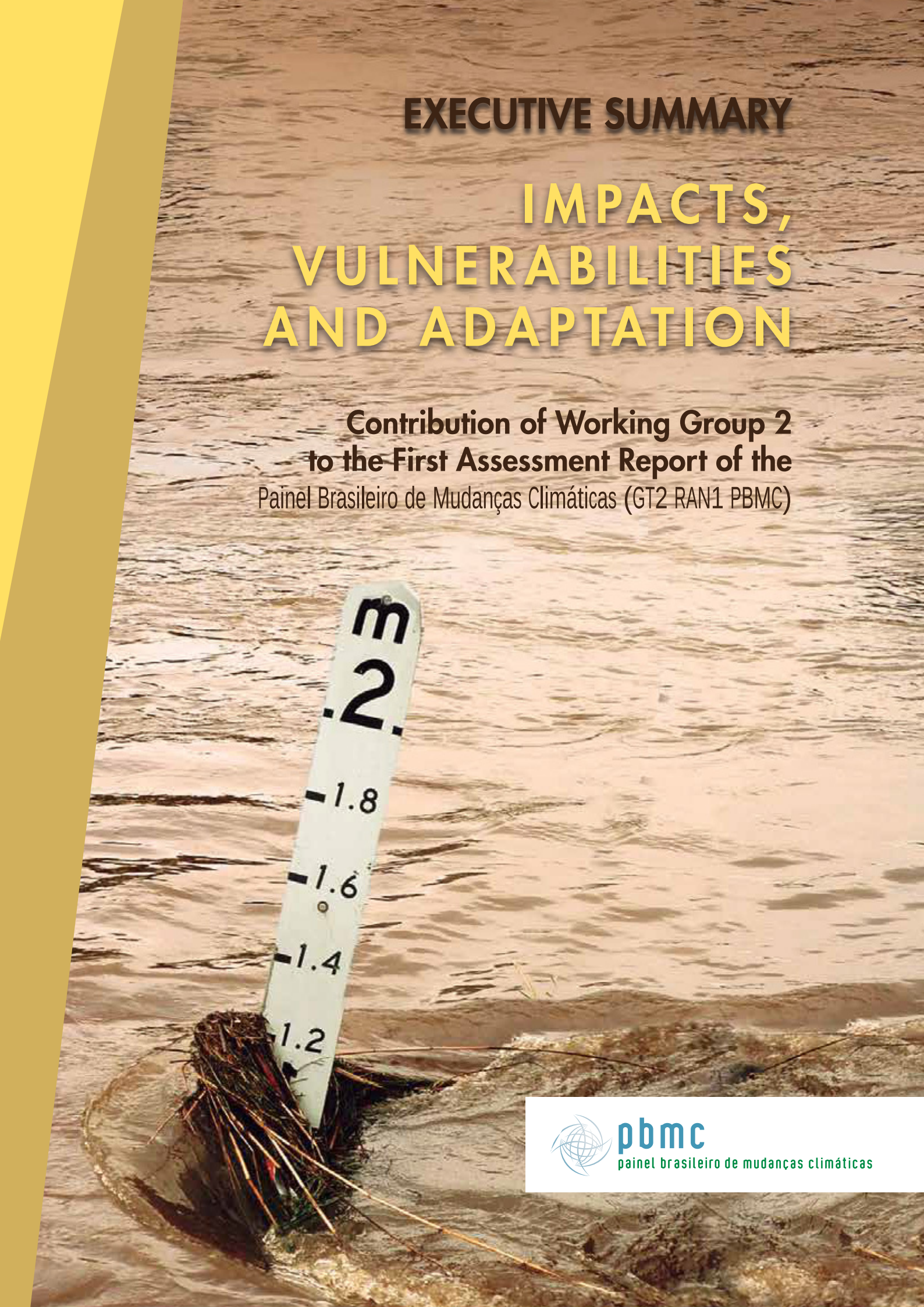
EXECUTIVE SUMMARY

IMPACTS, VULNERABILITIES AND ADAPTATION

Contribution of Working Group 2 to the First Assessment Report of the

Painel Brasileiro de Mudanças Climáticas (GT2 RAN1 PBMC)



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Impacts, Vulnerabilities and Adaptation

Contribution of Working Group 2 to the First Assessment Report of the Painel Brasileiro de Mudanças Climáticas (GT2 RAN1 PBMC)

EXECUTIVE SUMMARY

Brasília, DF
2013

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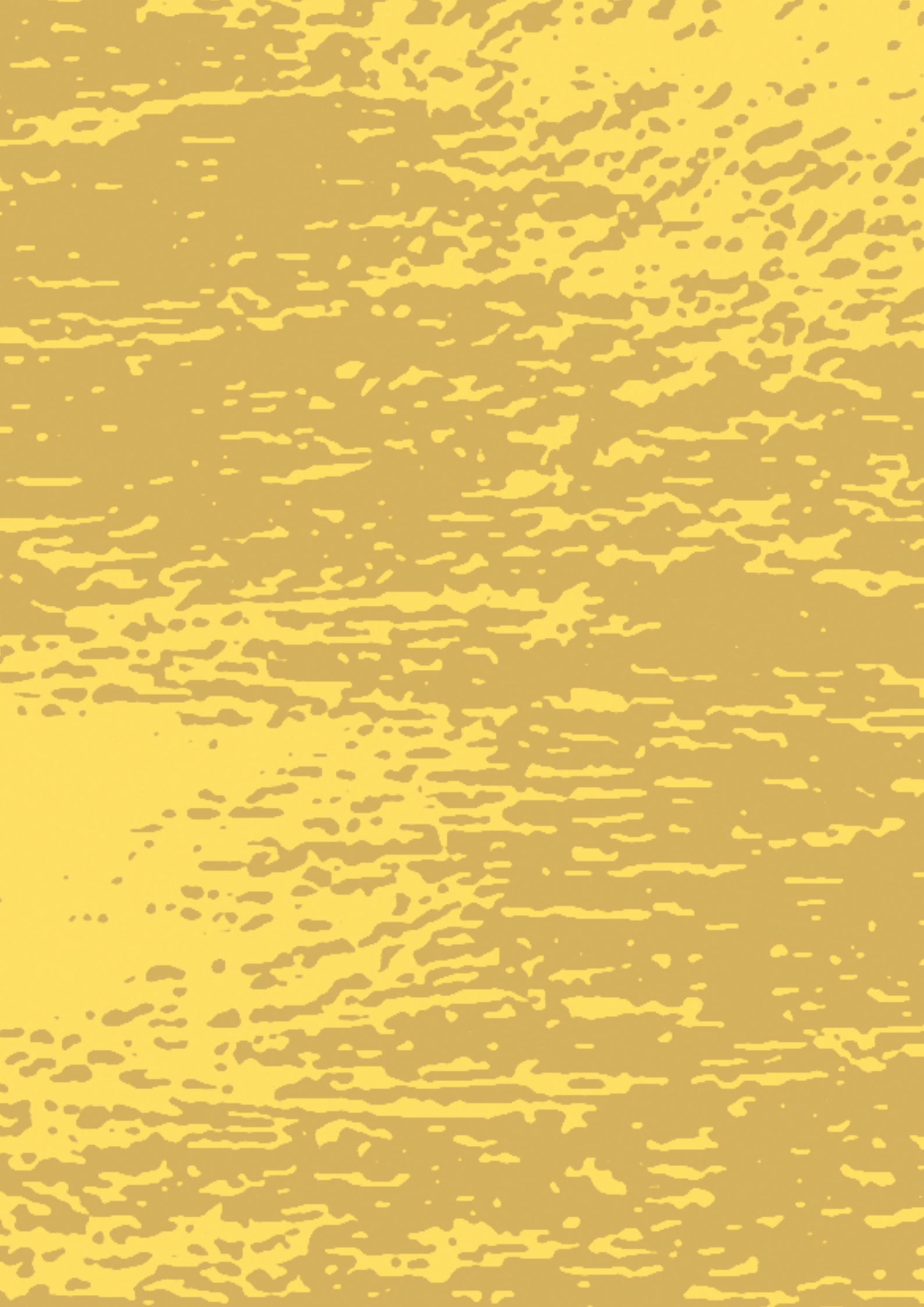

