Increased resilience for the economic development from climate and hydrological scenarios in the future Brazil: a proposal for the integration of risk assessment and multi-scale approach

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1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) shows that the climate change, especially in South America, imposes great threat to sustainable development since it directly and indirectly affects much of the population, public health, water resources, urban and rural infrastructures, coastal areas, forests, biodiversity as well as the economic sectors (agriculture, fishing, forestry production, power generation, industries) and their respective production chains.

Given this trend scenario, the accumulation of scientific and technical training to support the decision-making becomes as timely as challenging in order to allow the planning of public or private investments not only from observed data and safety factors, but also from projected data, taking into consideration the uncertainties in the decision-making process.

Thus, the Brazilian government has been working in the production of climate and hydrological scenarios - qualitative and quantitative information - to support discussions about a prospective planning that takes into account the increased resilience for the economic development as a central issue as well as the climate change as a boundary condition.

Nevertheless, it has become increasingly evident that the environmental parameters are no longer stationary, a fact that suggests the need to think about the dimensioning of assets (infrastructure) able to provide certain environmental resource to users.

Therefore, the need to think about the existing and in-planning assets essentially involves the reasoning on the proposal for a multi-scale approach of measures to increase resilience. As much as possible, this approach should take into

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consideration prospective information derived from climate modeling. Such approach aims to extend the working life and the benefits of public investments in water-resource infrastructures in order to preserve natural resources and meet the user's expectations.

2. METHODOLOGY

2.1 Reinterpreting the Risk Assessment steps

The risk assessment of the increased resilience for the economic development of water-user sectors requires a risk assessment that takes under consideration aspects such as hazard, exposure, vulnerability and capacity.

According to Wang *et al.* (2014), identifying the "hazard" is the first step for Risk Assessment. According to Wang (2015), "hazard is usually considered an external event that generates stimuli such as stresses and pressures able to cause a disaster within a system. As for the cities, it may be seen in the form of extreme weather events such as heat waves, cyclones, tornadoes, droughts, floods and fires caused by climatic events combined with other factors."

"Exposure" is associated with the geographic issue in which a given infrastructure asset under analysis is exposed to a certain condition, according to a specific scenario of the variable that may influence the performance of a given infrastructure.

Then, according to Wang *et al*. (2014), "vulnerability" is considered to be the sensitivity of a system of interest and the probability of loss related to a given hazard and a scenario under analysis. In this case, the loss may be associated with performance/functionality decrease, which is often represented by monetary units. According to the authors, vulnerability assessment is the key step to understand how a given system is a function of different exposure scenarios considering a given hazard.

Finally, according to Wang *et al.* (2014), "capacity" is seen as the system's ability to accommodate (future) impacts arising from a given scenario, hazard, exposure and vulnerability without losing the system's functionality and integrity. Usually, they may be described as social, human, financial, environmental and physical capitals, although there are many other representations. The capacity reinforcement could benefit from mitigating actions.

Figure 2.1 illustrates the steps for determining measures that may provide increased resilience and thus extend the benefits of investments over the asset's useful life by considering the proposal for a multi-scale approach with variation in the uncertainties and necessary details.

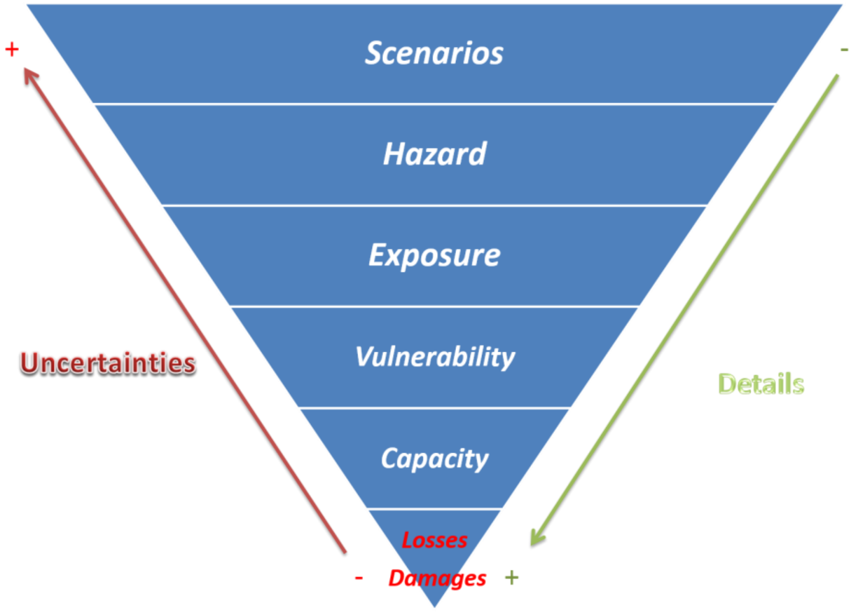

Figure 2.1 – Risk assessment steps to assess infrastructure assets. (Prepared by the authors)

Regarding the water resource infrastructure assets, the measurement of losses and damages generates less uncertainty in their metrics due to a big amount of details. Diametrically opposite, the use of scenarios with low occurrence of details leads to greater uncertainty.

2.2 Presenting the multi-scale approach according to Wang (2014)

The studies by Wang (2014) have made significant contributions to the understanding of resilience-enhancement measures in infrastructure sectors in general.

Figure 2.2 summarizes the multi-scale approach suggested by Wang (2014) for infrastructure sectors. Such approach shows the correspondence between the actions to increase resilience (standards, planning measures, regulatory policies and national priorities) and the elements that comprise the infrastructure network (materials, structures, systems and integration between systems).

