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CLIMATE CHANGE AND EXTREME EVENTS IN BRAZIL

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FBDS FOREWORD

The mitigation of, and adaptation to the effects of the global climate changes are now the greatest challenges for humanity. Our economic and scientific progress has contributed decisively to the solution of historic problems and increased the well-being of the population but has also brought an enemy that has been invisible so far. We have become dependent on the generation of electricity, transportation of passengers and goods, food production and other needs, all of which involve greenhouse gas emissions.

As a consequence, there has been a rise in the average temperature of the planet and, according to the Intergovernmental Panel on Climate Change, an increase of 2ºC in the average temperature of the Earth appears to be inevitable over the coming years, even if all of the actions to reduce emissions and capture the carbon come to fruition. In the most pessimistic scenario, with present business practices maintained for the coming years, scientists forecast an increase of more than 6°C in the average temperature of the Earth, with catastrophic consequences for the ecosystems and for mankind. Although there is a small margin of uncertainty, for the majority of scientists there are no longer doubts about the risk of climate changes or the role of man in aggravating them.

As the climatic balance of the planet is fragile, the increases in temperature have already created new situations, such as the reduction in the permanently frozen icecap in the Arctic Circle, or the intensification of phenomena that already existed, such as hurricanes in the south of the United States. All these alterations have shown great destructive force, affecting millions of people and causing losses of billions of dollars.

Extreme climatic events such as heavy rainfall, high winds and hurricanes, storm tides and severe droughts present the greatest destructive forces as a result. In addition to the intensity of them, it is more difficult to manage plans for adaptation to and mitigation of their effects, due to the inability to forecast them precisely. Hurricane Catarina, which hit the Brazilian coast in 2004, was the first time that a hurricane had been recorded in the South Atlantic.

The relationship between these extreme climatic events and global climate changes, have not been fully studied by the Brazilian scientific community. With the aim of motivating new studies and making society aware of the risks, Lloyd's and the Brazilian Foundation for Sustainable Development (FBDS) have established a partnership for the production of this publication, and the holding of a seminar to present its contents and debate with the country's leading specialists in the subject.

This booklet is divided into four themes to help understanding of climate change in Brazil:

• Global climate change and extreme events in Brazil, addressing how global climate change affects the occurrence of these events - such as severe flooding - and their impacts on Brazilian society;
• Risk and adaption in the energy sector in Brazil, regarding the dependency of Brazilian electricity generation on hydro power plants and how changes in the intensity and distribution of rain during the year may affect the balance between electric supply and demand;
• Adaptation in the agricultural sector in Brazil, which studies the risks to food production and the possible adaptation measures;
• Sea level rises in large Brazilian coastal cities, considering how sea level rises might affect the Brazilian population and infrastructure close to the Atlantic Ocean, especially in the major cities of Rio de Janeiro and Recife.

Our hope is that this publication fulfills its role in alerting the Government, companies and civil society to the difficult challenges that climate changes bring. Adaptation plans will be essential to enable us to reduce the damage both to life and to property that the changes in temperature and rainfall - and the intensification of extreme climatic events associated with them - will bring.

Israel Klabin

President Fundação Brasileira para o Desenvolvimento Sustentável - FBDS

LLOYD'S FOREWORD

Climate change scientists frequently tell us to expect the unexpected. Brazil experienced this first hand in 2004, when Cyclone Catarina hit land without warning. Meteorologists had never witnessed this before. It seems that the world today is experiencing more and more once in a lifetime events: floods in central Europe and cyclones in the South Atlantic, so we need to prepare for the unthinkable and the improbable.

International attention often focuses on the role of the Brazilian rainforest – a critical carbon sink, but the purpose of this report is different. We want to advise policy makers, academics and businesses how climate change will affect Brazil, not how Brazil will affect climate change. I make no apology for the fact that it makes sombre reading, with predictions of heatwaves in São Paulo, warmer winters and autumns and intense rainstorms in various parts of the country.

Brazil is already experiencing unusual events. São Paulo farms lost $50 million during a heatwave in 2004, typically humid parts of Amazonia are drying up and pipelines carrying gas from Bolivia have been damaged by extreme weather.

Academics, businesses, government officials and insurers will find this report invaluable as a tool to deepen their understanding of how climate change will change Brazil.

The publication, produced by the Fundação Brasileira para o Desenvolvimento Sustentável (FBDS) in partnership with Lloyd's contains reports on four key challenges facing the country:

• Extreme weather;
• The Electric power system;
• Adaptation of Agriculture.
• Sea Level Rise;

Each of these reports analyse the extent to which Brazil is already experiencing climate change; makes a prognosis for the future – notoriously difficult on climate change – and, most importantly, suggests ways to mitigate the effects of changing weather systems here in Brazil.

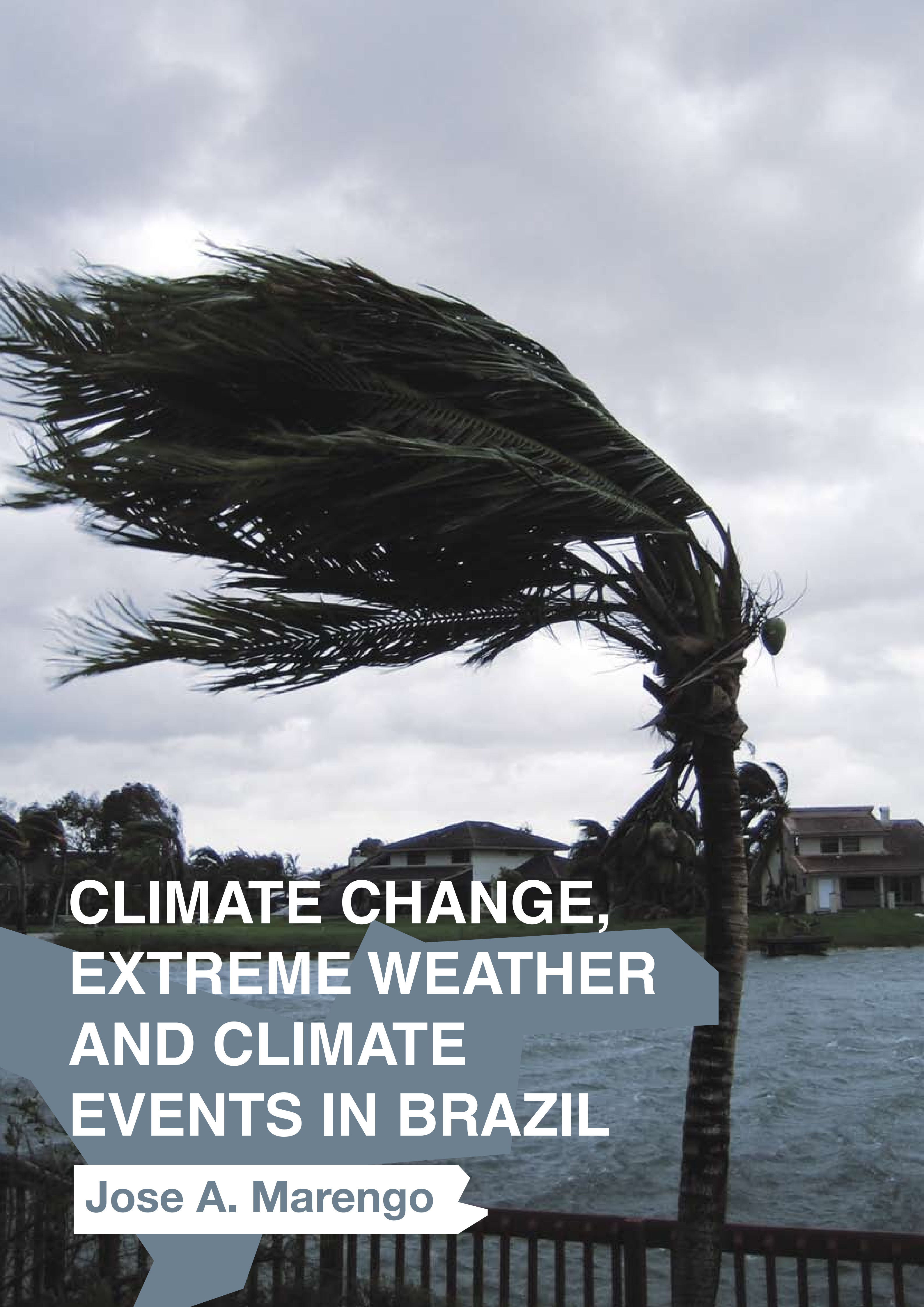
The conclusions reached by FBDS mirror the findings of Lloyd's 360 Risk Insight work on climate change , in particular the need for businesses, farms and householders to start thinking now about how they can adapt their properties to more extreme weather events. At the strategic level, it is essential that businesses and governments look for ways to slow global warming and reduce CO_2. But we also want to see pragmatic policies, which help people to cope with the changes that are already happening. One particular merit of FBDS' report is to identify specific measures which could be taken by insurers in Brazil to manage the risk of climate change.

Lloyd's is listening to these ideas. We have a 321 year history of adapting to the world's risks. Reports like this excellent study from the FBDS improve our understanding of where today's challenges lie. I recommend it to the reader.

Marco Antonio de Simas Castro

General Representative & Managing Director Lloyd's Brazil

[1] Details at: http://www.lloyds.com/News_Centre/360_risk_insight/The_debate_on_climate_change/.



CLIMATE CHANGE, EXTREME WEATHER AND CLIMATE EVENTS IN BRAZIL

Jose A. Marengo

SUMMARY

Extreme climatic events may occur in many different ways, for example as floods, prolonged droughts, heat waves, typhoons and tornados.

These meteorological phenomena are nothing new. Over many centuries, mankind has developed a good grasp of the frequency of extreme weather events and the geographic locations where they are most likely to happen.

But this is changing. All the available information shows that the occurrence of extreme weather events has increased in terms of both frequency and intensity. This has been especially marked since the second half of the 20th Century.

In Brazil, a number of extreme events have occurred in recent years. Typhoon Catarina caused floods and landslides and resulted in several deaths as well as significant economic losses to the South of the country. The same region recently experienced torrential rain and strong winds which led to a new spate of damage.

Extreme weather has also damaged the gas pipelines that link Southern Brazil to Bolivia . This has caused significant consequences for the population in the States of Santa Catarina and Rio Grande do Sul.

In southeast Amazônia, historically a tropical, humid region, unusual weather conditions have lead to lower river levels - reduced navigation has cut off some isolated communities. Some rivers have even become totally dry and forest fires have affected the livelihood of local residents, in some cases causing airports to be closed. This phenomenon was apparently caused by an anomalously warm tropical North Atlantic, causing dry air to descend from the south over this part of the Amazon region.

Future climate projections indicate more water vapor and more dynamic processes in the atmosphere, so that extreme winds, as well as other phenomena, may occur with greater frequency and intensity.