SUMMARY OF PRINCIPAL CONCLUSIONS

This document presents the main contributions of Volume 2 of the *Primeiro Relatório de Avaliação Nacional (RAN1)*, the first national assessment report from Brazil. This volume was structured according to the scope previously defined by the coordinators and primary authors of the chapters by *Grupo de Trabalho 2 (GT2)*, the second working group of the *Painel Brasileiro de Mudancas Climáticas (PBMC)*.

The surveys summarized here are the product of an extensive review of the literature available in Brazil in recent years, which were considered the main results of the Working Group 2 of the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). The development of volume 2 sought to:

(i) identify the vulnerabilities of the country in the face of global warming;
(ii) evaluate the different impacts in key sectors of the economy and society, according to the clima te projections until the end of the century; and
(iii) identify studies on, and measures for, adaptation to climate change in Brazil by the year 2012.

Definitions

Climate change: defined by the IPCC refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that of the Framework Convention on Climate Change, where climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and which is in addition to natural climate variability observed over comparable time periods.

Adaptation: es el ajuste en los sistemas naturales o humanos en cuanto una respuesta a los estímulos climáticos reales o a sus efectos, lo que permite explorar oportunidades benéficas. is the adjustment in natural or human systems in response to actual or climatic stimuli or their effects, which allows the exploitation of beneficial opportunities.

Vulnerability: is the degree to which a system is susceptible to, and unable to cope with, the adverse effects of climate change, including its variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change, as well as the variation to which a system is exposed, its sensitivity and its capacity adaptation.

INTRODUCTION AND FOUNDATION

The climate change scenarios point to a change in average temperature above 2°C, which include large imbalances in ecosystems fundamental to the survival of humanity. As the planet warms, rainfall and temperature patterns change and extreme weather events such as droughts, heavy rains that may cause floods, cold and heat waves become more frequent, with major impacts in all regions of the planet [*GT2* 1; 2].

In March 2004, Hurricane Catarina hit Brazil, the first hurricane ever observed in the South Atlantic. In the south and southeast of Brazil heavy rains have become more frequent in the last 50 years. Apart from climate change, the main factors that contribute to increased vulnerability are:

- population pressure,
- disordered urban sprawl,
- poverty and rural migration,
- low investment in infrastructure and services, as well as
- problems related to governance with intersectoral coordination.

Climate change is one of the most complex challenges of this century, and no country is immune to the potential impacts that may arise. The challenges are interconnected and include controversial political and economic decisions, as well as technological advances with global, far-reaching consequences.

Climate Change on the National Level

Some regions of Brazil may experience changes in temperature and rainfall with global warming. Intensifications of severe events should occur, causing severe impacts in cities and areas vulnerable to climate change. In the agricultural sector, the consequences of global warming will be numerous.

Due to low levels of social and economic development, the population in the northeast region is the most vulnerable to climate change. This assessment is based on the assumption that population groups with worse conditions of income, education and housing would suffer the greatest impacts of environmental and climatic changes.

In the future perspective of a warmer climate, the semiarid northeast may turn into an arid region. This may affect the regional subsistence agriculture, water availability and health of the population, requiring it to migrate to other regions. [*GT2* 3]

Temperature and precipitation patterns of some regions of Brazil may change due to global warming. Along with the change in annual rainfall patterns, or even where there is no change of the annual total, intensification of severe events should occur. An increase of extreme events, especially rainfall, may occur in large Brazilian cities vulnerable to climate change, such as Sao Paulo and Rio de Janeiro [*GT2* 3].

In the agricultural sector, the consequences of global warming will be numerous. It is expected that the increase of temperature will promote an increase in evapotranspiration and consequently, an increase in water stress, with direct influence on climate risk for agriculture. On the other hand, with the increase of temperature, a reduction of frost in the south, southeast and southwest of the country will occur, with a beneficial effect in areas where the cultivation of tropical plants is currently restricted.

In general, studies show that the evaluations, considering projections from global or regional climate models, of changes in large-scale land use or scenarios projected for the future, may alter the regional climate, which would be warmer and drier over the eastern *Amazônia* biome [*GT2* 3].

Climate dynamics should cause a migration of crops adapted to the tropical climate to southern areas of the country or higher altitude zones, to compensate for the climate difference. At the same time, there will be a reduction in the cultivation areas of temperate crops. An increase close to 3°C will cause a possible expansion of coffee and sugarcane crops in areas at higher latitudes [*GT2* 3].

The areas cultivated with corn, rice, beans, cotton and sunflower, will suffer a sharp drop in the northeast region, with significant loss of production. Two regions may be more affected: the entire area

of the semi-arid northeast, now responsible for most of the regional production of corn, and the northeastern *Cerrado* regions, such as southern Maranhão and Piauí states, and western Bahia.

Identified gaps

- One of the challenges impeding the development of studies with climatic variables has been the lack of good quality meteorological information based on complete, long-term series.

- Many of the future projections on climate change impacts on agriculture are based on current species, without adaptation. There is a paucity of studies on agricultural scenarios that incorporate genetic improvement of crops, especially drought.

Natural Resources and Management of Ecosystems and their Uses

Water Resources

> Climate change impacts the water regime of the Brazilian hydrographic basins differently. The impact of climate change should consider the hydrological diversity of the territory of the country.

Brazil has a large availability of water unevenly distributed in its territory, in which the average annual flow of rivers is 179,000 cubic meters per second (m^3/s), which corresponds to approximately 12% of the world's surface water availability.

