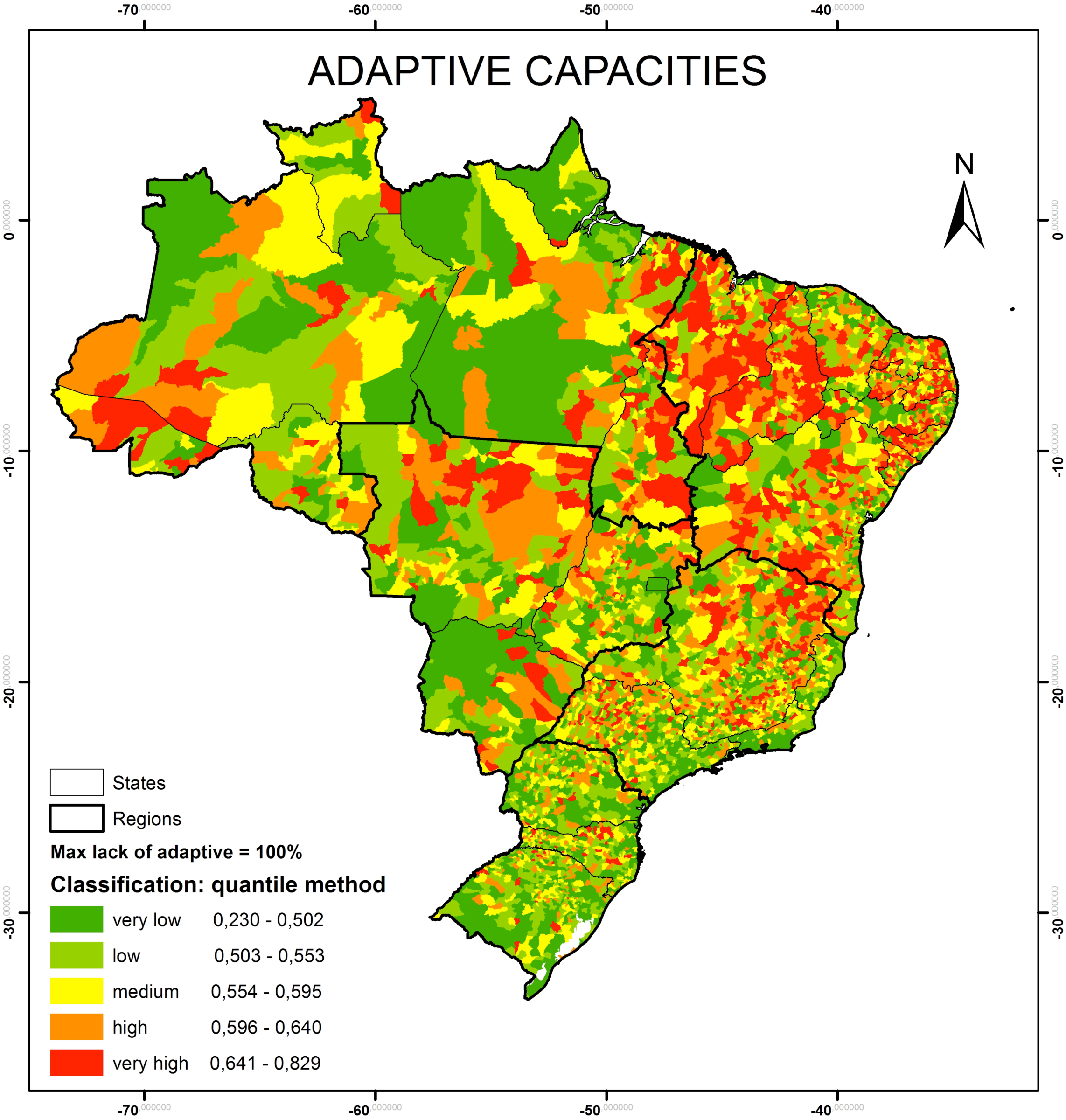

Figure 10: Lack of Adaptive Capacities map (by county).