Future climate studies indicate that after 2010 precipitation may tend to increase in southern Brazil, as well as in western Amazônia and the coastal region between Amapá and Ceará. Lower rainfall can be expected in southern and central Amazônia, west central Brazil and most of Northeast Brazil. Worse case scenarios show a possible increase in dry spells in eastern Amazônia and parts of Northeast Brazil, while the number of consecutive wet days may decrease in most of Northeast Brazil, west central Brazil, and western and southern Amazônia.

Heavy rainfall indices show increases in the frequency and intensity of extreme rainfall in southern and southeastern Brazil, and, to a lesser degree in western Amazônia and the costal region of eastern Amazônia and northern Northeast. Rainfall may decrease all the way down the coast of eastern Northeast Brazil, from Rio Grande do Norte to Espírito Santo.

By 2020, while rainfall will tend to increase in western Amazonia and in Southern and Southeastern Brazil, the rest of the regions are likely to record less heavy rains.

By 2030, the dominant pattern shows a possible reduction in the total amount of rainfall and number of wet days in tropical South America, with a tendency for more heavy rainfall in regions such as western Amazônia, and southern and Southeastern Brazil.

Some business and companies may suffer directly or indirectly from the consequences of a possible global warming. Directly, without any adaptation, they may experience difficulties in maintaining current levels of production or operational efficiency.

The insurance industry can contribute to the efforts against global warming by creating the right incentives for its clients. This could mean offering innovative and less costly products to businesses and individuals which pursue best practices in relation to climate change. Also, insurance companies could dedicate part of their investment portfolio to “green” investments, such as alternative energy projects, industrial emission reduction projects and retrofit projects for commercial and residential buildings.

1. INTRODUCTION

In meteorological or climatological terms, wide departures from a mean climate state (hereafter 'extreme events') occur on scales ranging from days to millennia. The most important for human activities, however, are perhaps the short-term extreme (weather related) and the medium-term (climate related) events, given their potential for significant impacts. Extreme weather and climate events are also an integral aspect of climate variability, and their frequency and intensity may vary with the prospects of climate change. A natural disaster may be amplified by human activities such as deforestation of slopes nearby cities, or construction in risk areas, magnifying the effect of extreme rainfall. This hardly ever kills people of itself, but landslides produced by them in areas near riverbeds or below deforested slopes are harmful for society.

One of the most important questions regarding short-term extreme events is whether their occurrence is increasing or decreasing over time; that is, whether there is a trend for the envelopes within which these events preferentially occur. Variability and changes in the intensity and frequency of extreme events depend not only on the rate of change of the mean of a selected variable, but also on whether there are changes in the statistical parameters that determine the distribution of that variable. The most difficult trend analysis is that of extreme precipitation, because of the low degree of correlation among precipitation events. Therefore, reliable estimates of trends in extreme precipitation events are possible only for regions with dense networks that have remained stable over time. The lack of homogeneous and high quality long-term climate observations, or the difficult access to data banks, many of them in the hands of government institutions in large parts of South America is the greatest obstacle to quantifying the change in extremes over the past century (Haylock et al. 2005, Vincent et al. 2006).

Historically, climate variability and extremes have had negative impacts on the population, increasing mortality and morbidity in affected areas. Extreme weather events have become more intense and/or more frequent during the last 50 years in southeastern South America. Exceptional rainfall events occurred in mid-December 1999, and produced floods and landslides along the north central coast of Venezuela with over 10,000 fatalities reported, and economic losses estimated in excess of US$1.8 billion (Lyon, 2003). Similar events also occurred in February 1951 and February 2005. In Brazil, high vulnerability was demonstrated to a single catastrophic event. In Southern Brazil, the period 22 to 24 of November 2008 saw heavy rainfall in Santa Catarina State cause severe floods and deadly mudslides. In March 2004, in the same state, Hurricane Catarina, possibly the first hurricane affecting the continent, was detected, leaving 9 deaths and losses to the order of US$ 1 million dollars.

With the prospects of climate change, scientists, policymakers and governments from around the world are seeking to understand the nature of the changes that are likely to occur during the 21st century and beyond, and the effects these changes could have on human populations and the socio-economic systems that underpin them. Changes in precipitation have implications for the hydrological cycle and water resources in a future warmer climate.

Climate change is expected to alter average temperature and precipitation values, and to increase the variability of precipitation events, which may lead to even more intense and frequent floods and droughts. Evidently, extreme flood and drought events can cause economic and ecological damage and, in the worst case, can put lives at risk. In general, many economic activities and environmental processes are highly dependent on precipitation. Occurrences of large-scale precipitation deficits often have severe effects on activities such as agriculture, forestry, hydroelectricity production, wetlands and wildlife. Their surpluses are often beneficial to the aforementioned activities. However, a persistence of anomalously wet conditions can also have severe effects, such as flooding and delays in harvesting, amongst others. Because of this, the economic and social costs of increasing extreme events will also be higher, and the impacts will be substantial in the areas and sectors most directly affected, such as agriculture, hydroelectricity generation, large cities and biodiversity.

In this chapter, we make a review of extreme events in Brazil observed during the last 50 years, with a quantification of the tendencies in each region of Brazil or whenever data allow. In addition, we performed analyses of future climate change projections up to 2030 for Brazil, based on the regional climate change projections developed at INPE. The focus is on rainfall extremes. One special section is dedicated to Amazônia, where extremes are discussed in terms of possible consequences in the region. In conclusion, we reflect on some recommendations for mitigation and adaptation measures and practices that could be raised in the debates and discussions with stakeholders and policy makers.

2. HISTORICAL WEATHER AND CLIMATE EXTREMES IN BRAZIL

Climate variability and extreme events have been severely affecting Brazil over recent years. In subtropical Brazil, Groisman et al (2005) and Marengo et al. (2009) detected a systematic increase of very heavy precipitation since the 1950s, and in Southeastern Brazil they detected an increase in the frequency of extreme rainfall events. For the state of São Paulo, Carvalho et al. (2004) found that extreme rainfall events exhibit an inter-annual variability linked to El Niño and La Niña, as well as intra-seasonal variations associated with the activity of the South Atlantic Convergence Zone (SACZ) and the South American Low Level jet (SALLJ).

Floods cause huge economic disasters, both for non-insured people/companies, under insured people/companies and insurance companies. In addition, floods take large numbers of human lives. On the other hand, drought can cut off entire cities from their electricity, generated by rain fed water sources, causing major economic damage. Water shortages will lead to severe unrest in society, and drifting of the populations from entire regions.

In Southern Brazil, heavy rainfall affected Santa Catarina State from 22 to 24 November 2008, causing severe flooding and deadly mudslides, which affected 1.5 million people, resulted in 120 casualties and left 69,000 people homeless. Mudslides and flooding caused by the storms blocked almost all the highways in the region and cut off water and electricity to thousands of homes. It was reported that most of the fatalities were caused by mudslides that swept away homes and businesses. The storms ruptured a stretch of pipeline that carries Bolivian natural gas to Southern Brazil, and forced the suspension of the fuel supply to part of Santa Catarina and to the entire neighboring Rio Grande do Sul State. Some cities reported looting of supermarkets and pharmacies by hungry and desperate flood victims. This event has been described as the region's worst weather tragedy in its history.

An unusual combination of meteorological conditions favored the intensification of rainfall along the costal region of Santa Catarina. Unofficial estimates of the losses due to this extreme rainfall event and subsequent floods and landslides are to the order of $US 350 million, due to the closure of the Paranaguá Port, one of the most important ports in Southern Brazil (INPE 2008). Previous extreme events during the El Nino 1983, exhibited intense rains and floods, and produced an economic loss of about US$ 1.1 billion in the entire state of Santa Catarina. Furthermore, Munich-Re (2009) reported overall losses to the order of US$ 750 million, with insured losses of US$ 470 million.

In March 2004, a hurricane affected the coastal region of the same state, with losses to the order of US$ 1 billion (Pezza and Simmonds 2005, Pezza et al. 2009). The landfall of Catarina on the Brazilian coast in March 2004 became known as the first documented hurricane in the South Atlantic Ocean, promoting a new view on how large-scale features can contribute to tropical transition, in a region previously thought to be hurricane-free.

Rainfall deficits during the summer and fall of 2001 resulted in a significant reduction in river flows throughout the Northeast, Central-west and Southeast Brazil, thereby reducing the capacity to produce hydroelectric power in these areas. (90% of Brazil´s energy is from hydroelectric sources.) In an anomalously dry and warm summer, there was an excessive demand for energy for air conditioning and cooling systems, and this generated reductions in the levels of the reservoirs of the hydroelectric generation plants, reaching minimum critical levels (5% or less of the total volume). The large-scale nature of the deficits, affecting nearly the entire country, resulted in an energy crisis that forced the government to impose energy conservation measures in order to avoid total loss of power (blackouts) during part of 2001 and 2002 (Cavalcanti and Kousky 2004).

The drought that has been affecting Southern Brazil and Northern Argentina since 2008 determined a reduction in the production of soybean and grains in Argentina and, together with the international price reductions, determined a forecast reduction of about 30% in exportation; of about US$ 8-9 billion for 2009. This forecast would change if rainfall returns to normal and if soybean prices increase. The year 2009 is considered as the driest in 80 years. In southern Rio Grande do Sul State, bordering Argentina and Uruguay, many farmers say the drought has withered their corn and other grains. Winter grass for cattle couldn't be planted, and milk production has suffered. In 96 municipalities, they have declared a state of emergency due to the damages caused to soybeans, maize and bean crops, pastureland, and water supplies for human and animal consumption.

In Southern Brazil, national wheat production in the last harvest was six million tons – the highest output since 2004. The drought has delayed the planting of wheat in some regions of Santa Catarina and Rio Grande do Sul, and in parts of Paraná, which could hurt the southern hemisphere winter harvest, according to the Ministry of Agriculture. The official forecast for grain production for 2008-2009 is 5.5 million tons, which would be a nine percent drop in relation to what was predicted at the beginning of the year.

3. HISTORICAL CLIMATE EXTREMES IN AMAZÔNIA: SOCIAL AND ECONOMIC IMPACTS

Historically, there is evidence of extensive droughts, and perhaps widespread fires, linked to paleo El Nino Southern Oscillation (ENSO) events occurred in the Amazon basin in 1,500, 1000, 700 and 400 BP, and these events might have been substantially more severe than the 1982-83 and 1997-98 events (Meggers 1994). The best-documented case of an earlier drought event in Amazônia linked to El Niño was during 1925-26 (Sternberg 1968; 1987, and Williams et al. 2005). Rainfall anomalies in the central-northern Brazilian Amazônia and southern Venezuela in 1926 were about 50% lower than normal. During this particular drought, extensive fires prevailed in Venezuela and the upper Rio Negro basin. Unusually high air temperature anomalies were recorded in Venezuelan and northern Brazilian Amazonian towns for both 1925 and 1926, and it is plausible that the dryness in the northern portion of the Rio Negro basin in 1925 also contributed to the major drought in 1926 by a depletion of soil moisture.