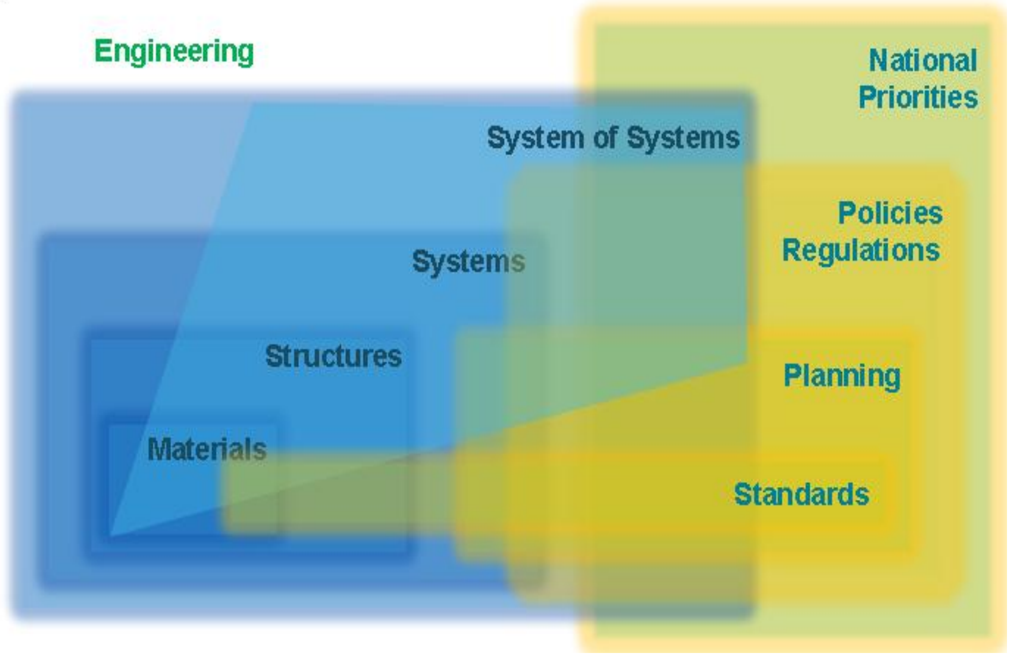

Figure 2.2 – Responses in terms of multi-scale approach. (Wang, 2014)

In this regard, it is worth emphasizing the importance of this proposal by Wang (2014) who summarizes the locus of action of the measures to increase resilience in different infrastructure sectors, including water resources.

2.3 Proposal for the integration between Risk Assessment and the Multi-scale Approach by Wang

According to Figures 2.1 and 2.2, which are based on the herein described scenarios, it is possible to identify the degree of exposure, build the vulnerability curves depending on the response capacity related to environmental parameter variations and to obtain the dose-response relations in the actions required to mitigate impacts on the existing infrastructure, as well as to remodel the future infrastructures according to such relations.

In the context of this proposal for integrating the Risk Assessment and the Multi-scale Approach by Wang (2014), one may initially use publicly available (www.inde.gov.br) quantitative projections of rainfall and temperature results arising from regional climate models (downscalling - 20 x 20 km) – EtaHadgen and EtaMiroc 5 – for the Representative Concentration Pathways (RCPs) 4.5 and 8.5 developed by the National Institute for Space Research (INPE- Instituto Nacional de Pesquisas Espaciais) as well as qualitative projections of water availability in the Base Stations of the National Electric System Operator (ONS – from previously described regional scenarios).

Based on the above mentioned, the development methodology in the current study meets the logic of the strata suggested in the multi-scale approach context. Figure 2.3 illustrates all the suggested methodological sequence.

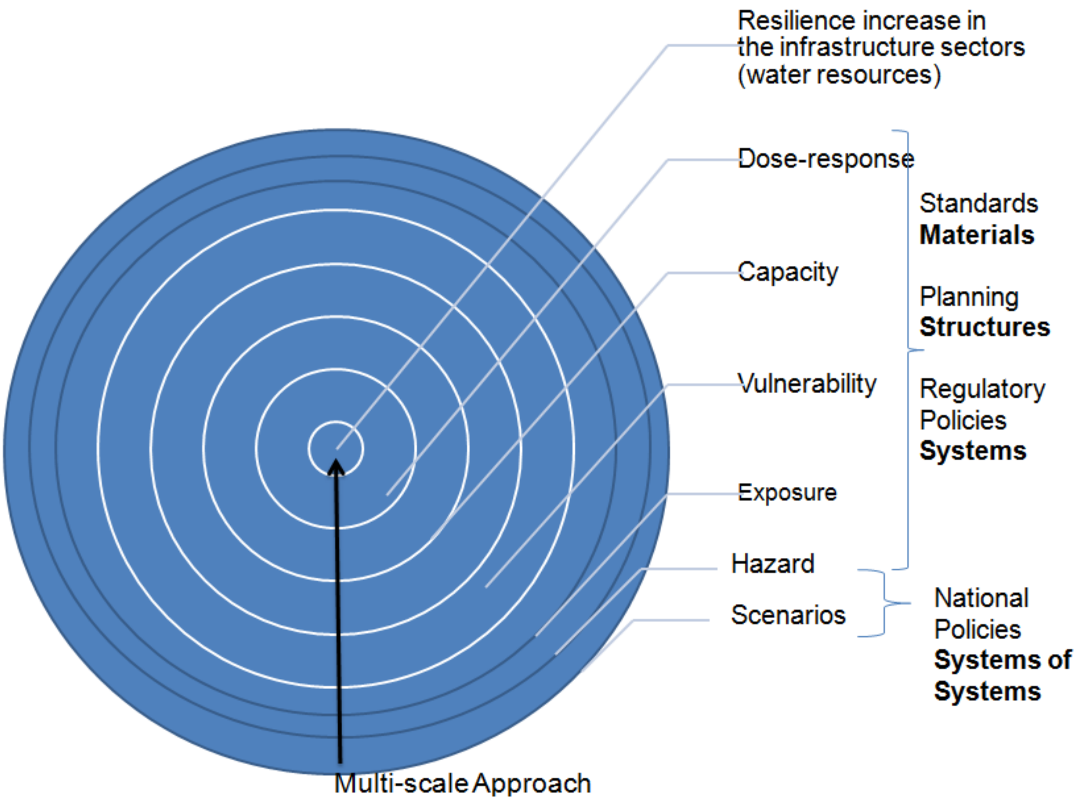

Figure 2.3 – Methodological proposal for integrating the Risk Assessment and the Multi-scale Approach by Wang (2014). (Prepared by the authors)

Figure 2.3 shows the proposal for the methodological integration of Risk Assessment and the Multi-scale Approach by Wang (2014). The successive performance of different risk assessment steps collated with the Multi-scale Approach by Wang (2014) suggests the coupling of these theoretical constructs, taking as its central goal the resilience increase in the infrastructure sectors (water resources). Thus, the multi-scale approach between National Policies and Systems of Systems suggested by Wang fits the scenarios to reduce uncertainties or to search for the target scenario for a specific public policy. According to Wang (2014), regulatory policies and planning may subsidize the sector in question with regard to the specific exposure, vulnerability and the capacity it is subjected to.