The hydrographic basin of *Amazônia* holds 73.6% of the national surface water resources, that is, the average flow in this region is almost three times greater than the sum of flows of all other Brazilian hydrographic basins. The specific flow indicates the flow generating capacity of one basin. In Brazil, specific flow ranges from less than 2 liters *per* second each square kilometer ($l/s.km^2$) in the river basins of the semiarid region, to more than 40 $l/s.km^2$ in the northwestern *Amazônia* biome. [*GT2* 4.1]

The impact of climate change should consider the hydrological diversity of the Brazilian territory. Several studies have been conducted to identify trends in the country's different regions and river basins, considering the natural variations and possible effects of climate change. The trends found for the various regions of Brazil follows below:

- In the Amazônia no significant trends were observed in rainfall or flows, in the last decades.

- In the northeast, the studies were not consensual in identifying the presence or absence of lon g-term trends in rainfall.

- Rainfall and river flow into *Amazônia* biome and the northeast region showing variability in the interannual and interdecadal scales that are more important than trends of increase or decrea se, and these may be associated with patterns of large-scale climatic variation.

- In southern Brazil and northern Argentina, trends for increased rainfall and river flows have been observed since the mid-twentieth century, with the Paraná and La Plata rivers showing a downward trend from 1901 to 1970 and a systematic increase in flows from the early 1970s to the present. The *Pantanal* region is also part of this basin, so any change in the flow of the rivers mentioned above has direct implications on the storage capacity of this huge natural reservoir.

- The Paraná river basin exhibits a series of non-stationary flows of which characteristics are the following:

(1) the series of natural flows from the Tietê, Paranapanema and Paraná rivers (downstream of the Rio Grande River) are not stationary, showing an increase of mean flow after 1970;

(2) the rate of increase of mean flows increases from upstream to downstream;

(3) the rainfall stations in the Rio Grande, Paranapanema and Tietê river basins also exhibit non-stationarity; and

(4) only the Paranaíba river basin maintained stationarity of flows for the entire period of analysis.

- The river basins of the south and southeast regions are of great importance for generating hydroelectricity, corresponding to 80% of Brazil's installed capacity. The non-stationarity of the series of flows can have a significant impact on the calculation of guaranteed energy.

Climate change impacts the water regime of the Brazilian hydrographic basins differently. Models that allow the visualization of climate change scenarios indicate alterations for different hydrographic regions: [*GT2* 4.1]

- Rainfall in northern and northeastern Brazil does not have a definite change trend and may have significant reductions or moderate increases.

- Factors unrelated to climate change, such as sedimentation, may affect water supplies. The overall increase in temperature has a significant effect of increased evaporation, which could adversely affect the efficiency of storage in lakes.

Climate change may affect renewal rates, levels and renewable resources of groundwater.The risk of natural disasters, both floods and droughts, should be analyzed in conjunction with the concepts of exposure and vulnerability of populations, in addition to integration of an early warning system, coordinating local action plans and integration of contingency plans, which may avoid strong impacts with a high rate of deaths caused by extreme events, especially in urban areas.

Identified Gaps

Knowledge of current groundwater recharge in developed and developing countries is still incipient. There has been little research on the impact of climate change on groundwater, including the question of how such modification will affect the relationship between surface waters and aquifers that are hydraulically connected.

Freshwater and Terrestrial Ecosystems

All of the Brazilian biomes are vulnerable to climate change. Land use changes, disordered territorial expansion, and changes in rainfall patterns are indications of vulnerability for the six biomes.

The main impacts to which the natural terrestrial and Brazilian continental aquatic systems are subject include:

a) deforestation, fragmentation and impact on renewable natural resources due to changes in land use, and

b) deterioration on the quality of water resources and soil by pollution caused by anthropogenic activities. [*GT2* 4.2]

These two types of impacts, in turn, have a direct effect on the climate. Projected impacts by 2100 due to climate change include changes in rainfall and temperature increases for practically the entire Brazilian territory, implying extinction or modifications in the geographic distribution of species. [*GT2* 4.2]

All of the Brazilian biomes have points of vulnerability:

- the *Mata Atlântica*, due to its small and fragmented remaining forest cover;
- the *Cerrado*, due to its small coverage of protected areas in the face of rapid agricultural ex pansion;
- the *Caatinga*, due to accelerated environmental degradation, which in some places has already led to desertification;
- the *Pantanal*, vulnerable to changes in its flooding regime, especially in the face of projected drought scenarios;
- the *Pampas*, due to the profound changes of land use combined with susceptibility to invasive species; and finally,
- the *Amazônia*, due to the demand for infrastructural expansion, which cannot run the risk of being disorderly. In all of these biomes, the changes also make society vulnerable in terms of the economy and health. [*GT2* 4.2]

Identified Gaps

There is a need to implement strategies to adapt to ongoing changes. There are some initiatives for ecosystem-based adaptation, combining nature conservation with human development. These initiatives need to be scaled up.

Coastal Systems and Low Coastal Areas

> The Brazilian coastal system and low-lying coastal areas are vulnerable to the rising sea level. It is necessary to know and map vulnerabilities along the entire extent of the Brazilian coast.

The coastal system and low-lying coastal areas are vulnerable to the rising sea level, according to results presented by *GT1*. The lack of information on the effects of climate change on coastal ecosystems in Brazil impedes the quantification of future impacts. It is necessary to know and map vulnerabilities along the entire extent of the coast.

Some local studies dealing primarily with the effects of a possible rise of the average sea level on such systems were identified. [*GT2* 4.3]

Significant changes in the flows of major Brazilians rivers, with increased volume in the *La Plata* and *Paraná* rivers basins, and reduction in the *Pantanal* and *Amazonas* river basin were some of the impacts observed. The variation of these volumes will imply a new dynamic of sediment transport and its subsequent effects on the beach line.

Other impacts identified in the study include:

a) erosion and coastal progradation;
b) damage to coastal protection works;
c) structural or operational damage to ports and terminals;
d) damage to urbanization works of coastal cities;

e) structural damages or operational losses to sanitation works;
f) exposure of buried pipes or structural damage to exposed ducts;
g) saline intrusion into estuaries;
h) saline intrusion into aquifers;
i) expansion of mangroves; and
j) damage to coral reefs.

The stage is set, and there is no doubt that the challenge of adaptation and mitigation of the consequences of these phenomena is huge, and cannot be carried out without a detailed technical reference composed of vulnerability analysis at the micro and macro scales.

Identified Gaps

- There is a great lack of information related to the effects of climate change on coastal ecosys tems in Brazil, as well as the vulnerability of these ecosystems to such changes. The limited infor mation available is just local studies that deal with the consequences of a possible rise of ave rage sea level on such systems.

- Analyses of vulnerability exist on a national scale, as shown here, or on a local one which leaves a gap in terms of planning. Related to these factors is the degree of uncertainty on the quantitative definition of climate change around the globe, creating a scenario of uncertainties as to decision-making by government.

- It is necessary to invest in systematic and long-term environmental monitoring, in territorial or dering and coastal management. Adaptation measures are mandatory to address future issues such as retreat, accommodation and protection of beaches

Ocean Ecosystems

> Climate change may promote a large-scale redistribution of maximum catch potential of various fish species, with an increase in high-latitude regions and falls in the tropics. Brazil may reduce its fishing potential by 6% over the next 40 years.