Contrary to the above droughts, the droughts of 2005 as well as those in 1963-64 and in 1979-81 did not occur in association with El Niño events. In 2005, large sections of southwestern Amazônia experienced one of the most intense droughts of the last hundred years. The drought severely affected the human population along the main channel of the Amazon River and its western and southwestern tributaries, the Solimões (also known as Amazon River in the other Amazon countries) and the Madeira Rivers, respectively. The river levels fell to historic low levels and navigation along these rivers had to be suspended, isolating small villages, and affecting tourism and cover along the Solimões and Madeira Rivers. This led various countries of the Amazon region (Brazil, Bolivia, Peru and Colombia) to declare a state of public calamity in September 2005. The drought did not affect central or eastern Amazônia, a pattern different from the El Niño-related droughts in 1926, 1983 and 1998, and the last two also experienced intense warming in the tropical North Atlantic along with warming in the equatorial Pacific. The 1963 drought was linked to warming in the tropical North Atlantic, similar to the 2005 drought.

Zeng et al (2008) shows an interesting analysis of river levels for the Amazon streamflow measured at Obidos (which captures rainfall from about 90% of the total Amazon drainage basin). It shows an unusually long and slow decrease since 2000, culminating in late 2005; a trend consistent with the precipitation anomaly. The 2005 rainfall deficit was mostly in the southwestern Amazon as noted in Tabatinga (a station on the Solimões River, the main stem of the Amazon), which captures the rainfall from the upper Amazon basin with source water mostly from the eastern Andes. The Tabatinga river stage shows a rapid drop in 2005, but it lacks the several years of slow decrease seen in the Obidos streamflow. The Tabatinga river stage was one of the lowest in the 24-year period analyzed. The seasonal cycle in the Amazon is long, so that the drought impact on the ground was felt mostly as a particularly severe dry season when water level is at its lowest. To capture the seasonal aspects, the 9 years with lowest streamflow for Obidos and Tabatinga are shown in Figure 1.

As the rainforests dried, serious wildfires broke out in the region, damaging hundreds of thousands of hectares of forest. These wildfires produced extensive smoke that affected human health and closed airports, schools and businesses. The ecological impacts affected the feasibility of sustainable forest management in the region, which is currently advanced as a promising basis for the regional economy (Brown et al., 2006). In 1997-98, fires associated with an exceptional drought caused by El Niño devastated large areas of tropical rain forests in northern and eastern Amazônia (Nepstad et al. 1999). The number of forest fires in 2005 was about 300% higher than in 2004 as a consequence of the dry conditions (Marengo et al. 2008a, b).

The causes of this drought were not related to El Niño, but to an anomalously warm tropical North Atlantic. The drought conditions were intensified during the dry season in September 2005, when humidity was lower than normal and air temperatures 3-5 °C warmer than normal. Due to the extended dry season in the region, forest fires affected part of southwestern Amazônia almost 300% larger than normal. As a consequence of fires, air traffic was affected due to the closing of the Rio Branco International Airport in state of Acre in western Amazônia; schools and business were closed due to smoke, and many people had to be treated in hospitals due to smoke inhalation (Marengo et al 2008a, b; Zeng et al 2008, Cox et al. 2008). There are no complete estimates of the cost of this drought. For the Acre State, the Civil Defense estimated a loss of about US$ 87 million due to the fires alone, which represents about 10% of the State's GDP.

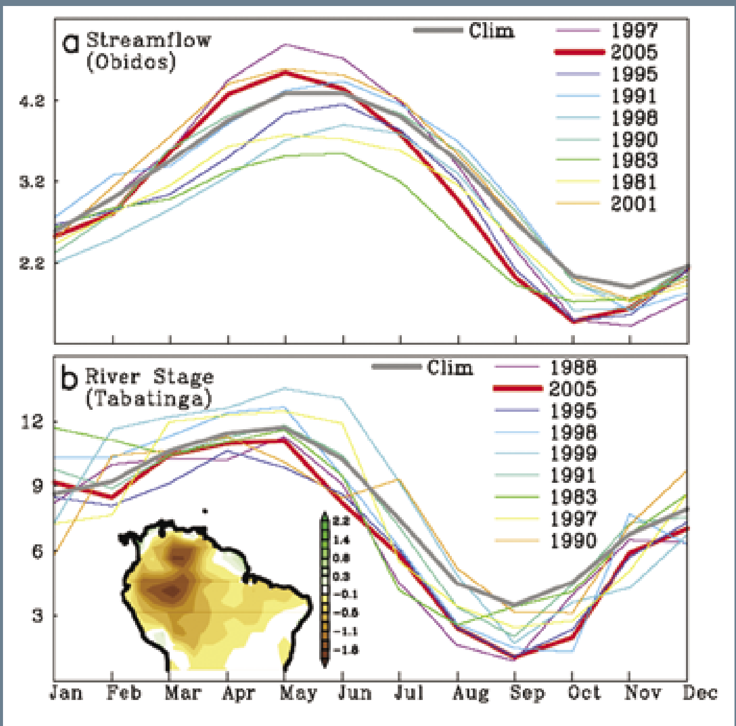


Figure 1. The 'driest' years for (a) the whole Amazon basin as indicated by the streamflow measured at Obidos (1.9 S, 55.5 W; (b) the upper Amazon basin (Solimões River) at Tabatinga river stage (4.25 S, 69.9 W; in meters). Year 2005 is in thick red, long-term climatology (1979–2005 for Obidos, 1982–2005 for Tabatinga) is in thick gray. Other dry years are thin lines in different colors. These 'driest' years were chosen and ranked in the key according to the lowest water level in that year Zeng et al. 2008

Figure 2a

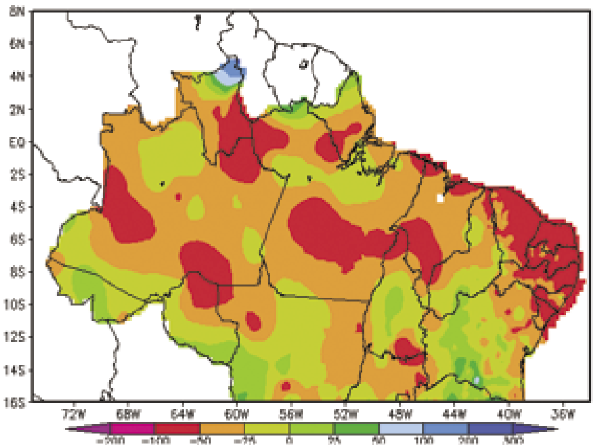


Figure 2b

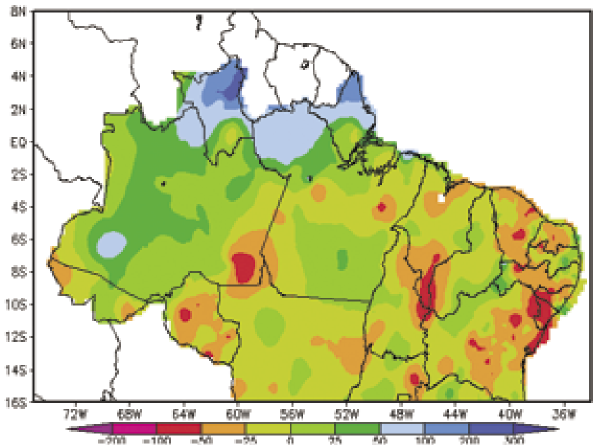


Figure 2a shows rainfall anomalies during November2004-February 2005, and shows the large negative rainfall departures in most of western Amazõnia, Marengo et al (2008a) shows that in December 2004 and January 2005, rainfall in that region was almost 30-40% below normal, enough to reduce the water levels in the upcoming months.

In contrast, 2009 (Figure 2b) featured very intense rainfall and floods in the Amazon and Northeast Brazil regions. According to the BBC, Brazilian authorities say almost 408,000 people still cannot return home because of floods that began in March 2009. The government has released more than US$ 435 million in aid for victims of the flooding in the North and Northeast of Brazil. The Amazon region has experienced near-record flooding and has evacuated thousands of people. Water levels at a measuring station on the Rio Negro in Manaus, have shown levels that are surpassed only by the record set in 1953, since 1903 when measurements started in Manaus. Water levels at a measuring station on the Rio Negro in Manaus, the Amazon's largest city, stood just 74 centimeters (29 inches) below the record set in 1953. Across the Amazon basin, river dwellers are adding new floors to their stilt houses, trying to stay above rising floodwaters that have killed 44 people, and left 376,000 homeless by June 2009. Flooding is common in the world's largest remaining tropical wilderness, but this year the waters have risen higher and stayed longer than they have in decades, leaving fruit trees entirely submerged.

Only four years ago, the same communities suffered an unprecedented drought that ruined crops and left mounds of river fish flapping and rotting in the mud. The unusually intense rains have been caused by two simultaneous climate phenomena: La Niña, characterized by an atypical cooling of the surface waters of the Pacific Ocean, and the anomalously warm surface waters of the tropical Atlantic Ocean south of the Equator, that favored the formation of a low pressure belt on land in the equatorial region, known as the Intertropical Convergence Zone (ITCZ), where hot, humid winds bring cloud masses and cause heavier than normal rainfall, usually in March and April, in northeastern Brazil. The ITCZ usually moves on in March, but stayed put until May in 2009. While in 2005, rainfall during the peak season from February to May (FMAM) was almost 50-100 mm below normal, during 2009, the Amazonian states experienced excesses to the order of 100-200 mm above normal.

Nearly 400,000 children are also missing classes, either because roads are blocked, classrooms are under water, or schools are being used as shelters to accommodate the homeless. The situation is said to be most critical in the state of Amazônas, where a quarter of all pupils are affected. In Northeast Brazil, the worst flooding in at least two decades washed out bridges and roads, destroyed hundreds of homes, and caused huge losses for agriculture. The states hit hardest by the intense rainfall and flooding are Amazônas in the North and Maranhão, Ceará, Piauí and Paraíba in the Northeast, but parts of Rio Grande do Norte, Bahia, Pernambuco and Alagoas, also in the Northeast, have been affected as well.

4. CLIMATE CHANGE PROJECTIONS AND EXTREMES

Some global circulation models suggest that Amazônia may be vulnerable to extreme drying in response to circulation shifts induced by global warming (Li et al. 2006), possibly leading to a dieback of tropical rainforest with a potential acceleration of global warming (Cox et al. 2004). Fluctuations in the meridional sea surface temperature (SST) gradient are a dominant form of tropical Atlantic variability over inter-annual to multidecadal time scales and have been linked to droughts and floods in Amazônia and Northeast Brazil. Therefore, future changes in the tropical Atlantic meridional SST gradient are one possible driver of climate change for the Amazon region, with impacts from regional up to global scale through carbon cycle feedbacks (Cox et al. 2000, 2004, 2008; Li et al. 2008).

Over the last decade, Amazônia has experienced two droughts; in 1997/1998 and 2005. Both droughts caused significant rainfall anomalies and hydrological stress, significantly increasing the number of fires detected in this region (Aragão et al. 2008). The areas affected by fires are expected to become more vulnerable to recurrent fires. The interaction between land-use and climate change is likely to generate a positive feedback (e.g. Cochrane et al. 1999), increasing the vulnerability of Amazônia to climate change, and having significant effects on the global carbon cycle.