Vulnerability

The hotspots of vulnerability in Brazil (figure 11) are clearly located in the counties in North and Northeast Regions. Other states hold counties with very high vulnerability but they are more spatially isolated (Northern Minas Gerais and in the Ribeira Valley in the south of SP). In the group of counties with highest vulnerability (1,113 counties), 8 states contained 778 counties (69.9% of this group), almost all of them in North and Northeast Regions. Besides that, in this group, 711 counties are in the Northeast Region and 182 in the North Region, totalling 893 counties in very high level of vulnerability, which corresponds to 80.23% of the group and

16.04% of all counties. Among the 100 most vulnerable counties, 5 states concentrated 69 counties, of which 58 are located in the North and Northeast Regions.

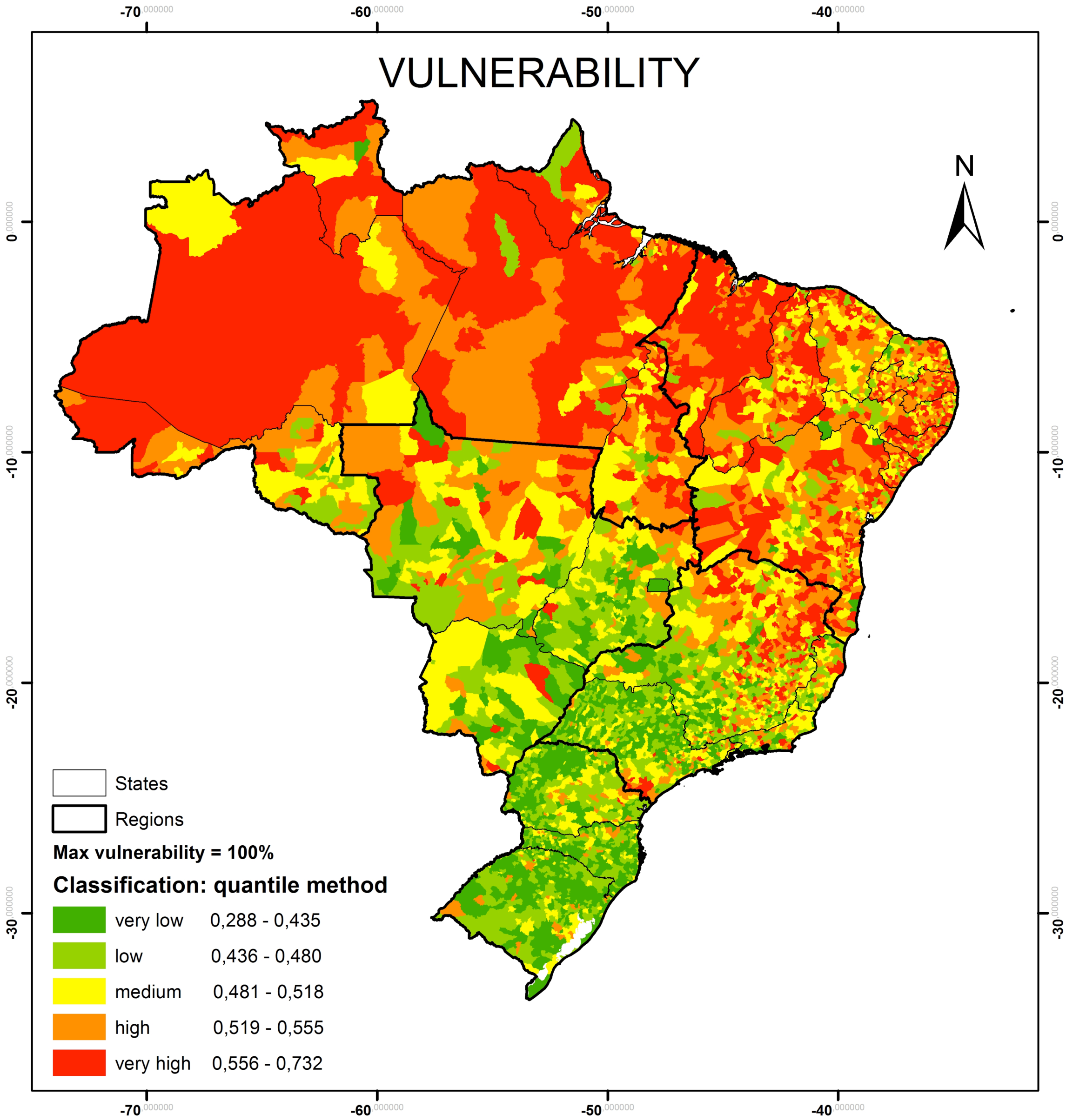

Figure 11: Vulnerability map (by county).