3. STEPS FOR APPLYING THE INTEGRATION PROPOSAL OF RISK ASSESSMENT AND THE MULTI-SCALE APPROACH BY WANG (2014)

3.1 Scenarios

In this sense, the development of climate scenarios using climate models is critical for understanding the potential impacts caused by climate changes. The vulnerability assessment and the development of strategies and actions for a given region are only possible if they are based on future climate projections. However, climate model simulations often show a bias arising from systematic and cumulative errors. In the current case, when dealing with Regionalized Climate Models, the errors result from the Global Climate Models. With respect to this issue, regionalized results from Climate Models Eta HadGen-2ES and Miroc5 were used in two RCP scenarios (4.5 and 8.5). Climate modeling results start from the evaluation of the current weather integration and compare it with the observed data to verify the model's ability to describe the Brazilian climate main features. Future integrations are analyzed and compared with the current weather to determine the future climate changes predicted by the Eta model linked to global models. The observational data encompasses the (1961-1990) integration period. Spatial averages (seasonal, annual and monthly) and all the available two-dimensional variables were generated in all integration periods.

3.2 Hazard and Exposure

Hazard - the factor that motivated the current study - arises from the potential occurrence of drought projected in Brazil, without losing sight of the historical series. Regarding this step, there is the introduction of regions – the object of actions -, accumulated variation of annual rainfall throughout (1961-2007) historical series below the national average, according to (ANA, 2013). Additionally, there is the exposure of water-user sectors given their location in the territory, regarding the projected scenario.

Exposure is identified according to the scenario and its corresponding featured hazard. From this point on, vulnerability and responsiveness are featured. In this step, qualitative considerations will be presented in view of the information availability for building the sensitivity curves of the assets (water-user sectors), the capacity to respond to variations in the nature parameters, among them, the rainfall.

3.3 Vulnerability, capacity and dose-response

The construction of the vulnerability curve in regards to time, the capacity curve in regards to environmental parameters and, finally, the dose-response curve in regards to climatic parameters and capacity may be developed based on the access to a robust database. Linear regressions, probability and return period calculations should be used in building the relation between capacity and climate parameters.

4. PROPOSAL FOR APPLYING THE INTEGRATION OF RISK ASSESSMENT AND THE MULTI-SCALE APPROACH BY WANG (2014) IN BRAZIL

Subsequently to the integration logic suggested in the current study, the quantitative and qualitative results from the Brazilian water-resource sector are made available to each of the steps identified in item 3.

4.1 Scenarios

Regarding the scenario step of the integration proposal suggested by the current study, Figure 4.1 provides a sample of a typical climate modeling result of the maximum rainfall amplitude in Brazil. This amplitude corresponds to the maximum difference of the (2011-2040) projection period in relation to the (1961-1990) observed period for HadGen-2ES Model, in the summer, in a forcing scenario (RCP) 8.5.