The main effects observed in the oceans result from the storage of a quantity of heat from the atmosphere, creating a substantial increase in water temperature of the surface layers, as well as an increase in sea level due to the thermal expansion of water. A no less serious consequence is also the acidification of the oceans due to the dissolution of carbon dioxide in water. All of these changes have caused diverse effects on marine life in the oceans.

Recent studies have shown that climate change may promote a large-scale redistribution of maximum catch potential (MCP) of various species, i.e., fishery potential, with an increase of 30% to 70% in high-latitude regions and drops, in the tropics. The losses and gains of the MCP in tropical latitudes will be around 10% but, may reach values between 15% and 50% on the tropical west side of the Atlantic Ocean off the Brazilian coast. The prediction is that Brazil will decrease its MPC by 6% in the next 40 years. [*GT2* 4.4]

Positive aspects from changes in the environment may also occur. Studies show an increase in fish production, in some regions, due to changes in the distribution patterns and abundance of some species, among other aspects of their biology. [*GT2* 4.4]

Identified Gaps

Little is known about the effects of climate change on the ocean pelagic ecosystem and the marine organisms that inhabit it, many of which are high-value commercial resources, or of great importance to the food security of many fishing communities in various parts of the world.

There are many uncertainties that need to be further evaluated. The answers to the questions arising from environmental changes in the ocean ecosystem cannot be found or constructed without conducting research to further understanding of the connections between the atmosphere and ocean, especially regarding the effects of climate change on this ecosystem and its inhabitants.

Food System and Security

> Global warming may endanger food production in Brazil. Climate change will have different effects on the availability of foods in the Brazilian five federative regions, and by 2030, the country could lose about 11 million hectares suitable for agriculture due to climate change.

Global warming may endanger food production in Brazil if no mitigation or adaptation measure is performed. Agricultural scenarios point to a reduction of the "low risk and high potential" cultivable area in 2020 and 2030. By 2030, Brazil could lose about 11 million hectares of land suitable for farming due to climate change. [*GT2* 4.5]

The negative effects on the supply of commodities should result in significantly higher prices of some raw materials, especially basic foods such as rice, beans and all meat products. This will offset the decline in productivity on the value of agricultural production, which will have remarkable adverse effects on the poorest contingents of the country's population and their consumption of basic food items.
Therefore, some adaptive measures for the agricultural sector follow, listed below: [GT2 4.5]

- To achieve national development, food security, adaptation and mitigation of climate change, as well as economic goals in the coming decades, Brazil will need to significantly increase the yield per area of cultivation of food and pasture systems, while at the same time reduce defo restation, and rehabilitate millions of hectares of degraded land while adapting it to climate change.

- Adaptive measures could promote advances in incorporating new models and paradigms of agricultural production. The decentralization of production, search for solutions best adapted to local conditions, and diversification of the domestic supply of foods and nutritional quality are possible solutions for adaptation in agriculture.

- Additional possible solutions include the genetic improvement of varieties tolerant to drought, transition of production from monocultures to integrated production systems, expansion of ac cess to efficient irrigation technology, and management mechanisms that preserve and increase the level of soil carbon.

- The use of new practices of agricultural management contributes to overcoming problems cau sed by climatic extremes, such as defense against frost on coffee crops, or the adoption of more drought-tolerant cultivars in non-irrigated crops.

- The development of new agricultural technologies and the promotion of the reduction of gree nhouse gas emissions (GGE) promote increased crop productivity.

- The Brazilian government and the private sector are steadily facilitating the adoption of best agricultural practices for soil conservation, including direct planting and the most efficient sys tems in terms of resources, similar to crop-livestock integration schemes, which are by nature more resistant to climatic shocks than some modes of intensive cultivation.

- The government is extending credit and funding for the Plano Setorial de Mitigação e de Adap tação às Mudanças Climáticas para a Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura, a sectoral plan for mitigation and adaptation to climate change for the consolidation of a low carbon economy in egriculture. Known as Plano ABC, it is composed by sustainable, low-emission technologies developed for tropical and subtropical conditions.

- The accumulation of carbon in agricultural soil can be qualified to receive payments in both, voluntary and formal, future markets.

Gaps Identified

- There are few studies that quantify the emission factors of tropical and adapted farming systems.

- More integrated and advanced evaluations on the impact of climate change are particularly urgent in the agricultural sector, to guide policymakers on investments priorities and phasing.

- A recent survey conducted by the *Empresa Brasileira de Pesquisa Agropecuária* (EMBRAPA), the Brazilian agricultural research corporation, showed that, even with advanced breeding tech niques, it takes about ten years of research and development (R&D) activities, with a minimum cost of about US$ 6 million, to develop, test and produce a new cultivar or variety tolerant to heat and/or drought. [*GT2* 4.5]

Human Agglomerates, Industry and Infrastructure

Rural Area

> The impacts of climate change will emerge at the regional level and will mostly be concentrated in the poorest regions of Brazil.

The results show that the economies of the northeast region, due to its high social vulnerability, and of the states of Mato Grosso and Mato Grosso do Sul, due to their concentrated agricultural production concentration in soybean, would be intensely affected. The drops predicted would exceed 5% of GDP for most of the states mentioned. [*GT2* 5.1

Studies point to an upsurge of migration towards the southeast of Brazil, the intensity of which depends on the scenario in question. Moreover, there will be migration flows of low-skilled workers. The muni-cipalities in the northeast with the worst social indicators in the region will suffer the greatest impacts of climate change. [*GT2* 5.1]

The impacts of climate change should occur at the regional level, concentrated in the poorest areas of Brazil. It is necessary to adapt strategies to promote the resilience of affected populations.

Urban Areas

Brazilian cities are vulnerable to climate change. According to each region's characteristics, impacts will occur at different scales.

Cities face significant impacts from climate change both in the present and future. These impacts have potentially serious consequences for human health and livelihoods, especially for the urban poor, informal settlements, and other vulnerable groups.

Increasing the resilience of cities involves addressing basic reduction of poverty. A resilient city is one that is prepared for current and future impacts of climate change, thereby limiting their magnitude and gravity.

Brazilian cities are vulnerable to climate change. Almost the entire northeast, the northwest of the state of Minas Gerais and the state capitals São Paulo, Rio de Janeiro, Belo Horizonte, Salvador, Brasília and Manaus are the areas in Brazil most susceptible to the effects of climate change that may occur by the end of this century. [*GT2* 5.2]

In the next 30 years, Rio de Janeiro is the city that will most suffer among the municipalities in that state with a rise in sea level, heavy rains, flooding and loss of biodiversity, in addition to increasing diseases incidence, induced by climate change.

The map below shows the areas of Brazil most susceptible to climate change.