The Disaster Risk Index in Brazil

The final result of the construction of the index is the Disaster Risk Map, which is a product of exposure and vulnerability analysis and shows the risk outlook for the 5,565 Brazilian counties. The map (figure 12) shows the result of the formula shown in the figure 3, combining/overlaying exposure to natural hazards and climatic changes with vulnerability in the counties. In general, the strong influence of exposure in the final risk level can be observed, because the spatial patterns of counties at high and very high risk follow the general patterns of exposure, with hotspots in the North Region, especially in the watershed of the Amazon River; counties in the east region of the Northeastern Region coast ; Northern MG; central parts and coastal area of SP; the midwest of

PR; Itajai-Açu River Valley in SC; the mountainous regions of the states of MG, ES, RJ, SP, PR, SC and RS; Paraíba do Sul Valley (SP and RJ); coastal area of ES; large areas of the states in the south of Central West region.

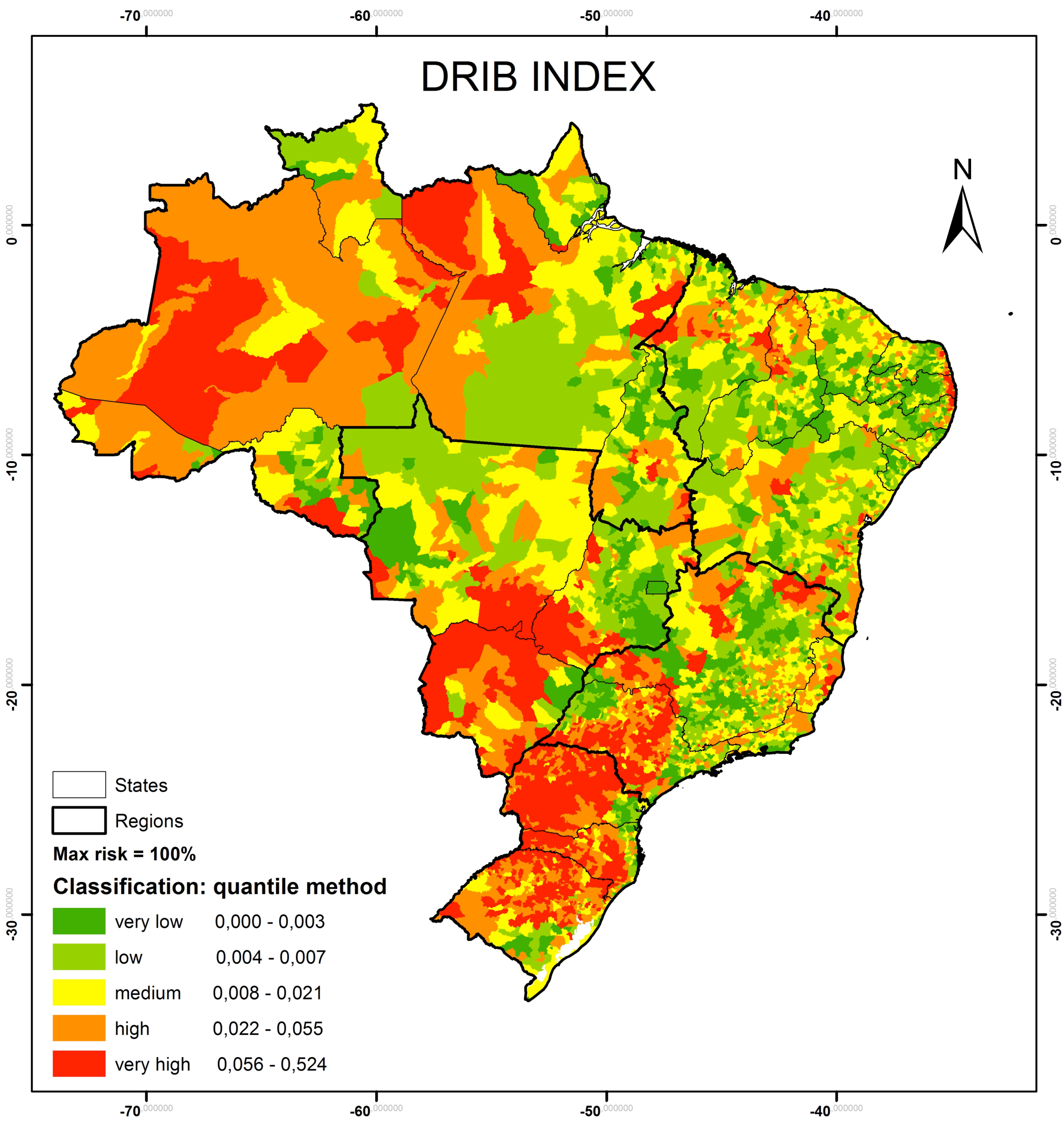

Figure 12: Risk map (by county).

Eight of the top 10 counties have very high level of exposure. Nevertheless, the risk can be reduced in these counties as a function of their moderate levels of vulnerability. In this group, the very high level of exposure is due to the very high exposure to landslides, mainly in counties located in the Centre-South of the country. However, because of the very high vulnerability in the North and Northeast counties, events with same magnitude could cause more serious and these counties would have more difficulties in coping and recover from the impacts of a given disaster if compared with counties from the south-centre area of the country.

DISCUSSION

Above all, the results analysis of natural disasters risk index in Brazil shows that the counties in very high risk situations have very high exposure to natural hazards, especially counties located in the South Region, but hold relatively moderate to low vulnerability, making these counties less susceptible, more capable of coping with the occurrence of these phenomena and adapting to social and environmental changes that may occur in the medium to long term. On the other hand, counties located in the basin of the Amazon River (mainly) and in the Northeast Region face high exposure conditions to natural hazards (not as high as the counties in the South Region), however they have serious conditions of susceptibility, very low capacities for dealing with, coping, facing and recovering from adverse conditions that arise when disaster strikes, and have very low capacity for adapting to current and future social and environmental changes, taking into account climate change scenarios.