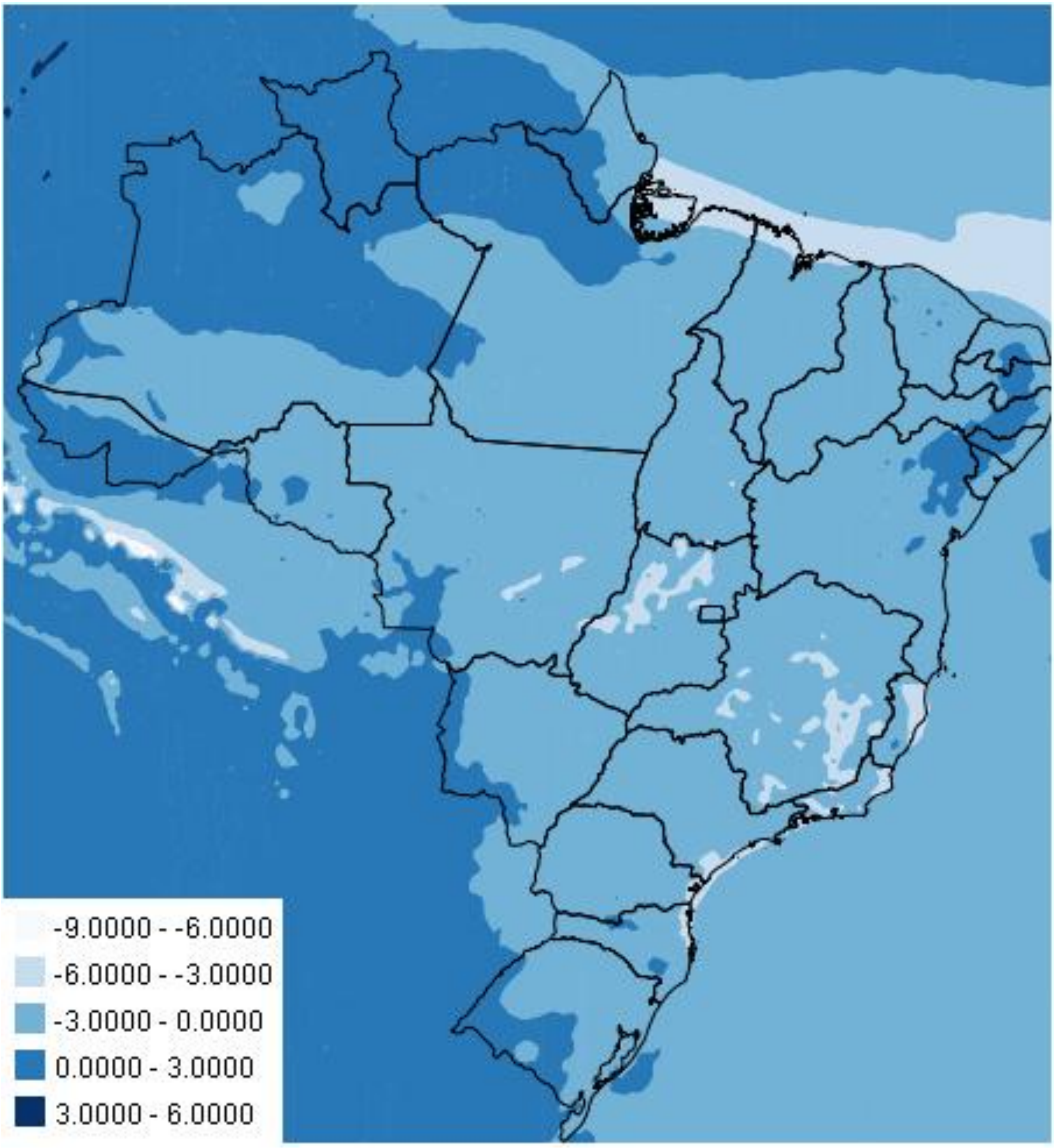

Figure 4.1 – Rainfall variation amplitude in mm/day (1961-1990 x 2011-2040) HadGen 8.5. (Access in April 2015)

4.2 Hazard and Exposure

According to the proposed methodology, this subsection presents the annual average of the (1961-2007) historical series - with emphasis to the Northeast, part of the Southeast and Midwest regions - in terms of rainfall lower than the Brazilian annual average (1761 mm). Figure 4.2 shows the annual average rainfall in Brazil by highlighting the above-mentioned regions.

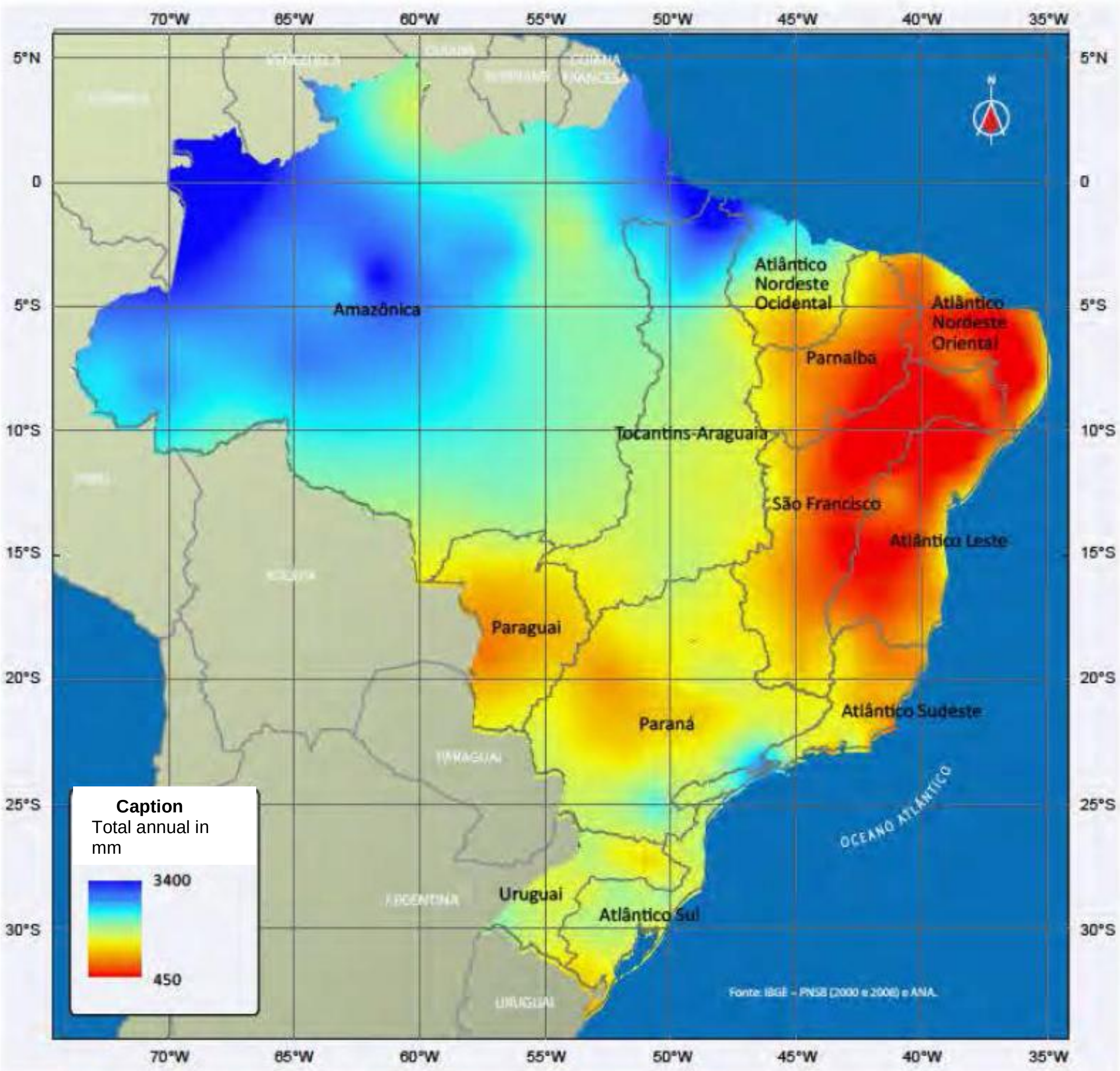

Figure 4.2 – Average annual rainfall (1961-2007) in Brazil. (ANA, 2013)

4.3 Water availability scenarios

After all the steps for rainfall bias correction, evapotranspiration estimates and, consequently, the obtainment of the past natural flow anomalies, Figure 4.3 shows the 2011-2040 period anomaly trends for each of the climate models and forcing scenarios (RCP) 4.5 and 8.5.