The drought of 2005 was the subject of a numerical study by Cox et al (2008). They used the HadCM3LC global model from the UK Hadley Centre run with aerosols, and predict a 2°C increase in the Atlantis Decadal Oscillation AMO Index (that is highly correlated with the meridional SST gradient in the tropical Atlantic) by the end of this century. As a consequence, this GCM projection suggests that the conditions of 2005 will be experienced more and more frequently under increasing atmospheric CO_2. Although climate model projections differ in detail, a preliminary assessment of the results from the GCMs used in the IPCC Fourth Assessment Report (under the SRES A1B scenario including anthropogenic aerosols), also indicates an increasing risk of exceeding the 2005 AMO index. Figure 3 estimates the probability of a “2005-like” year occurring in the HadCM3LC model run with aerosols, based on the fraction of years in a centered 20-year window that exceeds the 2005 AMO Index value. The model suggests that 2005 was an approximately 1 in 20-year event, but will become a 1 in 2-year occurrence by 2025, and a 9 in 10-year occurrence by 2060. These thresholds obviously depend on the rate of increase of CO_2, which is itself dependent on the emissions scenario chosen. These results suggest that 2005-like droughts in Amazônia will become much more frequent under conditions of reducing aerosol loading and unmitigated CO_2 increase.

For South America, projections for the end of the 21st century from the IPCC AR4 (www.ipcc.ch) and the INPE´s Climate Report (www.cptec.inpe.br/Mudancas_climaticas) are unanimous concerning the changes in most temperature indices that are expected within a warmer climate, with differences in the spatial distribution of the changes and in the rates of the trends detected across scenarios. However, consensus and

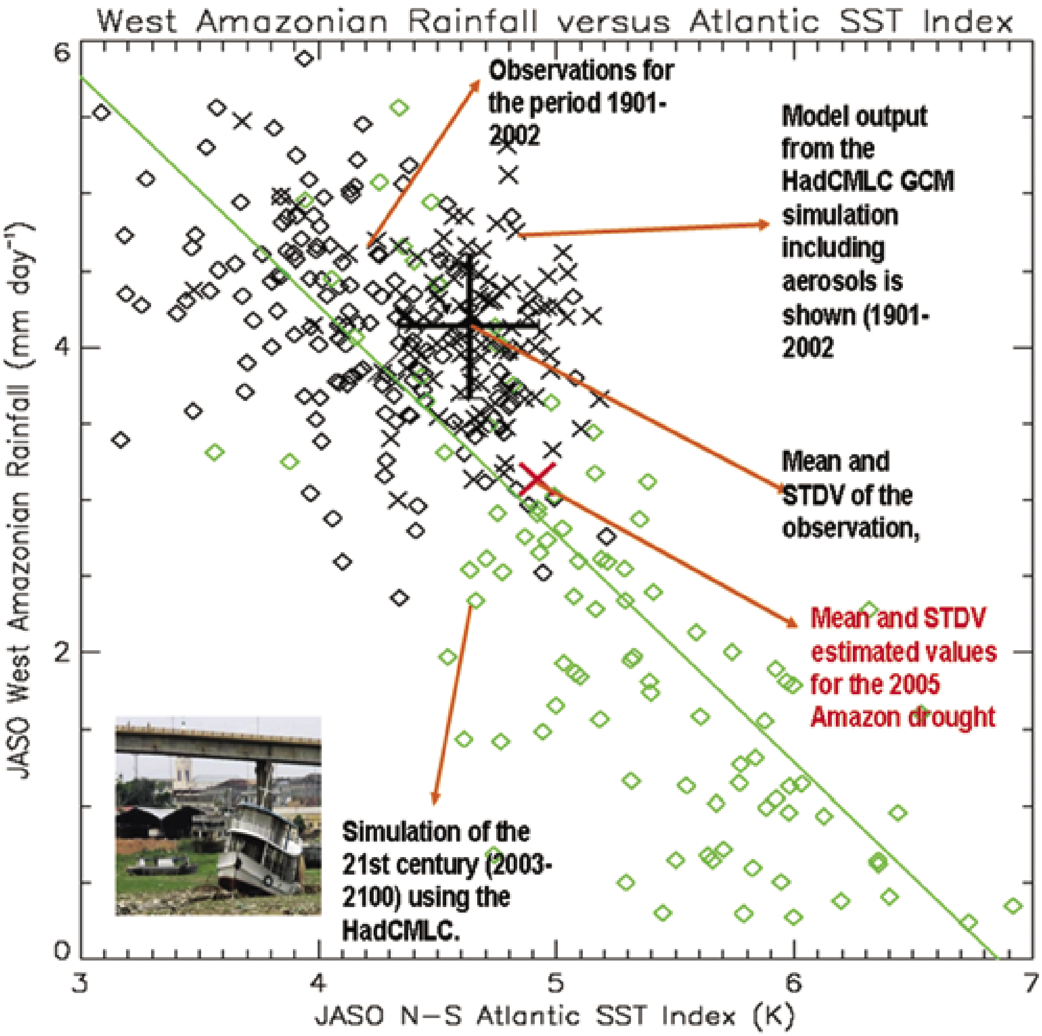


Figure 3. Relationship between July-October (JASO) anomalies in rainfall in Western Amazônia and in the AMO Index of the north-south SST gradient across the Tropical Atlantic ocean. Observations for the period 1901-2002 are shown by black diagonal crosses. Model output from the HadCMLC GCM simulation including aerosols is shown by black diamonds for the historical period (1901-2002) and in green diamonds for the simulation of the 21st century (2003-2100). The green line shows the best fit to the GCM output, the large black cross shows the mean and standard deviation of the observations, and the red diagonal cross shows estimated values for the 2005 Amazon drought (Cox et al. 2008).

significance are less strong where regional patterns are concerned, and while all models show consistency in the warming signal, the same cannot be said for rainfall extremes. Even though the consensus is not as high as in other regions, the tendency is that more models show rainfall reductions in eastern Amazônia, while in western Amazônia the projections show an increase between 2071-2100.

With regard to climate extremes, Tebaldi et al. (2006), Marengo (2009), Marengo et al. (2009) assessed worldwide projections of changes in climate extremes from an ensemble of eight global IPCC-AR4 models and from HadRM3P regional model projections, under various emission scenarios for the 2071-2100 time-slice. The HadRM3P regional climate change projections from Marengo et al (2009) shows that for both high and low emission scenarios (A2 and B2), there is a tendency for rainfall reductions in central-eastern and southern Amazônia, mainly due to an increase in the frequency and intensity of consecutive dry days. On the other hand, extreme rainfall events seem to be more frequent and intense in western Amazônia. This is consistent with the climate change projections derived from the IPCC AR4 global models (Tebaldi et al. 2006), where increases in consecutive dry days in central and eastern Amazônia, and increase in intense rainfall events in the area were also detected in western Amazônia for the intermediate scenario A1B.

The combined analyses of rainfall extremes from both global and regional models suggest that this increase in rainfall in the future would be in the form of more intense and /or frequent rainfall extremes, while rainfall reductions would be in the form of longer and more intense dry spells. In eastern Amazônia and Northeast Brazil, the risk of drought is likely to increase. In Southern and Southeastern Brazil, the increase in mean precipitation is also associated with the increase in the wet day frequency, and reductions in consecutive dry days. However, these projections are for 2071-2100, and not much is said about near term periods, such as 2030.

5. REGIONAL CLIMATE CHANGE PROJECTIONS AND EXTREMES UP TO 2030

Climate change projections derived from Regional Climate Models (RCMs) may be considered, with some reservation, as extremely useful for studies on climate impacts, because of the sub-continental pattern and magnitude of the changes, which are more refined than the coarse grid spacing, which poses limitations to the representation of topography, land use, and land-sea distribution.

High-resolution future climate change scenarios developed from regional climate model results have been produced in various parts of the world (See reviews in Marengo et al. 2009 and references quoted). Downscaling experiments on climate change scenarios in South America have recently become available for various emission scenarios and time-slices until the end of the XXI Century, using various regional models forced with the global future climate change scenarios as boundary conditions from various global climate models.

The methodology for dynamic downscaling of climate change scenarios and a description of the global model and the three regional models used is shown in Marengo et al. (2009a, b, 2007). In this report, we show the projections of climate extremes using the Eta-CPTEC 40 km lat-long regional model nested into the global climate model of the Hadley Centre at the U.K. Met Office HadCM3P AOGCM that was run under the "perturbed physics" approach (Collins et al 2006). The Eta-CPTEC/HadCM3 models were run for the present (1961-1990) forced by observed sea-surface temperatures and sea-ice. For the future, 2010-2100, the HadCM3 is forced by SST estimates from the oceanic component of the HadCM3 model. We used six rainfall-based indices of extremes used by IPCC (2007a) for the A1B intermediate emission scenario (Nakicenovic et al 2000). The analysis will focus on 2010-2030.

The indices used are:

1. Total annual precipitation, PREC
2. Maximum number of consecutive dry days: CDD
3. Maximum number of consecutive wet days: CWD
4. Number of days with precipitation greater than 20 mm: R20
5. Fraction of total precipitation due to events exceeding the 95th percentile of the climatological distribution for wet day amounts: R95P
6. Maximum 5-day precipitation, the annual maximum consecutive 5-day precipitation total that could lead to flooding: R5XDay

These indices do not represent extremely rare events, for which the computation of significant trends could be a priori hampered by the small sample sizes. The selected indices were calculated on monthly and/or annual bases, and some are based on thresholds defined as percentiles (e.g. R95P) or some fixed value (e.g. R20) and they are used to facilitate the comparison between stations. R95 is defined as precip>95th considering quintiles of the climatologies computed from the same model's historical run between 1961 and 1990.

Figure 3 shows that by 2010 precipitation would increase in Southern Brazil, as well as in western Amazônia and the coastal region between Amapá and Ceará. Rainfall reductions would be expected in southern and central Amazônia, west central Brazil and most of Northeast Brazil. The extreme indices show increase in the frequency of dry spells in eastern Amazônia and parts of Northeast Brazil, while the number of consecutive wet days tends to decrease in most of Northeast Brazil, west central Brazil, and western and southern Amazônia. The extreme rainfall indices show increases in the frequency and intensity of extreme rainfall events in Southern and Southeastern Brazil, and to a lesser degree in western Amazônia and the costal region of eastern Amazônia and northern Northeast. Reductions in the extremes of rainfall are detected from southern Amazônia all the way down the coast of eastern Northeast Brazil from Rio Grande do Norte until Espírito Santo.

By 2020, while rainfall extremes and totals tend to increase in western Amazônia and in Southern and Southeastern Brazil, the rest of the regions tend to show a decrease in rainfall extremes. In 2030, the dominant pattern is a reduction in the total amount of rainfall and number of wet days in tropical South America, with a tendency for increase in the rainfall extremes in regions such as western Amazônia, and Southern and Southeastern Brazil. The projected reduction in rainfall extremes is consistent with an increase in the projected number of consecutive dry days.