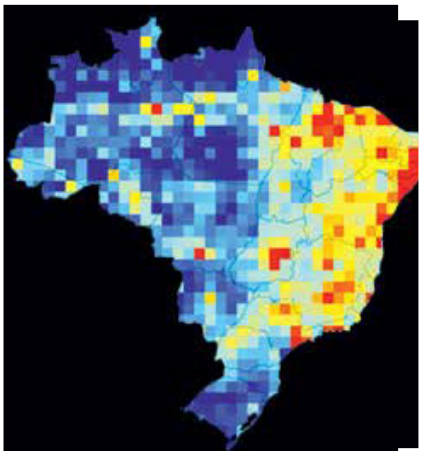

Figure SEE.1. *Areas of Brazil most susceptible to climate change, according to the combined socioclimatic vulnerability index (SCVI). Areas most susceptible to climate change are in red, corresponding to areas of high population density.*

The possible impacts of these changes will occur at different scales, according to the specific characteristics of each region of Brazil. It is necessary to know and map the vulnerabilities of Brazilian regions to identify, propose and implement adaptation measures. [*GT2* 5.2]

When dealing with concerns about climate change and risk of disaster in cities, in practical terms, disaster risk reduction and climate change adaptation can be integrated in many cases. [*GT2* 5.2]

Energy Sector

The energy sector may be affected by climate change in different ways, both in regard to the energy resources base and transformation processes, as well as aspects of transportation and energy consumption.
In terms of energy supply, virtually all options are exposed to some degree of vulnerability to climate change.

The energy sector may be affected by climate change in different ways, both in regard to the energy resources base and transformation processes, as well as aspects of transportation and energy consumption. [*GT2* 5.3.1]

In terms of supply, nearly all power options are exposed to some degree of vulnerability to climate change. In general, it is expected that renewable sources are more susceptible to such phenomena, since their potential depends on a flow that is closely linked to climatic conditions. This is the case of hydroelectric, wind and biomass energy. [*GT2* 5.3.1]

Transportation infrastructure and energy transfer can extend for thousands of kilometers and may therefore be exposed to a series of extreme climate events. The identification of the vulnerabilities of the energy sector to climate change is essential for the formulation of adaptation policies. [*GT2* 5.3.1]

Industrial Sector

The cost of inaction may impact the various sectors of Brazilian industry and may be higher than implementing adaptation measures to climate change.
It is essential to expand studies and mapping of risk areas and to establish prevention plans, especially for the areas most vulnerable to climatic extremes.

The impacts caused by industrial disasters may be devastating, with serious implications when combined with factors such as the lack of mapping of at-risk areas and prevention plans. Moreover, and linked to risks of environmental disasters in the industrial sector, are the trade and services sectors, which may be dramatically affected by distinct effects (direct and indirect), for example, the temporary stoppage of the system of production and distribution of goods. [*GT2* 5.3.2]

The scope and magnitude of impacts will vary according to local conditions, type of industry installed, transportation systems, projects and policies implemented, as well as adaptation capacity to minimize costs and risks of accidents.

Adaptation measures are needed, including a breakdown of associated risks and vulnerabilities so that the sector develops. In this perspective, disaster prevention plans will be necessary that encompass not only a particular industrial facility, but the entire regional context in which each unit or industrial complex is inserted. [*GT2* 5.3.2]

The cost of inaction may impact the various sectors of Brazilian industry, and may be higher than the cost of implementing measures for adaptation to climate change.

Transportation Sector

Climate change will affect transportation systems, with impacts on urban mobility in large cities, and consequences on economic growth and quality of life.
Opportunities for adaptation in the transportation sector include mitigation actions, investments in infrastructure improvement and diversification of the transportation matrix.

Climate change will affect transportation systems, potentially preventing urban mobility, with consequences on economic growth and quality of life of populations. All modes of coastal transportation are considered vulnerable, but the exposure and impacts will vary by region, mode, location and condition of infrastructure. [*GT2* 5.3.3]

Climate change projections report that changes in sea level, temperature and precipitation variations, and increased occurrence of extreme weather events (including intense rainfall), will adversely affect transportation infrastructure. [*GT2* 5.3.3]

The planning of transportation systems should consider the risk analysis for the rise in temperature, and increased frequency and intensity of precipitation, floods and storms. Thus, integration of climate, transportation and development policies is important, as well as monitoring of climatic data and a reassessment of current transportation policies and standards [*GT2* 5.3.3]

Mitigation efforts are essential to reduce the threat of climate change. However, adaptation practices to increase the resilience of the transportation sector, and reduce the impacts of extreme weather events, should be accelerated.

In regard to transportation adaptation measures, some experiences were identified: relocation of roads and waterways; changes in the projects, and replacement and adjustment of structures such as bridges, roads and pavements, to withstand the possible effects that weather conditions and climate change might have on the industry. [*GT2* 5.3.3]

Opportunities for adaptation in the transportation sector include mitigation actions that will improve air quality and reduce greenhouse gas emissions, having a positive impact on the health of populations and transportation conditions, based on more efficient, less carbon-intensive and safe public transportation. However, investments in necessary infrastructure that is appropriate to the context of climate change, and new modes of transportation, will also be essential.

Identified Gaps

- It is necessary to know and map the vulnerability of Brazilian regions in both urban and rural areas, in order to identify, propose and implement adaptation actions. Identification of the ener gy sector's vulnerabilities to climate change is essential for the formulation of adaptation poli cies.
- There are few scientific studies on the impacts of climate change on industry. It is essential to broaden studies and mappings of at-risk areas, and establish prevention plans, especially for the areas most vulnerable to climate extremes.
- The absence of studies on vulnerabilities, potential impacts of climate change and options for adaptation of the transportation industry in Brazil is a gap in the national literature on climate change and transportation.
- New studies and research are needed on climate change and vulnerability of transportation infrastructure, to provide more conclusive findings that can be applied in public policy, planning and the identification of industry solutions.

HUMAN HEALTH, WELL-BEING AND SAFETY

Human Health

Climate change and extreme weather events pose a threat to human health, welfare and safety of the Brazilian population. This may be exacerbated in the absence of health and sanitation policies.

Climate change will contribute to droughts and floods on a large scale, which are occurring more frequently since the last decade, and that very seriously affect food production, and thus worsen the nutritional status of populations in many countries, and often claim lives. [*GT2* 6.1]

The poorest communities will be especially vulnerable because they are concentrated in high-risk areas, have less capacity for adaption, and are more dependent on local resources that are climate sensitive. Climate change poses a risk to human health. [*GT2* 6.1]

Extreme weather events such as storms, floods, heat and cold waves and droughts are becoming more frequent every year. These events can cause deaths from natural disasters, as well as the occurrence of diseases and loss of materials, and represent vulnerability in the Brazilian context. [*GT2* 6.1]

In Brazil, cities grow quickly, without urban planning. Poverty belts expand on the peripheries of large urban centers, and socioeconomic inequality makes their inhabitants more vulnerable to the impacts of climate change. [*GT2* 6.1]

Precarious buildings in at-risk areas, lack of basic sanitation and exposure to diseases are examples of the vulnerability of the poorest communities to climate extremes. Urban areas also suffer from changes to the climate profile related to local issues such as land use profiles. [*GT2* 6.1]

Human Safety

> Climate change will affect certain population groups who already live in at-risk areas in a particularly acute way. The estimate is that 30 million people living in relatively isolated or remote areas will be affected by extreme weather events. In the event of disasters, their vulnerability will increase due to the difficult access to their homes

The negative consequences of extreme weather events (floods, landslides and population displacement from regions affected by floods or prolonged periods of drought) affect both rural and urban areas, with different impacts and implications. On one hand, due to the rapid process of Brazilian urbanization, the largest populations of exposed persons are concentrated in urban areas, as well as many of the social investments in infrastructure. On the other hand, rural populations and primary productive activities, agriculture and livestock are also affected, which are very susceptible to climate variations. [*GT2* 6.2]

The growth of the urban population and increased urbanization in Brazil revives concern over the relationship between social inequality and environmental problems, especially in the context of climate change and extreme weather events. [*GT2* 6.2]

This urban expansion process was conducted largely without adequate planning, with occupancy of unsuitable areas that are susceptible to flooding and landslides. The intensification of weather events brings a new urgency to confront this problem.