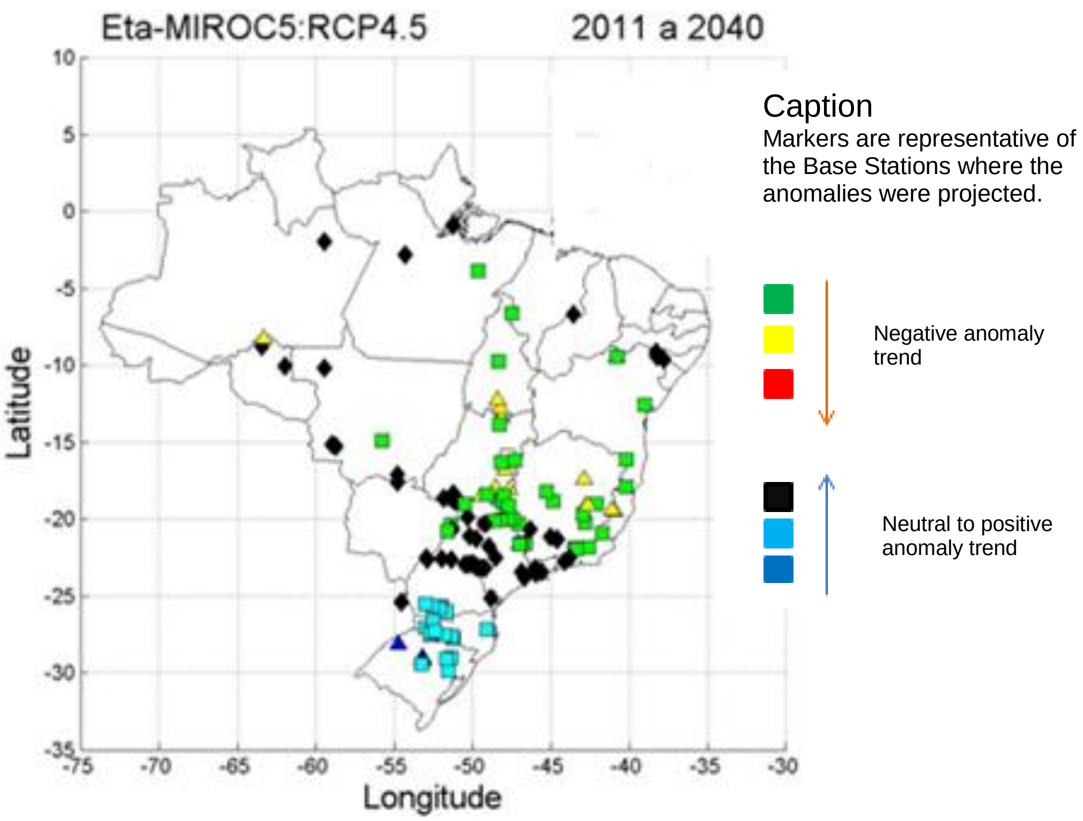

Figure 4.3 (a) – Projection of natural flow qualitative anomaly for Miroc5 (RCP-4.5)

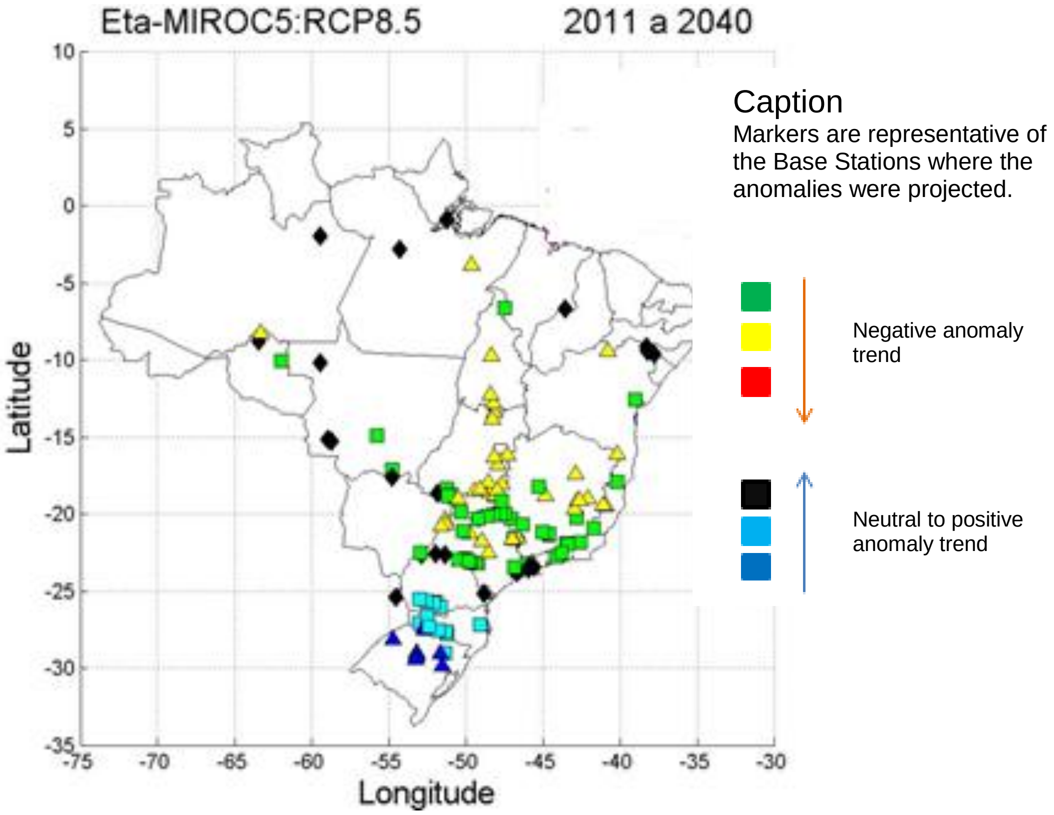

Figure 4.3 (b) – Projection of natural flow qualitative anomaly for Miroc5 (RCP-8.5)