Table 1 shows a synthesis on the simulated (1961-90) and projected trends of the rainfall indices as produced by the Eta CPTEC model, averaged by region in Brazil. Based on the few available observations, we can say that the simulated PREC present time annual rainfall climatology is close to the observed climatology, with a systematic underestimation in regions such as Amazônia and overestimation in Southeastern and Southern Brazil, between +10 and -10 %. For the other indices, for regions with enough observations to calculate those indices (such as Southern and Southeastern) for 1961-90, the agreement between model and observations is quite acceptable, between +15% and -15%.

Table 1. Summary (1961-90) and projected (2010, 2020, 2030) indices of extreme rainfall for five regions of Brazil. "Value" represents the index value produced by the Eta CPTEC model, and "Anoma" represents the difference between the values of the indices of future and the present.

PREC (mm/ year)	1961-1990	2010		2020		2030	
	Value	Value	Anoma	Value	Anoma	Value	Anoma
Amazon	1905.5	1835.5	-69.9	1980.9	75.5	1798.7	-297.8
Southern	1712.5	1986.0	273.2	1815.2	102.3	1662.7	-203.8
Northeastern	476.5	543.0	66.6	481.7	5.2	753.9	1.9
West Central	1222.3	1291.61	69.3	1249.9	27.5	1108.4	-177.1
Southeastern	1518.4	1829.4	311.0	1585.3	66.8	1566.5	-136.3

R20mm (days)	1961-1990	2010		2020		2030	
	Value	Value	Anoma	Value	Anoma	Value	Anoma
Amazon	18.6	17.4	-1.2	20.0	1.3	15.9	-2.7
Southern	24.5	29.2	4.6	26.7	2.1	22.0	-2.6
Northeastern	3.9	5.2	1.3	4.3	0.4	5.7	1.8
West Central	12.4	12.0	-0.3	12.7	0.2	9.7	-2.7
Southeastern	21.4	27.2	5.7	23.2	1.7	19.8	-1.6

CDD (days)	1961-1990	2010		2020		2030	
	Value	Value	Anoma	Value	Anoma	Value	Anoma
Amazon	33.7	37.4	3.5	37.9	4.1	42.5	8.8
Southern	34.5	27.8	-6.7	24.2	-10.3	49.3	14.8
Northeastern	90.4	108.5	18.0	125.9	35.4	149.1	58.6
West Central	45.8	39.8	-6.0	38.8	-7.0	61.9	16.0
Southeastern	48.6	47.8	0.9	33.6	-15.0	74.4	25.8

R95p (mm/ year)	1961-1990	2010		2020		2030	
	Value	Value	Anoma	Value	Anoma	Value	Anoma
Amazon	384.1	331.1	-52.9	378.1	-5.9	354.4	-29.7
Southern	371.3	364.2	-7.0	336.7	-34.6	334.4	-36.9
Northeastern	69.1	98.2	29.0	83.8	14.6	111.1	41.9
West Central	275.9	226.5	-49.4	233.2	-42.6	219.2	-56.8
Southeastern	314.7	331.7	16.9	286.5	-28.2	306.1	-8.7

CWD (days)	1961-1990	2010		2020		2030	
	Value	Value	Anoma	Value	Anoma	Value	Anoma
Amazon	37.1	35.2	-1.9	44.5	7.4	26.8	-10.3
Southern	13.8	15.1	1.3	14.1	0.2	13.9	0.1
Northeastern	12.1	10.6	-1.5	10.7	-1.5	9.5	-2.7
West Central	13.9	15.8	1.9	19.7	5.7	14.2	0.3
Southeastern	14.5	17.3	2.8	16.9	2.4	16.9	2.4

RX5day (mm/ year)	1961-1990	2010		2020		2030	
	Value	Value	Anoma	Value	Anoma	Value	Anoma
Amazon	111.7	111.8	0.1	121.2	9.5	106.0	-5.7
Southern	138.1	147.0	8.9	153.1	15.0	147.3	9.2
Northeastern	73.6	87.0	13.13	69.3	-4.3	95.5	21.8
West Central	114.1	101	-12.7	115.2	1.1	110.5	-3.6
Southeastern	143.7	162.6	18.8	157.7	13.9	143.8	0.1

6. IMPACTS OF CLIMATE CHANGE IN AMAZÔNIA: A SUMMARY

For Amazônia, we can say from the Table 1 and Figures 4-6 that for the Amazon region, by 2010, 2020 and 2030, there is an increase in the frequency of consecutive dry days in relation to the present. The fact that by 2100, there is an increase in the CDD in the region suggests a strong inter-annual variability, even though the tendency would be for an increase in the CDD frequency. The PREC and CWD indices demonstrate projections of rainfall reductions in the region and show inter-annual variability, meaning that in some years or decades rainfall could increase, but in general the tendency is for a reduction by 2100. The indices of extremes show decreases in the Amazon region as a whole, varying in magnitude from 2010 to 2030, but Figures 1-2 show that in western Amazônia the tendency is for increase in the rainfall extremes by 2030. This suggests opposite behaviors in the projections of rainfall between western and eastern Amazônia, consistent with the simulations of mean and extreme climate from the IPCC AR4 models.

These changes in rainfall together with the projected warming in Amazônia that may reach up to 4-6 °C would certainly have impacts on the population, biodiversity, and human activities. The projected increases in the frequency of daily and seasonal extremes may imply longer dry spells in eastern Amazônia and more frequent droughts, as in 2005. This would augment the risk and vulnerability to fires and dry conditions would have a negative impact on human heath, agricultural activities, biodiversity and forest management, hydroelectricity generation and river transportation, and on the socioeconomic side, the loss of many man-hours of work and the children's access to school.

7. ADAPTATION AND MITIGATION OPTIONS

Extreme climate events may affect Amazônia, as expected from climate change. Drought events can increase significantly the number of fires in the region even with decreased deforestation rates. We may expect that the ongoing deforestation, currently based on slash and burn procedures, and the use of fires as a traditional measure for land management in Amazônia will intensify the impact of droughts. Increase in droughts may be expected as a consequence associated with natural climate variability or human-induced climate change, and therefore a large area of forest may be under increased risk of fire.

The impacts of fires on the Amazonian region could be reduced with the support of governments, since fires in the region are mainly induced by human activities and could be avoided and/or diminished by: the introduction of fire-free land management techniques; reinforcement of monitoring, controlling and application of the current Brazilian legislation on illegal fires; the creation of protected areas (Aragão et al. 2008, Nepstad et al. 2006); and environmental education programmes. Some initiatives, such as the creation of the Extractive Reserve statutes, the Pilot Program to Conserve the Brazilian Rain Forest (PPG7), and Ecological–Economic Zoning (ZEE) project have been implemented in Brazil in attempts to approach the ideas of sustainable development and territorial planning in Amazônia (Alves 2008).

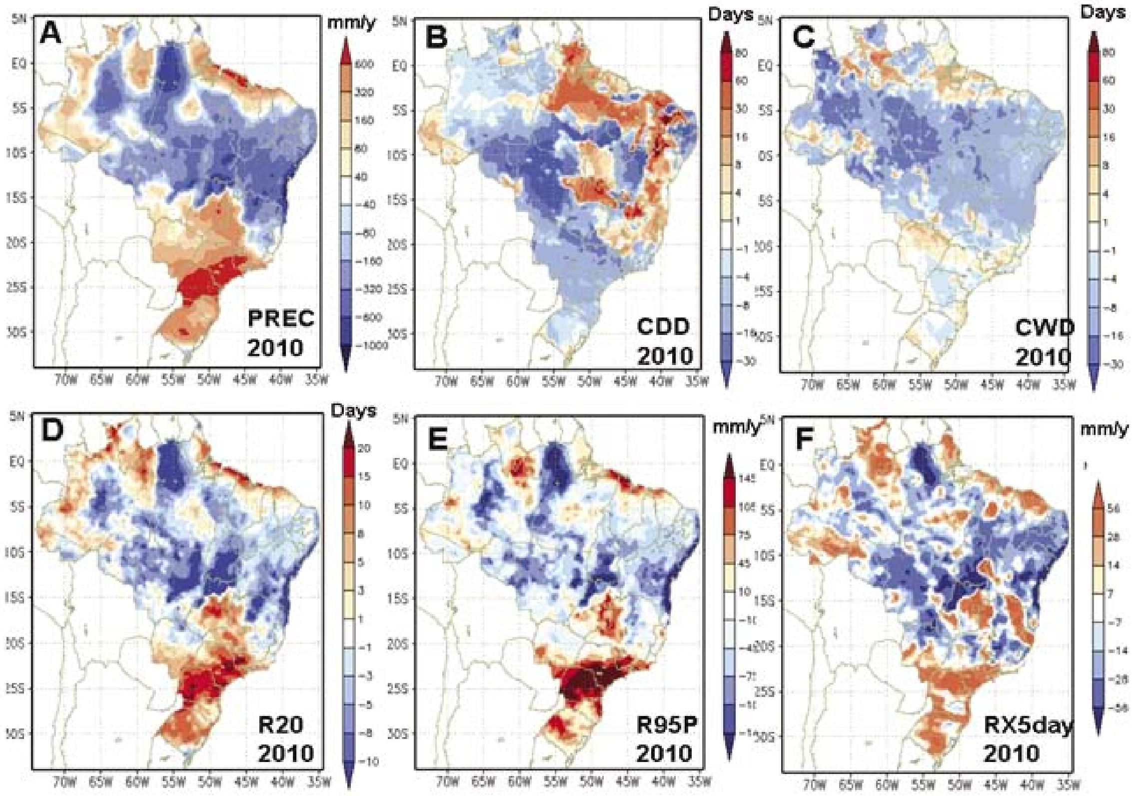


Figure 4. Indices of precipitation and extremes derived from the Eta-CPTEC (40 km) climate change projections for 2010, for the A1B scenario. Indices are defined in Frisch et al (2002). Figures show changes for the year 2010 relative to the present time (1961-90) simulated climatology from the Eta-CPTEC.