Regarding exposure, it is clear from the results that the confluence of urban areas (mainly those counties with the highest population densities), and areas with higher frequencies of occurrence of natural hazards - landslides, floods, droughts, and sea level rise, are configured in the areas where people are more likely to be affected by one or more hazardous event(s). The mountainous areas of South and Southeast Regions of the country are naturally prone to landslides (high hypsometry, steep slopes, frequent heavy rains, soils structurally susceptible to mass movement, abundance of fractured rocks). However, these processes have a disproportionate impact due to territorial structuring (urban occupation of steep slopes), modifications imposed on the environmental systems operation (deforestation, modification of topography, soil, and the water cycle in the surface and subsurface of soil). Additionally, it is the most densely populated region of the country.

As demonstrated in the presentation of the results, 80.23% of the counties in very high vulnerability condition are located in the North and Northeast Regions, especially in the latter. This means that 13.6 million people live in counties that have very high vulnerability in the Northeast Region alone, out of a total of 24.9 million people (in very high vulnerability group) living in counties that are most susceptible, have lower capacity for coping with, recovering from and adapting to changes imposed by the impacts of disasters and climate change. The clear North-South spatial division in terms of vulnerability patterns is defined mainly by the huge socio-economic inequalities between these two poles of the country, historically constructed over the past 500 years.

Indicators of susceptibility, the lack of coping capacities, and the lack of capacity to adapt to changes imposed by disasters and climate change, can contribute to buttress regional and intra-regional inequalities in Brazil which expose the Northeast Region as it holds the highest vulnerability rates in the country. In the case of lack of coping capacity, there is an alarming overlap between, on the one hand, sets of counties serious lacking in DRR and DRM indicators and, on the other, areas/regions that are heavily exposed and that display recent disasters history. Outstanding cases in this regard are the river basins of the Amazon, Parnaíba, Paraiba do Sul, Rio Doce, Itajaí-Açu, Zona da Mata of Pernambuco and Alagoas, the mountainous regions of RJ, MG, ES, SP, PR, SC, the semiarid Northeast and North of Minas Gerais.