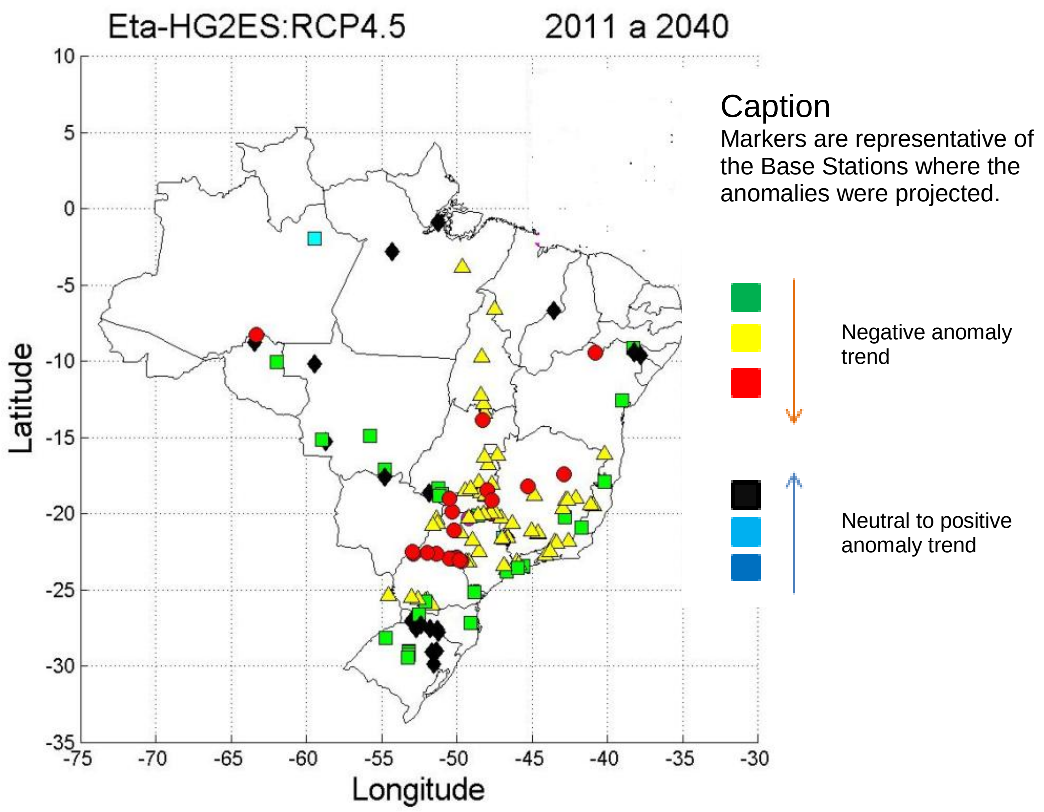

Figure 4.3 (c) – Projection of natural flow qualitative anomaly for HadGen-2ES (RCP-4.5)

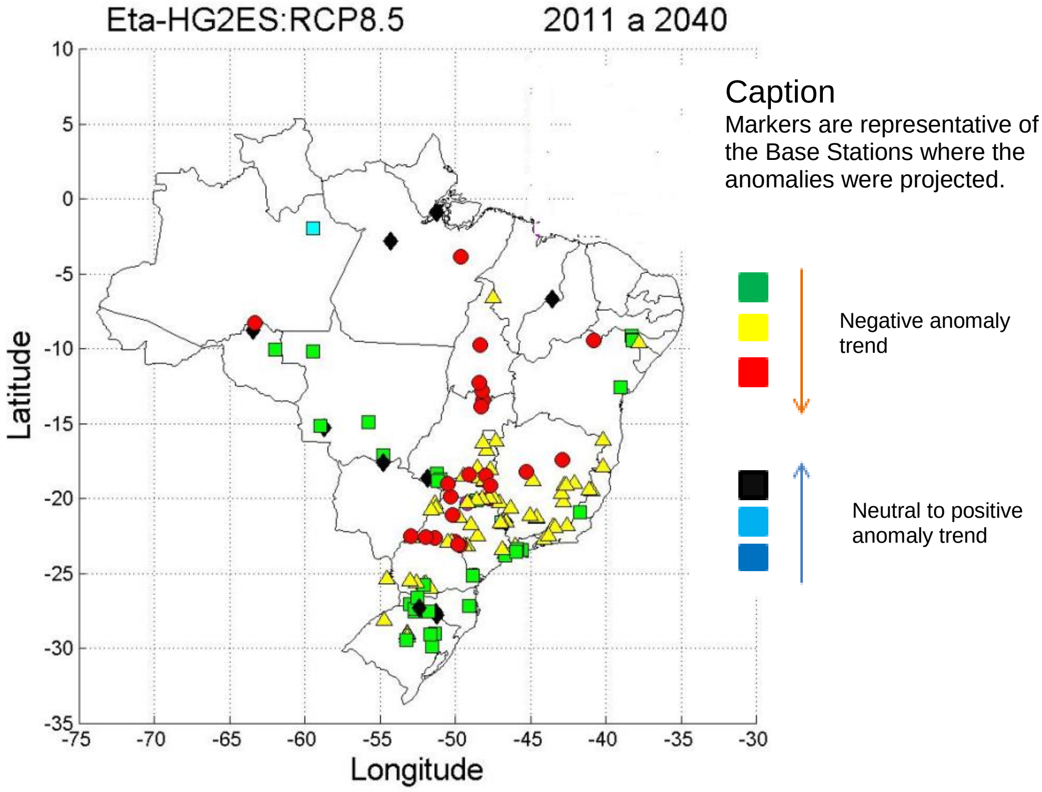

Figure 4.3 (d) – Projection of natural flow qualitative anomaly for HadGen-2ES (RCP-8.5)

Based on Figures 4.3 (a) and (b) it is possible to understand, in qualitative terms, that:

(i) Regarding Miroc5, there is a downward-flow trend in the Brazilian Center-East Region and an increasing trend in the South Region, which is enhanced when there is the change from scenario 4.5 to 8.5.