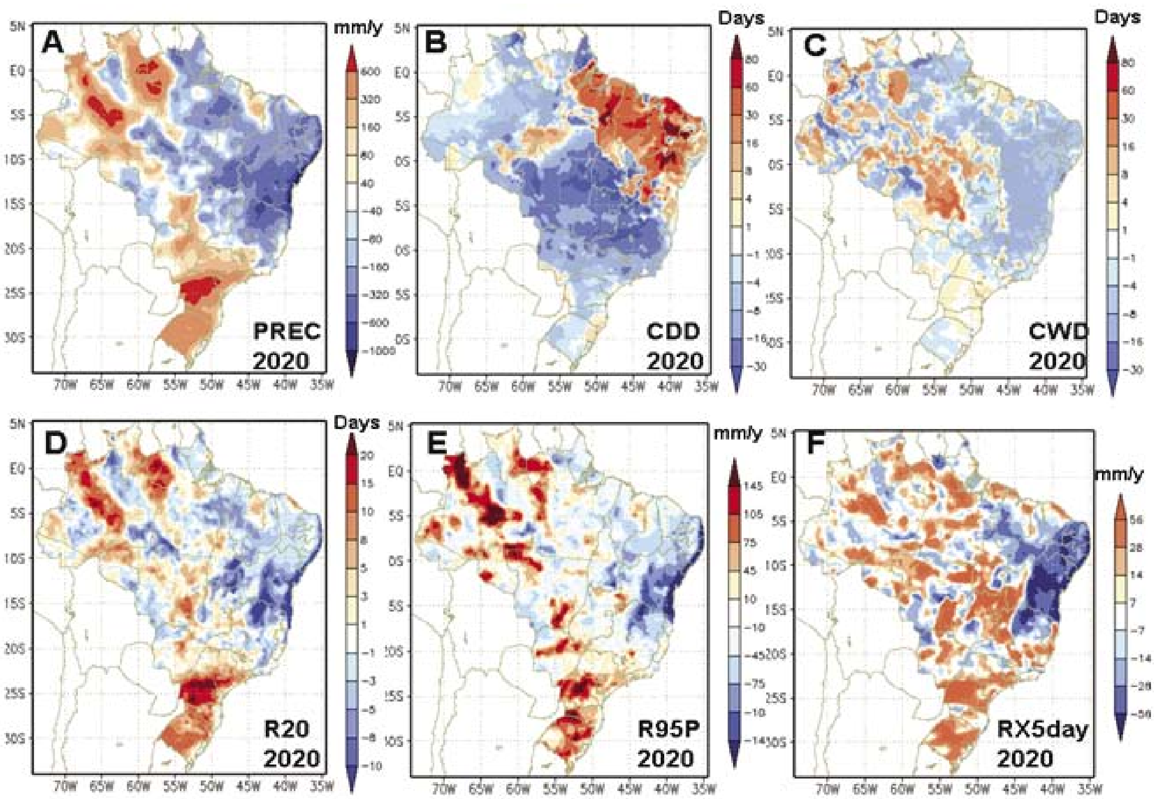


Figure 5. As in Figure 4, but for the year 2020.

Recent proposals to compensate developing countries for reducing emissions from deforestation and degradation (REDD) under forthcoming climate change mitigation regimes are receiving increasing attention. International climate policy discussions are considering REDD as a potential contribution to mitigating climate change. The debate has recently gained new momentum, however, with proposals to compensate developing countries that succeed in reducing emissions from deforestation (REDD) with financial incentives, such as tradable carbon credits (Laurance 2007). The concept would most likely involve countries lowering deforestation rates below a national historical baseline, and a novel mechanism could be included in a post-2012 Kyoto regime (Santilli et al. 2005; UNFCCC 2005). Crediting emission reductions on a national rather than on a project level would have the major advantage of accounting for in-country 'carbon leakage' which occurs when deforesting activities are simply displaced rather than avoided (Aukland et al. 2003). REDD would thereby address one of the major objections raised in past policy discussions against including avoided deforestation under the CDM. Globally, the Amazon stands out as the region with the greatest potential to contribute to climate change mitigation through REDD (Ebeling and Yasue, 2008).

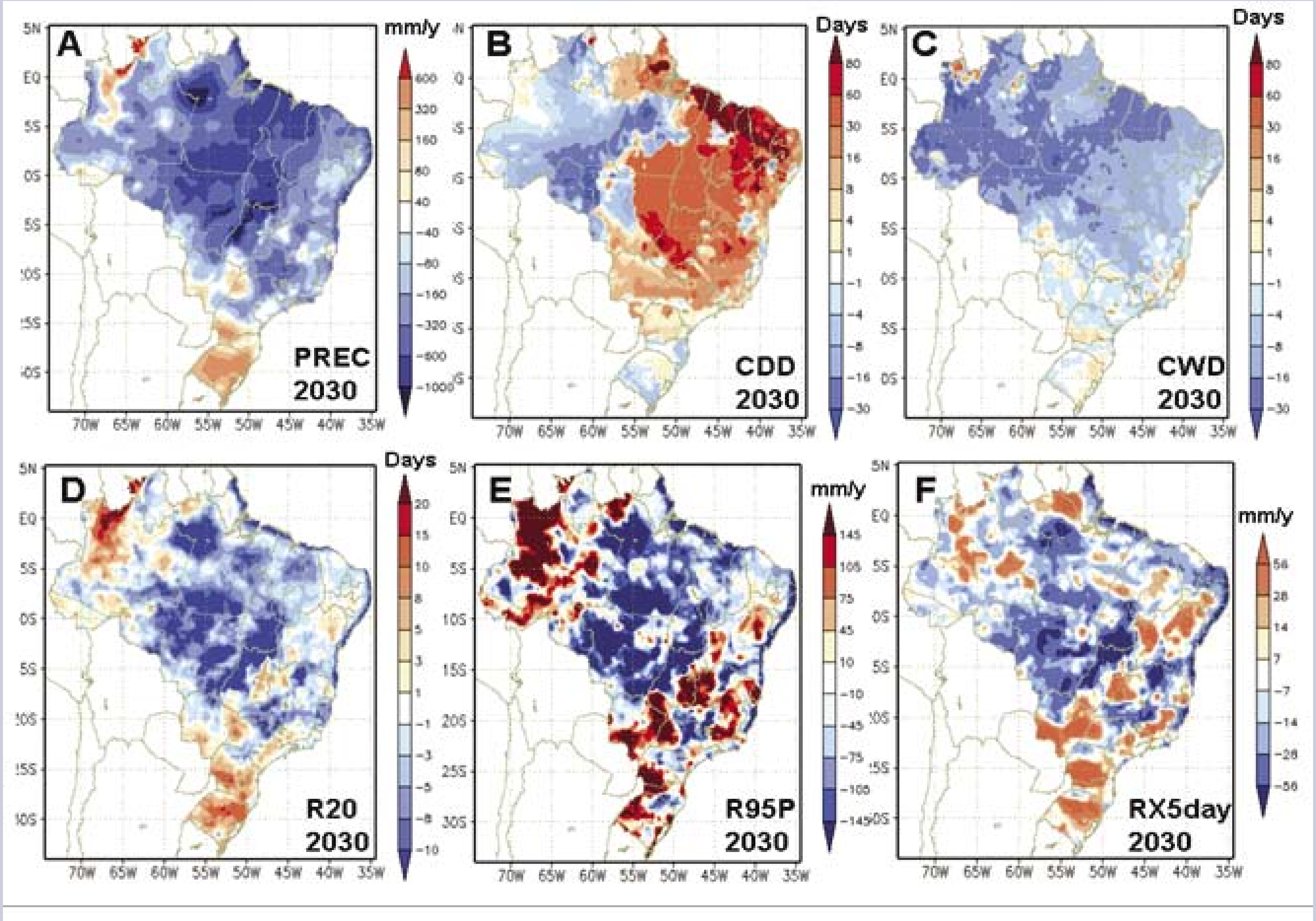
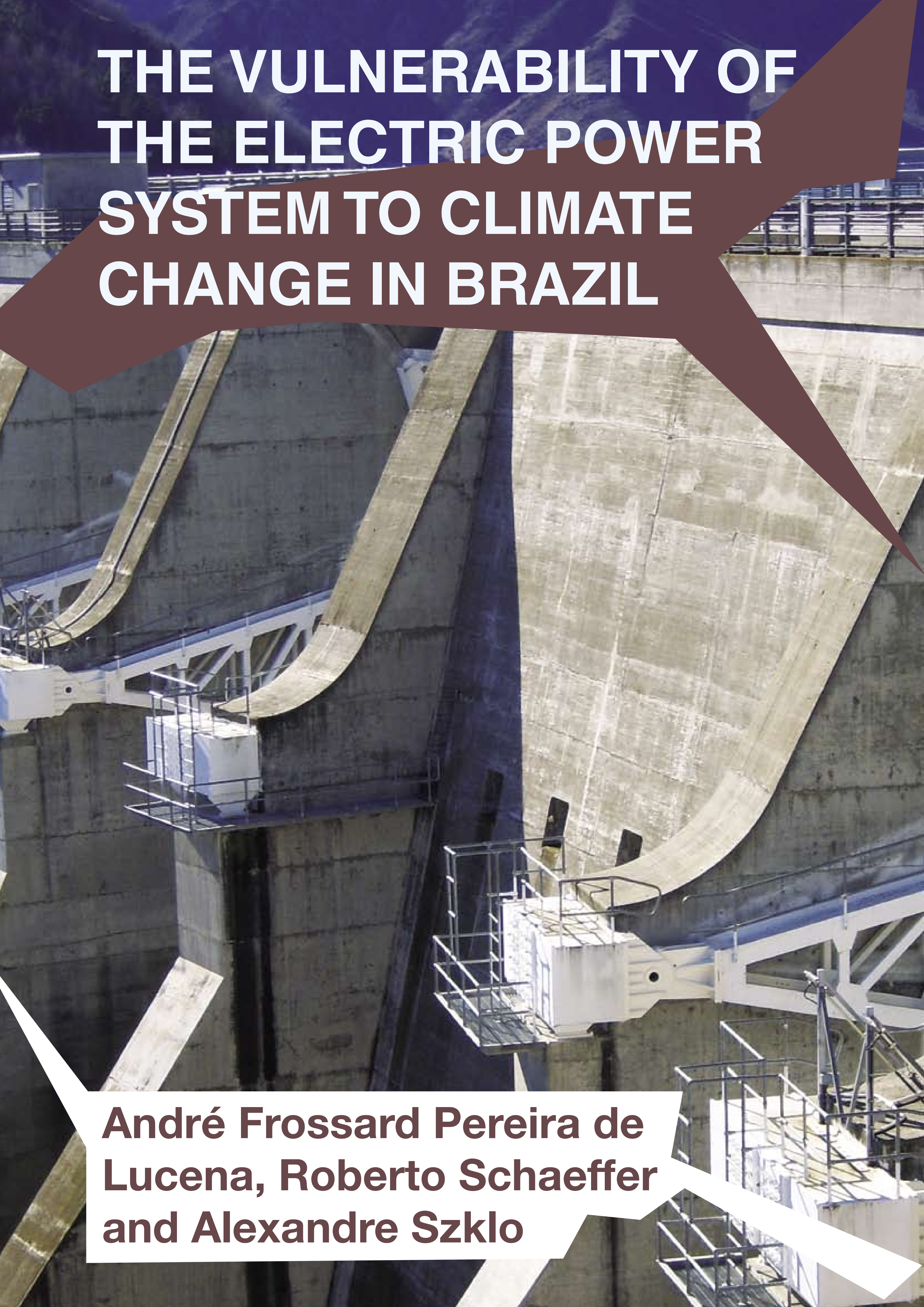


Figure 6. As in Figure 4, but for the year 2030.