Even with population concentration in urban areas, it should be highlighted that there is a significant proportion of the population residing in rural areas. Brazil has 30 million people living in relatively isolated or remote areas, and these populations will also be subject to the effects of extreme weather events, and their vulnerability will increase due to difficult access in the event of a disaster.

Specific population groups, due to their cultural and economic organization features, such as indigenous groups and quilombo communities, made up of descendants of escaped African slaves, are especially susceptible to extreme weather events and require specific action. This is even more important after disasters, when the re-articulation of the social organization structure can take a long time to reorganize. [*GT2* 6.2]

There is still no national system of registration of disasters. Given the recurrence of extreme weather phenomena, it is also important to build a historical archive, in which information on the occurrence of disasters, responses to these (during and after), as well as a detailed contextualization of the characteristic features the region before disaster hits, can be stored.

In this historical perspective, it would also be important to monitor the evolution of the disaster situation over time, what happened to the area where the disaster occurred, what happened to the people affected, and what was the effectiveness of actions taken by government with respect to the various factors involved. Certainly, monitoring of disaster situations and a critical review of procedures would be essential to ensure improvement of the social security system in risk situations, particularly in the current conjuncture, when the effects of climate change are beginning to be felt. [*GT2* 6.2]

Subsistence and Poverty

> The impacts of climate change will accentuate social inequalities. These impacts will tend to generate food insecurity due to the decrease in subsistence agriculture production, with a consequent lack of food for the populations directly exposed to climatic adversities.

The populations most vulnerable to the effects of climate change are those who, for social reasons, are more vulnerable to environmental disasters, and have less capacity to protect and respond to adverse impacts, due to people's limited access to basic goods and services, including health care. [*GT2* 6.3]

In the perspective of climate change, family farming communities dependent on rainfall will be much more sensitive to changes in rainfall patterns, in comparison to others where the dominant means of livelihood is less sensitive to climate factors. Similarly, a fragile ecosystem such as the *Caatinga* in the semiarid region is more sensitive to a reduction of precipitation than other ecosystem.

Another consequence of increased vulnerability is the high concentration of the population in urban areas, with people dependent on subsistence activities fleeing the harsh conditions of rural areas being more vulnerable to such risks; survival conditions will worsen, with implications on poverty, and consequently on the type and quality of peoples' diets, resulting in varying degrees of malnutrition and health problems. Aspects of food insecurity are also considered, due to the predicted fall in production of traditional agriculture. Migration to towns and cities will aggravate the type and quality of peoples' diets, resulting in varying degrees of malnutrition and health problems, as a result of deteriorating health conditions of the peripheries of urban centers. [*GT2* 6.3]

The existence in Brazil of different endemic infectious diseases sensitive to climate may result in changes to their cycles, favoring both increased and decreased incidences due to variations in temperature and humidity, among other factors. There is also the possibility that these diseases will redistribute spatially as a result of regional demographic phenomena. This was the case with outbreaks of *kala azar* (visceral *leishmaniasis*), observed in northeastern capitals at the beginning of the 1980s and 1990s, a consequence of the large rural-urban migration driven by prolonged droughts. [*GT2* 6.3]

The greatest impact of climate change is expected in the northeast, with reduced rainfall and increased temperature, with consequences on food production with traditionally-cultivated species; these impacts will tend to generate food insecurity due to a decline in agricultural subsistence production.

The impacts of climate change, with effects on food production and, more broadly, on the living conditions of the most vulnerable populations, will likely make social differences more pronounced, especially affecting the poorest people and resulting in hunger as poor populations are more directly exposed to climate adversities. Perhaps industrial agriculture will be able to respond to climate change. However, subsistence agriculture will face greater difficulties and should radically adapt by exploring more appropriate activities, given its vulnerability. [*GT2* 6.3]

In the case of the *Amazônia* biome, major challenges remain to be faced concerning to conservation and preservation, especially to maintain economic activities without destroying new areas, and to reduce the risks of climate change. Agricultural and environmental policies are also important to address socio-environmental issues in *Amazônia*. The reduced destruction of natural resources in *Amazônia* will depend on the development of more sustainable agricultural activities, and incentives such as payment for environmental services.

Identified Gaps

- Further research is needed on the effects of these weather events and their impacts on hu man health, in order to assist in structuring the application of adaptation actions, and reduce the vulnerability of the population to these events. The theme of human health should be expan ded beyond conventional considerations regarding adaptation of the affected populations, to consider the potential co-benefits of health that should be considered when formulating mitigat ion policies.

- A systematic mapping of the areas that are most subject to the hazards and risks of climate change does not exist. Existing mappings are not available to, or are not easily accessed by, residents or individuals who are interested in living in these areas.

- In addition to mapping, it is important to understand the social reality in which the most vulne rable groups are found, in order to build more effective policies to reduce this vulnerability.

- The literature on disasters and approaches to dealing with them is already well-established internationally, although in Brazil it remains undeveloped.

Multisectoral Impacts, Risks, Vulnerabilities and Opportunities

> The impacts of climate change will accentuate social inequalities. These impacts will tend to generate food insecurity due to the decrease in subsistence agriculture production, with a consequent lack of food for the populations directly exposed to climatic adversities.