Based on Figures 4.3 (c) and (d) it is possible to understand, in qualitative terms, that:

(ii) Regarding HadGen-2ES, there is the enhancement of the natural flows downward trend in the Brazilian Central-Southeast, part of the Northeast and North Regions and low expansion of flows in the Southern Region.

4.4 Vulnerability, capacity and dose-response

The vulnerability of the water-user sectors is subjected to the water use priority. The Law 9433/2007, in its first article section III, states that, in the case of water shortage, the water-resource use priority is the consumption by humans and animals. The other uses (consumptive or non-consumptive) become restricted to the priorities previously established by regulatory authorities. Figure 4.4 presents the (qualitative) Atlas Brazil (2010) classification of water supply for human consumption taking the 2025 horizon into considering.

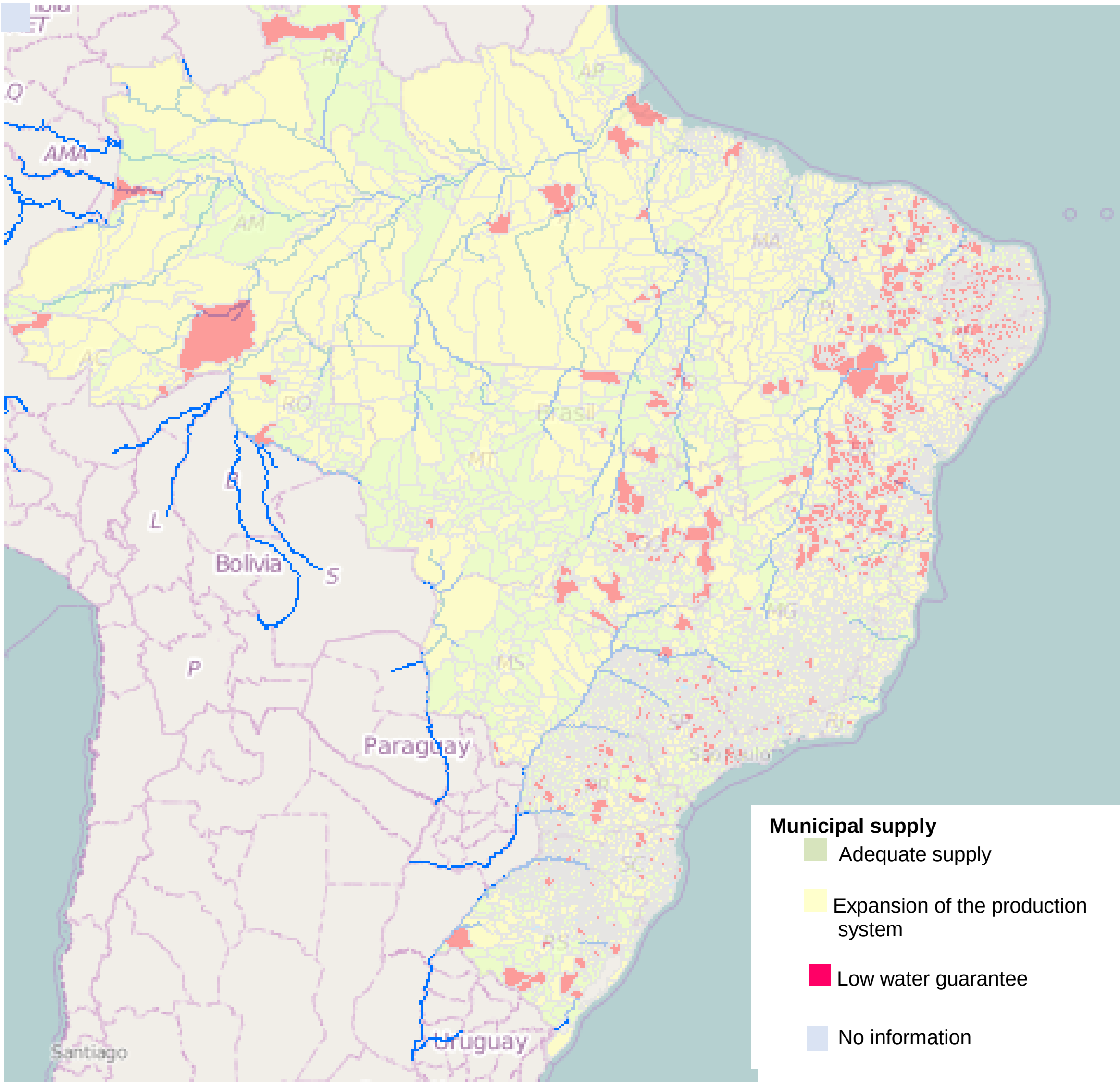

Figure 4.4 – Municipal water supply classification. (ANA, 2010)

Based on Figure 4.4, it is possible to understand that there is the need for expanding the water producing system in the North, Midwest and Southeast Regions. In addition, the Brazilian Northeastern Region as well as certain locations in the Midwestern, Northern and Southern Regions show low water guarantee. Figure 4.5 is complementary to Figure 4.4 and shows the classification suggested by the National Water Agency (2014) in terms of the criticality in some basins and river sectors in Brazil.