The introduction of payments for environmental services (PES, Hall 2008) offers an opportunity for traditional and indigenous populations to be compensated for contributing to carbon sequestration in meeting the challenge of ameliorating global warming. As one mechanism among several for promoting biodiversity conservation and sustainable development, pro-poor PES initiatives could eventually be incorporated into an international post-Kyoto framework to encourage reduced emissions from deforestation. Financial compensation in the form of PES income would reward resource-users for their efforts to either preserve forests and other natural resources intact, and/or introduce production systems that generate economic surpluses and sustain local populations without destroying the resource base upon which people's livelihoods depend.

Brazil's *Bolsa Floresta* Program, implemented by the Amazonas State Government in June 2007 as a PES scheme for small farmers in the state, has enjoyed some success and has become the model for future PES implementation in all Amazonian states and countries. Under this scheme, a monthly amount of R$50 (US$25) was paid to over 4000 households in five 'sustainable development' protected areas, extending to 8500 families by the end of 2008. The aim is to support traditional populations in their pursuit of nondestructive activities such as extractivism, fishing and tree fruit cultivation, and to discourage illegal deforestation. In future, Brazil's states could bear a primary responsibility for forest management and the introduction of PES schemes.

Although the rainfall projections of the various IPCC AR4 models differ substantially in Amazônia, the results suggest that this region may be drastically altered not only by increases in the GHG concentration, but also due to development schemes, land-use and land cover in the coming decades. Because of changes in mean and extreme climate in the future, forest loss may be greatest along the southern and eastern areas of the basin, and the impacts of those changes would also affect weather and climate in other regions, such as the La Plata Basin in southeastern South America. Conserving Amazonian forests and reducing deforestation is an option that will not be easy to implement. The investment, however, would surely be worth it. The fate of the greatest tropical rainforest on earth is at stake.



THE VULNERABILITY OF THE ELECTRIC POWER SYSTEM TO CLIMATE CHANGE IN BRAZIL

André Frossard Pereira de Lucena, Roberto Schaeffer and Alexandre Szklo

SUMMARY

This paper analyses the impacts that global climate change may have on hydroelectric production in Brazil and proposes some adaptation measures to overcome these impacts. To do so, dynamically downscaled climate projections of the HadCM3 general circulation model for the A2 and B2 IPCC SRES scenarios were used in a hydrological-energy simulation. The results point to the fact that the reliability of hydroelectric generation in Brazil might be compromised. In some regions – such as the North and Northeast – hydropower production may be affected, as the water availability in those regions significantly declines.

Climate impact studies rely on the downscaled results of General Circulation Models. These models project the evolution of climate variables – e.g. temperature and precipitation – based on a scenario for the evolution of the concentration of greenhouse gases in the atmosphere. However, there is still great uncertainty with respect to how the probability distribution functions of climate variables may alter in a climate change scenario. In fact, the probability of extreme climate events is not necessarily proportional to changes in mean values. Therefore, the assessment of future climate extreme events and their impacts on natural and human systems still needs further understanding.

As it relies heavily on renewable energy, the Brazilian energy system is vulnerable to climate changes. Hydropower plays a major role in the country's supply of electricity and accounted for 80% of Brazil's electricity generation in 2008. Alterations in the hydrological cycle induced by climate changes can affect electricity production. The concentration of electricity generation in this single source exposes the system to extreme climate events – such as pluri-annual dry spells – and may affect the country's ability to meet electricity demand. Also, given the increasing environmental restrictions on building new large reservoirs, the ability to compensate for dryer rainfall regimes will be reduced as the energy demand expands, due to the lack of a buffering capacity. The adaptation measures proposed range from demand-side policies, such as energy conservation and increased energy efficiency, to supply-side policies, that promote the expansion and diversification of the country's energy matrix through different renewable alternatives.

Physical damage to hydroelectric generation facilities, as a result of extreme weather events related to global climate change is not expected. The electric transmission lines spread throughout the country may become more vulnerable to potential very strong winds, especially in the South, but the possible impacts cannot be foreseen with the models currently available.

The insurance industry has the opportunity to contribute to the improvement of practices in the electricity sector. Some insurance companies already offer products specifically for alternative energy projects, such as subsidized insurance for wind farms or protection from price volatility to wind and solar plants. These kinds of innovative products can create the right incentive to expand the development of low-carbon projects. On the demand side, the insurance industry can provide special products to residences and businesses with green-building initiatives, such as using passive solar, active solar, and photovoltaic techniques or using plants and trees through green roofs and rain gardens for reduction of rainwater run-off.

1. INTRODUCTION

Brazil's economy relies heavily on renewable energy sources. Some 45% of all energy produced in the country came from renewable energy sources in 2008. In the power sector, this reliance is even greater. Hydroelectric power plants accounted for 80% of Brazil's electricity generation in that same year (MME, 2009). The availability and reliability of these renewable energy sources, however, are a function of climate conditions, which can vary in the light of global climate changes (GCCs) related to the emission of greenhouse gases (GHGs).

Historically, long-term energy planning in Brazil has not examined the possible impacts of GCC on the vulnerability of renewable energy sources. Therefore, the focus of this paper is to analyze the vulnerabilities of the electric power system in Brazil to GCC. This is done by assessing the impacts that new climate conditions, such as those projected up to 2100, could have on the production of hydroelectricity in the country.

Two GCC scenarios resembling the two emission scenarios A2 (high emission) and B2 (low emission)[2] proposed by the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (IPCC, 2000) were translated into variations in energy supply for hydropower. Although GCC may also affect the supply[3] of other renewable (e.g windpower and liquid biofuels) and non-renewable (e.g gas-fired thermoelectric generation) energy sources, as shown in Schaeffer et al. (2008), these other energy sources are not examined in this work. This paper focuses only on hydroelectricity, for it is the most important primary energy source for electricity generation in Brazil (MME, 2009).

Climate models are approximate representations of very complex systems. The level of uncertainty about the impacts of the concentration of GHGs on the global climate (global climate model), and on the Brazilian climate in particular (regional climate model), becomes evident when comparing the results of different climate models (Marengo, 2007). In this sense, given the already large uncertainties associated with the future evolution of GHG emissions (the A2 and B2 storylines), GHG concentrations in the atmosphere, GCC, and the uncertainties added by the modelling tools used to translate the projected climate conditions into impacts on the Brazilian energy sector, the results presented in this paper have to be interpreted with caution.

Also, in addition to the uncertainties of the energy models, the estimated impacts of GCC on the Brazilian electric power sector presented in this paper are intrinsically dependent on the climate projections adopted. Therefore, in such a long-term scenario analysis, the trends and directions are the ones to be emphasized rather than the precise results provided, given the cumulative uncertainties related to this kind of study.

Hydropower dominates electricity generation in Brazil, and large hydro dams dominate the sector. With 791 hydropower plants in operation, the 25 largest plants with installed capacity higher than 1,000 MW account for 65% of the hydropower installed capacity and 49% of the country's total electricity generation capacity (ANEEL, 2009). There is still a considerable unused hydropower potential (estimated at about 170 GW - EPE, 2007a) scattered unevenly throughout Brazil, but largely located in the North region and away from the main consuming centres of the Southeast region, thus entailing higher electricity transmission costs as well as environmental constraints.

Because of the integrated operation of the national power grid (SIN) and the seasonal complementarities among the country's different regions, power generation at each hydro plant depends, to a large extent, on the incoming water flow and its variability at different times of the year. Thus, the relevant climatic variable[4] for the analysis discussed here is the long-range outlook for the rainfall and evapotranspiration regime in face of a possible new climate reality (Ambrizzi et al, 2007; Marengo et al, 2007; Salati et al., 2009).

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[2] For a more complete description of the A2 and B2 emission scenario assumptions, see IPCC (2000). The A2 and B2 IPCC emission scenarios were translated into climate projections for Brazil by a team of Brazilian climate specialists from CPTEC/INPE using the PRECIS (Providing REgional Climates for Impacts Studies) model. This is a regional climate model system developed by the Hadley Centre which downscales the results of the HadCM3 general circulation model (Ambrizzi et al, 2007 and Marengo et al, 2007).

[3] GCC may also impact the consumption of energy, especially in the case of greater use of air conditioning in the residential and services sectors. This was also investigated in Schaeffer et al. (2008).

[4] Other climatic variables, such as temperature, are also relevant. However, this study focused on the impacts of different rainfall regimes only, since it is the most relevant climatic variable to affect river flow.

2. METHODOLOGY

The two IPCC emission scenarios on which the climate projections used in this study were based – A2 and B2 – are two of four qualitative storylines (A1, A2, B1 and B2) characterized by different economic and energy development paths. They describe divergent futures in an attempt to cover a significant portion of the underlying uncertainties in the key driving forces for greenhouse gases emissions (IPCC, 2000).

The A2 scenario (pessimistic, high emission) describes a heterogeneous world, where regional oriented economic development is emphasized. In this scenario, there is less emphasis on economic, social, and cultural interactions between regions, which become more self-reliant and tend to preserve the local identities. Also, per capita economic growth and technological change are uneven and slow, which do not help to narrow down the gap between now-industrialized and developing parts of the world. Final energy intensities in the A2 scenario decline with a pace of 0.5 to 0.7% per year (IPCC, 2000).

In the B2 scenario (optimistic, low emission), there is an increased concern for environmental and social sustainability at the national and local levels. This scenario presents a world with continuously increasing global population at a rate lower than that of A2, intermediate levels of economic development and also more regionally heterogeneous technological innovations. The final energy intensity of the B2 scenario declines at about 1% per year, in line with the average historical experience since 1800 (IPCC, 2000).

The A2 and B2 IPCC emission scenarios were translated into climate projections for Brazil by a team of Brazilian climate specialists from CPTEC/INPE using the PRECIS (Providing REgional Climates for Impacts Studies) model[5]. This is a regional climate model system developed by the Hadley Centre which downscales the results of the HadCM3 global climate model . It uses the present and future concentrations of GHGs and sulphur projected by the A2 and B2 IPCC emission scenarios to make regional climate projections which are consistent with the global model[6] (Marengo, 2007). For the purpose of this paper, the PRECIS model provided projections for precipitation and temperature at a 50 km x 50 km square resolution for the 2025 – 2100 period, as well as the Baseline[7] period (Ambrizzi et al, 2007 and Marengo et al, 2007).

To assess the impact of a new rainfall regime on the electricity generation from hydroelectric power plants, it was necessary first to project how it would affect the incoming flow at each hydroelectric facility in the SIN. Secondly, with the projected flow series in hand, an operation simulation model called SUISHI-O (Modelo de Simulação a Usinas Individualizadas de Subsistemas Hidrotérmicos Interligados) developed by CEPEL (2007) was used to calculate the impacts on energy generation.

The first step is far from trivial. The water cycle is a global phenomenon of closed circulation of water between the surface and the atmosphere, driven by solar energy associated with gravity and the Earth's rotation. Thus, the water from precipitation reaching the ground can be subject to infiltration, percolation and evapotranspiration upon being exposed to solar energy (Tucci, 2004). The portion not infiltrating the soil, evaporating or being taken up by the vegetation becomes runoff which can be used for various purposes, including electricity generation.