The Northeast Region is also a source for concern because of its lack of adaptive capacities. Among the counties that are very highly lacking in adaptive capacities are those located in Maranhão and Piauí, which show negative indicators in illiteracy rate, mothers as household heads without completed primary education and with children under 15 years, specific policies and actions for the environment , proportion of deforestation, life expectancy at birth, fire spots, legislation and planning instruments and conservation areas. These are counties with low capacity for adapting to changes imposed by disasters and/or climate change. Maranhão is among the states with the highest deforestation rates in the Amazon rainforest, low rates of existence of conservation areas, high rates of fire hotspots, while showing very negative social indicators. These factors combined place Maranhão among the states most vulnerable to disaster risk and climate change in Brazil.

In overview, the results of the indicators establish the spatial patterns of risk of natural disaster in Brazil (as a product of exposure to natural hazards in terms of vulnerability). The areas that cause concern exhibit spatial patterns in which highlights counties which compose: Significant parts of the Amazon river basin, exposed to periodic floods, drought and potential sea level rise in your mouth / coast; Eastern Pará and Western Maranhão, exposed to floods, drought and landslides; Eastern coast of the Northeast Region in the states of RN, PB, PE and Recôncavo Baiano, exposed to landslides and floods; In the mountainous areas of the states of the Southeast and South Regions, predominately exposed to landslides, but also to floods and droughts.

It is evident that the disaster risk indicators in Brazil exhibit, once again, one North-South polarity that distinguishes counties exposed to floods and droughts (landslides in isolated spaces) in the North and Northeast Regions, which hold very high levels of vulnerability, resulting in high levels of disaster risk due to the high susceptibility, very low capacity to cope with and adapt to the socio-environmental changes imposed by disasters and climate changes; and counties greatly exposed to an overlap of multiple hazards (landslides, floods, flash floods, and droughts). The high population density located in high hypsometry and steep slopes areas, natural conditions (climate, geological structure and paedological conditions), makes them more prone to occurrences of mass movements while they are exposed to floods, droughts and potentially to sea level rise. However, exhibit lower levels of vulnerability, which makes these counties, especially those in South Region, more capable of withstanding, recovering, coping with, and adapting to the socio-economic, cultural and environmental changes that may arise with occurrence of disasters and climate changes.

CONCLUSIONS

This research represents an effort of assess vulnerability and risk in a more comprehensive way, considering indicators of exposure, susceptibility, coping and adaptive capacities. This disaster risk index is a quantitative approach that seeks a concept for risk and vulnerability analysis integrating national/local scales.

This type of approach has great potential for measuring exposure, susceptibility, coping and adaptive capacities because it uses indicators that outline revealed vulnerability of past events (Welle et al., 2013).

Nevertheless, the ability of these tools/datasets to capture local-specific risk and vulnerability is limited to a certain extent, then it is necessary approaches at the local level to capture specific characteristics of vulnerability (e.g. social networks, risk governance and performance of local governments in disaster risk management) and exposure (e.g. geo-environmental context assessment).

Specifically, the results of disaster risk indicators in Brazil showed that the risk is strongly interwoven with social-economic and cultural conditions and normal everyday life, as well as with the performance of state institutions dealing with DRR and DRM, in other words, vulnerability.

Spatial trends of disaster risk and vulnerability, products of this research, also have stressed the serious inequalities between and within regions of the country, which result in barriers to the development of the DRR and DRM in Brazil as a whole.

Therefore, the quantitative results and the spatial patterns that have been established on disaster risk indicators may stimulate further discussions, at the academic level and at the level of risk governance, on how to reduce exposure and susceptibility on the one hand, and on the other hand increase/improve the capacities to cope and adapt to the consequences of natural hazards.

Despite recent improvements related to planning, decision-making, risk culture and academic discussion of disasters in Brazil, especially after the disaster in the mountainous region of Rio de Janeiro in January 2011, much effort is still needed to make the country more resilient to current/daily and future disasters, with special attention to the local level, with the county being the most problematic, from a DRR/DRM point of view.

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