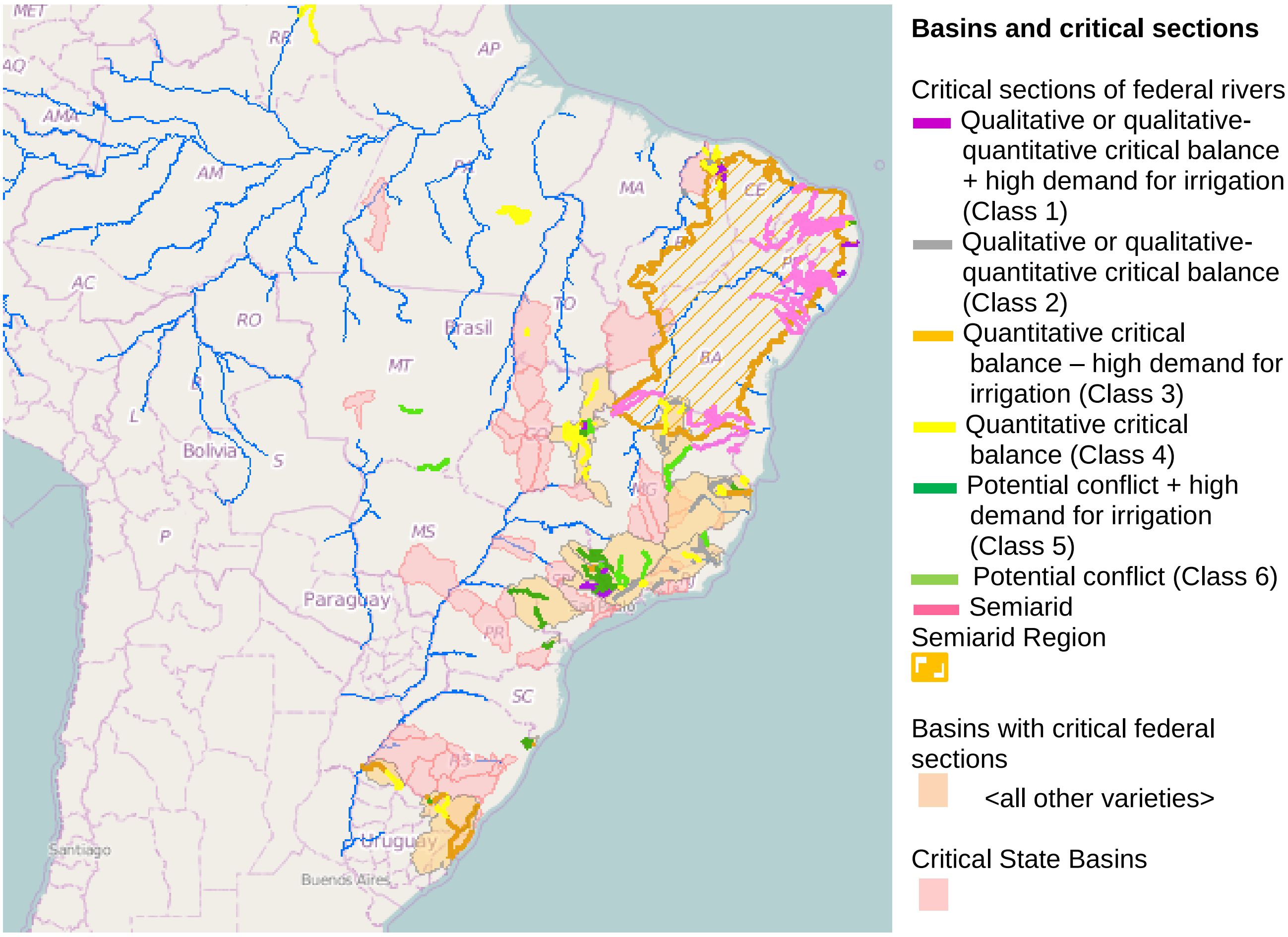

Figure 4.5 – Basins and sectors that need special attention in water resource management. (ANA, 2014)

Based on Figure 4.5, the Brazilian semiarid, as well as certain basins in the Brazilian Southeastern, Midwestern and Southern Regions, is considered critical in terms of the link between demand and supply and, ultimately, in terms of the type of water use, especially in irrigation.

Finally, since the results are in line with the suggested methodology, it turns out that the Brazilian Northern Region requires special attention to be given to investments in non-consumptive uses to enable more flexibility in water use in case of storage. Regarding the water supply for the consumption by humans, the deficit is still high, which makes the expansion essential to this region. As for the Northeast Region, especially the semiarid region, there is the need to pay attention and ensure water security since the past and future trends indicate rainfall reductions, increased temperature and the consequent water supply reduction. In the Midwestern Region, decreasing trends must to be taken under consideration by non-consumptive water-user sectors in their respective plans. In the Southeastern Region, due to the different uses with significant economic return, given the trends, it is essential to think in the increased resilience of water-user sectors in terms of storage capacity and the multiple water uses, including the link between water transport and energy generation. Fundamental attention should be given to the planning of consumptive and non-consumptive users in Southern Brazil, despite the positive trends, especially when considering the Miroc5 results.

5. FINAL CONSIDERATIONS

Natural disasters of climatic origin require the water resources infrastructure in the country to be adapted, which may be done in a multi-scale way. The first step would be the incorporation of new resiliency standards for infrastructures to be built in the country by taking under consideration the material, structure and interaction between water-user systems/sectors. The next step would be the incorporation of the same resilience standards to the country's existing infrastructure. This incorporation could be done at the time the existing infrastructure undergoes preventive maintenance processes or whenever repairs, due to damages caused by extreme weather events resulting from climate change, are needed.

It should also make the interventions according to the integrated proposal of risk assessment and multi-scale approach by Wang (2014), starting from the material up to the integration among sectors (planning).

There are only two damage reduction possibilities in the approach suggested by the current study: (i) reducing the hazard occurrence probability or / and (ii) reducing vulnerability to hazard at different levels, as suggested in Figure 2.3.

The reduction of carbon emissions and the climate change mitigation may minimize the likelihood of increased extreme events. Given the climate scenario, the impact of the hazard consequences may be reduced through water management because of the water exposure to hazard.

It is also possible to reduce the probability of exposure to climatic hazards by planning the natural resources (water) availability as well as to reduce the probability of indirect losses caused by damages inflicted to the water supply capacity and mitigate the impact to water-user sectors by developing contingency plans in response to extreme situations.

Finally, the greater challenge involves the understanding and the agreement between federal entities and society, in a way that the resilience measures increase - especially in water-user sectors - must preserve and guarantee the financial sustainability of services provided to the users and the economic return resulting from such use, as well as preserve and guarantee user's satisfaction.

Thus, changes in consumption patterns, in use and soil occupation models, prospective planning, regulatory model improvements - especially in the case of extreme hydrological events - and the internalization of water resource investments that seek multiple water uses are colossal challenges to be faced by Brazil in face of the trends in projections for environmental parameters, which are input for infrastructure assets and beneficial to the society as a whole.

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