Most studies show that the economic impacts of global climate change tend to be more intense, in relative terms, in less developed regions, considering different spatial scales.
The impacts identified in these studies most likely to occur in Brazil are:

a. Significant reductions of forest and woodland areas on farms;
b. Increase in pasture areas;

c. The center-west and northeast regions will be most severely affected;
d. Planting of sugarcane may increase;
e. Reduced economic growth;
f. Sectors and regions will not be impacted evenly;
g. The agriculture and livestock sectors are most sensitive to climate change, but other sectors will also be adversely affected;
h. Ranching will be more pronounced in rural regions in the northeast;
i. Increase of regional inequalities;
j. Increase of population expulsion from rural areas;
k. Increased pressure on demand for public services in large urban centers;
l. Increasing poverty;
m. Increased frequency and intensity of extreme events tend to have adverse impacts on producti vity and crop production, with negative effects on food security;
n. Heavy rains and floods increase costs to urban centers;
o. Human health conditions in Brazil could be severely affected, primarily due to the history of water-borne, vector-borne and respiratory diseases;
p. Climate change could be increase at-risk situations since it tends to intensify the occurrence of tropical diseases, poverty and disasters.
q. Increased vulnerabilities associated with climate change in the semi-arid northeast, which will mainly affect water availability, regional livelihoods and health of the population. The most vulnerable to climate change are those with fewer resources and less ability to adapt, such as low-income workers, and subsistence farmers in semi-arid areas. Climate variability would force populations to migrate, generating waves of climate refugees to the major cities of the region or to other regions, increasing social problems already present in large cities.
r. In terms of economic vulnerability to climate change among Brazilian states, in both scenarios (A2 and B2) from the IPCC, the center-west region would have the greatest cost impacts, rea ching 4.5% of GDP in 2050, in the B2 scenario. In this same scenario, in 2050, a permanent loss of 3.1% of regional GDP is estimated for the northern region, 2.9% in the northeast and 2.4% in the southeast compared to a scenario without climate change. In the case of the sou thern region, which would benefit in both scenarios, the gain would be significant in the A2 scenario (2.0 % of regional GDP in 2050).
s. Economic vulnerability of the northeast region, with a negative effect on GDP and employment. According to the climate change scenarios, the states most affected in terms of GDP and em ployment at the end of the projection period would be Pernambuco, Paraíba and Ceará, in relation to the situation without these changes. [GT2 7]

Identified Gaps

There are few studies dealing with climate change adaptation in various sectors of the economy. Some sectors have many studies related to the impacts of climate change, such as agriculture and energy, while studies for other sectors, such as transportation and industry, are still scarce.

IMPACTS, VULNERABILITY AND ADAPTATION AT THE REGIONAL LEVEL

Northern Region

Deforestation in the *Amazônia* biome intensifies vulnerability to climate change; therefore, the regulatory role of the global, regional and local climate that the forest performs is threatened.

According to 23 of IPCC models, intensification of the dry season and late start of the rainy season in southeastern *Amazônia* has an 80% probability of occurring. It is important to note that each degree of temperature change in a tropical environment is perceived with greater impact by tropical species, compared to species of temperate areas.

Amazônia is currently threatened by deforestation, responsible for genetic erosion and greenhouse gas emissions. Advances in the last five years, in monitoring and control of deforestation, in that biome have been identified, with a significant reduction in annual rates from 2005 to 2012. New environmental management tools, like Payments for Environmental Services (PES), emerge a promising way to promote conservation, aimed at mitigating and adapting to climate change. [*GT2* 8.1]

Based on the profound changes of land use observed in the northern region of Brazil, mainly from the mid-20th century on, the *Amazônia* rainforest role as a regulator of the global, regional and local climate is threatened.

If the frequency of El Niño events increases as a consequence of global warming, the forests will emit their large reserves of carbon into the atmosphere. The future accumulation of CO2, and consequently, the moment at which its concentration reaches hazardous levels, depends on continuous carbon absorption by the biosphere, including a major contribution from the *Amazon* rainforest.

The various global models, used in the IPCC Third Assessment Report and Fourth Assessment Report, differ on precipitation trends in Amazônia. Some predict reduced rainfall, others indicate an increase. But the average of the models indicates greater potential for reduced rainfall.

In regard to temperatures, all of the models project a conspicuous warming trend for Brazil. It is noted that temperature anomalies in the state of Pará will vary between 4-5°C in relation to the averages for 1961-1990, having the A2 scenario of the AR4 as a parameter while, under conditions from the B2 scenario, an increase of between 3-4°C was estimated. [*GT2* 8.1]

For the end of the century, the regionalized climate projection for the *Amazônia* biome presents a reduction in rainfall of 40% to 45%, and an increase of 5° to 6°C in temperature. [*SE GT*1]

Lagunas detectadas

There are uncertainties regarding trends in climate extremes for *Amazônia*, mainly due to the lack of reliable long-term data and limited information for large regions.

Northeast region

> The northeast of Brazil is very vulnerable to climate change, due to physiographic, climatic and socioeconomic conditions. The northeast will undergo greater population migration to urban areas, and the agricultural sector will have an intensification of the migratory effects resulting from climate change impacts.

The northeast region has physiographic, climatic and socioeconomic conditions that require attention to create policies to adapt to impacts from possible climate change conditions. Studies related to impacts of climate change on water resources, coastal resources, the process of desertification, and the agriculture (including family farms), energy and health sectors, confirm the fragility of the region. [*GT2* 8.2]

With less water availability in the country, the northeast region has a strong temporal variability (on interannual and decadal scales) of its rainfall. This is due to factors already relatively well-known. Therefore, its prediction is also a strategy to adapt to climate change. Increases are expected in temperatures, rates of evaporation and exacerbation of extreme events, which would generate significant impacts on reservoir levels in the region, a basis for planning and management of water resources in the northeast. [*GT2* 8.2]

Much of agriculture in the northeast, especially crops of cassava, cotton, soybeans, rice, corn and beans, would be heavily impacted by climate change. Cassava will suffer a drastic reduction in planting, possibly even disappearing from the semi-arid region in the northeast. Several studies also point to an intensification of migration effects resulting from the impacts of climate change on agriculture. [*GT2* 8.2]

In coastal environments, preliminary reflective studies indicate impacts that should be analyzed within the complexity of the marine behavior in order to identify their relationship to anthropic activities and the stability of coastal ecosystems. The main result expected is a broad retreat of the coastline of the northeast region, and an increased vulnerability of ecosystems sensitive to small variations in temperature, such as coral reefs. [*GT2* 8.2]

The northeast region has large pockets of geographic areas in the process of desertification, with negative impacts for regional socioeconomic indicators. In the health sector, studies confirm the relationship between the severity of climate change impacts and levels of dehydration, respiratory disorders and redistribution of infectious diseases due to usual migration events. [*GT2* 8.2]

Identified Gaps

- There is a lack of technical assistance for family farming in the face of the scenarios of climate change.
- An intensification of existing socio-economic arrangements and political-institutional and tech nical support is needed, since these play an important role in adaptation to climate change.
- Development and application of new, more sustainable agricultural practices adapted to the northeast is needed.
- There are few studies in coastal areas, considering the complexity of the marine environment to identify its relationship with human activities.
- There is a paucity of studies directly focused on the analysis of the relationship of climate change to the process of desertification.

Southern Region

There may be negative impacts on health in southern Brazil due to the emergence of endemic endemic infectious diseases sensitive to climate variations. Disasters such as landslides, death by drowning and building collapses may be more frequent. Agriculture and livestock in the region is vulnerable to climate change.

As the success of agriculture is directly related to the climate, much of the southern region's economy is influenced, directly or indirectly, by climatic variability or anomalies.

There are numerous records of the El Niño Southern Oscillation (ENSO) phenomenon, which accentuates the conditioning/adversity features of the climate on agricultural production, determining

production records or widespread losses. [*GT2* 8.3]

It should be added to the weather condition already affected by the ENSO, records of air temperature increase in various municipalities of Rio Grande do Sul, Santa Catarina and Paraná, which inevitably influence not only agriculture and food security, but environmental conditions such as the hydrologic cycle and the health of the population. Increases in rainfall and river flow, despite the uncertainties, are likely to intensify, as projected by the IPCC scenarios. Temperatures will follow the pattern of increase in average values, with reduced episodes of frosts and cold days. [*GT2* 8.3]

In terms of health, climate phenomena may influence human health directly by favoring endemic infectious diseases sensitive to climate variations, death by drowning, landslides and collapsing buildings, or heat waves, and indirectly by loss in agricultural production and consequent nutritional impact, a fall in standards of personal and environmental hygiene, as well as a determinant of demographic phenomena. [*GT2* 8.3]

Regarding rural activity, according to some projections, in a few decades the southern region will have a new geographical conformation of agriculture and livestock, without highlighting a possible suitability of crops currently restricted by cold over others, such as fruit adapted to the temperate climate. Soybeans and corn may be replaced by semi-perennial crops like sugarcane. Alternative techniques such as direct planting (DP) and integration of livestock cultivation and forest can mitigate climate risks. [*GT2* 8.3]

Identified Gaps

- There is a short interval of observations of temperature and humidity conditions.
- There are uncertainties in predictions of precipitation and river flow from the region.

Southeast Region

> In cities such as Rio de Janeiro and São Paulo, there has been an increase in extreme events associated with floods. The impacts of heavy rains in the capitals of the southeast, whether followed by floods or not, cause morbidity and mortality of the population.

The advance of agricultural production and urbanization in these states provoked destruction of forests, marsh and mangrove in the *Mata Atlântica* biome. The process of occupation of this region occurred mainly with cattle and coffee cultivation.

The deforestation of forests to plant coffee increased the variability of precipitation, increasing its abundance or scarcity. The average of the climate models studied indicates a greater likelihood of reduced rainfall in these regions as a consequence of global warming. [*GT2* 8.4]

In cities such as Rio de Janeiro and São Paulo, there has been an increase in extreme rainfall events associated with floods, among other processes that occur in the rainy season. All of them require analysis of risk scenarios and conditions of vulnerability, together with projections for intensification of rainfall events occurring in these countries. [*GT2* 8.4]

The impacts of heavy rains in the capitals of the southeast, whether or not followed by floods, will cause morbidity and mortality of the population. It is inevitable that long-term climate change will exercise effects on human health in urban areas. For. the region, which is home to four of the major Brazilian cities in addition to municipalities with over 1 million inhabitants, concentrate large fleets of vehicles and stationary sources of emissions of pollutants, and the risks to human health associated with these

issues. [*GT2* 8.4]

Existing studies identify signs of possible changes in hydrological and thermal regimes in the Paraná – La Plata river basin. The forecast for the region for the 21st century is an increase of 4 to 4.5 °C in mean air temperature with a higher frequency of extreme events. [*GT2* 8.4] A temperature rise of between 2.5 and 3 °C and an increased rainfall of 25% to 30% are projected for the end of the century. [*SE GT*1]

Agriculture must adapt by substituting species better acclimated to the new temperature patterns, combined with alternative techniques such as direct planting and intercropping of forests, livestock and agriculture.

Programs for biodiversity conservation are necessary as a strategy to reduce the region's vulnerability to a possible intensification of food insecurity. [*GT2* 8.4]

Another important aspect, not only in urban centers, is to adapt to water surplus, which may increase in some municipalities in the southeast (the models point to a decrease in rainfall in some areas of the southeast and increase in others), and will influence not only food production, such as access to water, and the health of the population, increasing the potential for the incidence of diseases related to climate change, inevitably resulting in the loss of quality of life in the region.

Identified Gaps

- Among the major cities in this region, the metropolitan regions of Rio de Janeiro and Vitória are on the coast, new, more in-depth studies on the potential impacts of the rising sea level and specific vulnerabilities are needed to strengthen information on this facet of the impacts caused in the southeast.

- In the metropolitan regions of Sao Paulo and Belo Horizonte, the increase of the urban popu lation and the form of occupation of their areas should be accompanied by greater investments in programs for the containment of floods and removal of vulnerable populations in at-risk are as. It is also a true need to increase existing civil defense programs for extreme situations such as floods and landslide

Center-West Region

Agricultural and livestock activities will suffer reduced productivity due to changes in the hydrological cycle, temperature increases and phenology changes.

The development of better adapted crop varieties and production techniques better adapted to future climate contexts must be part of comprehensive adaptation planning for the region.

The center-west faces many negative climate forecasts predicting that agricultural and livestock activities will suffer reduced productivity due to changes in the hydrological cycle and temperature increases, and also due to the strategic location of the region, located in the most important three biomes in the country: *Amazônia, Cerrado* and the *Pantanal*. [*GT2* 8.5]

The *Cerrado, Pantanal* and *Amazônia* biomes exchange genetic material between their buffer zones having been heavily impacted by their land use and occupation along the last century. In addition

to the environmental problems, the region is involved in a frame of deep social and land conflicts, which make it highly vulnerable if regional changes in climate occur. [*GT2* 8.5]

Currently, the center-west is the breadbasket of Brazilian grain production, and the Cerrado biome is classified as a hotspot of global environmental preservation as it holds the title of the most biodiverse savannah on the planet, and more than 48% of this biome has already been converted to agricultural use.

The study results indicate a reduction of flow of all river basins with significant tributaries rivers in the center-west (Tocantins/Araguaia, Paraná, São Francisco, Paraguay and Amazonas) for the period 2071-2100, relative to the historical average (1961-1990). The only exception was the Paraná River basin, which showed an increase in flow of 11% in the A2-BR scenario. The reduction trend is closely associated with variations in the parameters considered, especially real evaporation, the projections of which show a substantial increase in the five basins in the center-west. [*GT2* 8.5]

Changes in the hydrological cycle and temperature would be of paramount importance for the center-west region because a change in the phenology of crops (soy, rice, corn, coffee) may cause massive losses in agricultural and livestock production. Therefore, EMBRAPA has developed research on agroclimatic zoning for different crops. These results may help producers and the government to create adaptation strategies if areas become unsuitable for the production of numerous types of grains in the future. [GT2 8.5]

Studies developed by INPE and EMBRAPA suggest that temperatures will increase by between 1 °C and 5.8 °C in the center-west, with a drier and warmer period by 2070. This should predominate in the region for a period of seven months. Therefore, plants must withstand temperatures excessively above 32 °C during the hottest parts of the day, ceasing processes of photosynthesis and altering their normal growth phases. In the state of Goiás, a loss of 95% of the area fit for the production of Arabica coffee is expected. [GT2 8.5]

Identified Gaps

Due to the recent history of colonization that intensified beginning in the 1940s and 50s, the region still lacks a denser network for weather data monitoring. Thus, modeling patterns of precipitation and temperature anomalies based on data are from only a few existing weather stations, with the remainder of the data produced from simulations generated with mathematical calculations.


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