In a first attempt to deal with this complex issue and given the poor availability of historical data on precipitation, Schaeffer et al. (2008) firstly estimated the future flows at each power plant feeding the national grid using univariate time series models. Individual flow series were generated using seasonal twelve-period ARMA models applied to the historical flow series. This was possible because there is good availability of historical flow data at hydroelectric facilities in the country (ONS, 2007). Secondly, the impact of the alterations in the rainfall regime was incorporated into the projected flow series through hydrological sensitivity coefficients. However, due to lack of data on precipitation for all flow gauges, it was necessary to define reference plants from which the results were extrapolated to other hydropower plants in the same basin.

[5] *The lateral boundary conditions for the PRECIS model is given by the global atmosphere general circulation model HadAM3P, which constitutes the atmospheric component of the ocean-atmosphere global climate model HadCM3, forced with sea surface temperature anomalies (Marengo, 2007).*

[6] *For more detailed information on the methodological aspects of the PRECIS model see Marengo (2007) and Jones et al. (2004).*

[7] *Baseline refers to the results of the PRECIS model for the past, i.e. for the period 1961-1990. They are not historical values, but modeled values for historical concentrations of GHG in the atmosphere.*

Using water balance models, Salati et al (2009) projected the average annual runoff for the major Brazilian Basins for the baseline period (1961-1990) and five-year intervals from 2025-2100. The percentage change between the projections and the baseline were applied by Schaeffer et al. (2009) to the historical average annual inflow to each power plant's reservoir, so as to create a projected annual time-series for water inflows.

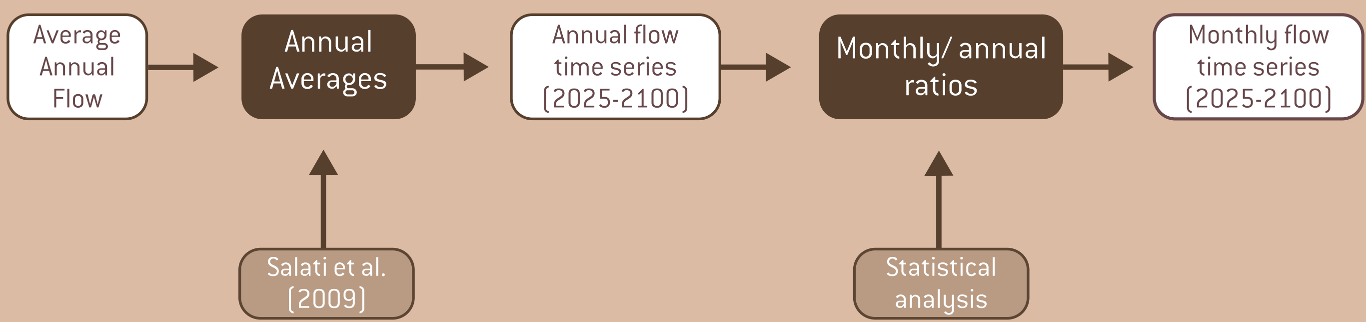
Seasonal variations play an important role in the operation of hydroelectric systems, especially in large countries like Brazil, where they can be complementary across regions. Therefore, in a second methodological stage, possible seasonal impacts caused by GCC were evaluated by Schaeffer et al (2009) through a similar methodology used by Schaeffer et al. (2008). Projected alterations in the ratio of monthly to annual averages were applied to the annual time series resulting from the results of Salati et al. (2009), to generate a monthly time series. Figure 1 illustrates this methodological procedure.

The month/year average ratios were projected by Schaeffer et al. (2009) using a statistical approach that uses panel data on precipitation and flow to estimate hydrologic sensitivity coefficients. Those ratios were calculated from a synthetic series that incorporated the impacts of projected precipitation changes (through hydrological sensitivity coefficients) onto an average monthly series (consisting of the average flow values for each month at each power plant).

Finally, with the flow estimates on hand, an operation simulation model called SUISHI-0[8] was used to quantify the variation on the Brazilian interconnected hydropower generation system. The series projected using the above methodology for incoming flow to 195 existing and projected (EPE, 2007b) hydroelectric facilities of the SIN were used as input to the SUISHI-0 model, which calculated possible variations in the Brazilian hydropower system's energy. This model calculates firm and average power for a given configuration of the hydroelectric system (power plants and their technical characteristics) and a given set of flow time series. Firm power, as calculated by SUISHI-0, is defined as the greatest market (demand) that the system can attend at all times, without deficit, assuming the hydrological series. Firm power can also be defined as the amount of electricity that can be produced in the worst hydrological period of the series. Average power, as calculated by SUISHI-0, can be defined as the amount of energy that can be produced assuming the average hydrological conditions, based on the input flow series.

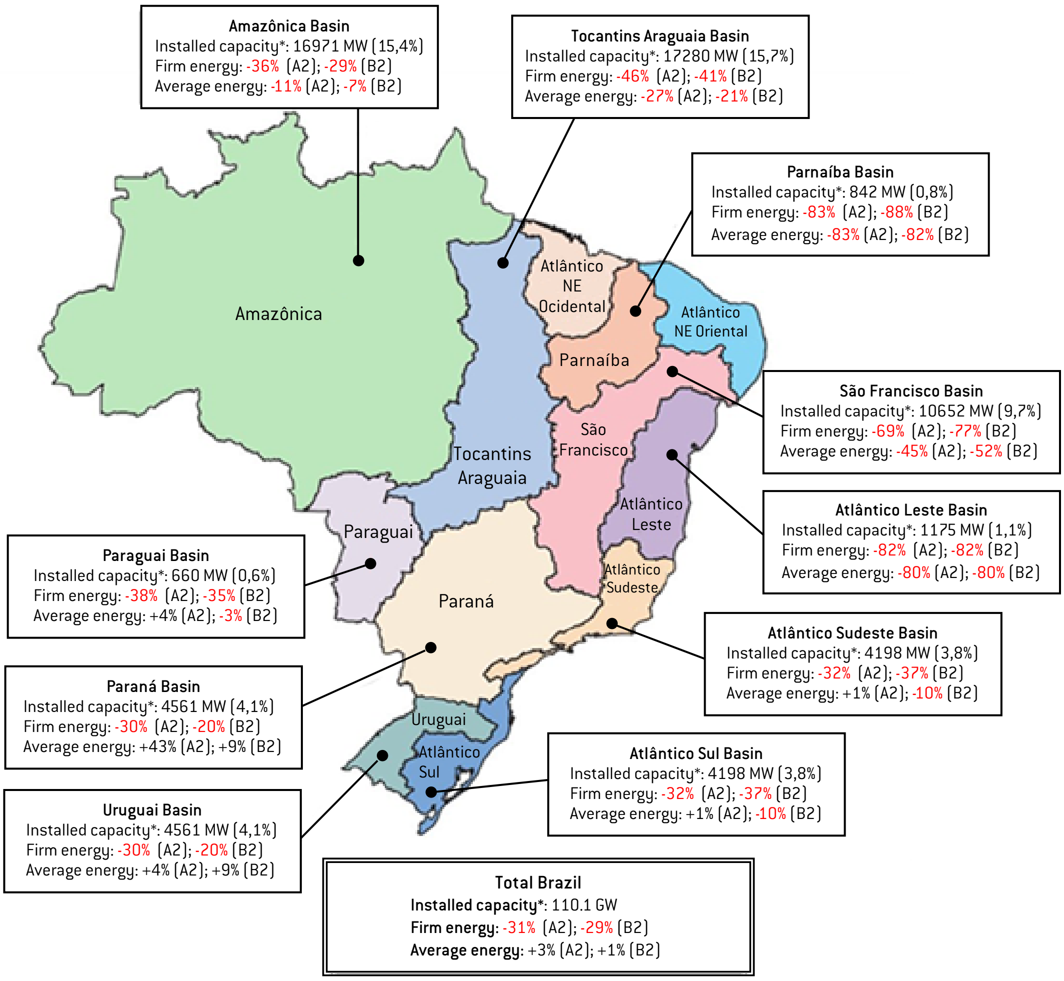
To ensure the supply of electricity, the expansion of the power generating system must be based on firm power, since it is, actually, what the system can guarantee – given the flow series – at all times without deficit. However, the average power is greater than the firm power. In other words, many times the hydroelectric system will be able to supply more energy than the firm energy. So, a reliable system must have an installed thermoelectric generation capacity to complement hydroelectricity in bad hydrological conditions, which would not be in use all the time. Therefore, the average and firm power projections give complementary measures of a hydroelectric system's capability.

Figure 1 – Hydrological Procedure Adopted



[8] The SUISHI-0 is a simulation model for the operation of individual hydropower plants in interconnected hydropower systems developed by CEPEL (2007). It was programmed in FORTRAN 77.

Figure 2 – Results from the SUISHI-O Model



Note: * - projected installed capacity for 2017 (EPE, 2007b)

tric potential would be mostly based on run-of-the-river hydropower plants with smaller reservoirs. Therefore, the ability to compensate for dryer rainfall regimes would be reduced as the energy system expands. In this case, the result on the likely expansion strategy based on run-of-the river hydropower plants would be the full use of the installed capacity only during the rainy season. During the dry season, these plants would need to be complemented by other power plants.

The transmission capacity is also an important buffer for variations in the natural incoming flow to hydropower plant reservoirs. The national interconnected grid of the SIN allows the operation of the hydro-thermo power system to compensate for losses in certain areas, by increasing production in others. In fact, the results from the SUISHI model do not include transmission restrictions. Since the firm power is calculated for the system with free exchange between regions, a restriction in transmission capacity would decrease the system's firm power even more, by not allowing the electricity generation in the southern basins to compensate for that in the northern regions.

Finally, the results for energy of the SUISHI-O model indicate the amount of energy the hydroelectric system generates assuming a single projected time series. One aspect which deeply influences a hydropower system is the occurrence of extreme climate events, such as droughts and floods. In fact, the impacts that GCC could have on the Brazilian power system would come by changing the average behaviour of water flows in the energy producing river basins, or by altering the probability of occurrence of extreme events, which may lead to unforeseen climate conditions that would jeopardise the planned operation of hydropower plants and lead to bad reservoir management. This study focuses on the first only, due to the nature of the climate projections that served as inputs to the analysis. Further analyses that incorporate the second may add even further to the better understanding of the impacts of GCC on the Brazilian electric power system.

4. ADAPTATION POLICIES IN THE POWER SECTOR

The possible loss in hydroelectric reliability and the country's high dependence on this particular source, raise the need to propose some adaptation policies on the demand side and on the supply side of the electric power system.

Overall, Brazil has successfully implemented several energy policies over the past 25 years. Policies for increasing modern renewable energy sources and domestic oil supply have been very successful. Yet, policies for increasing energy efficiency and expanding natural gas use have had limited success. Using lessons learned from past experiences, a variety of new energy policies and initiatives could help Brazil to advance socially and economically, as well as to achieve other important objectives of sustainable energy development while, at the same time, adapting its energy system to cope with GCC.

Demand-side policies

The first set of policy measures to help the country adapt to a new energy reality in the light of global climate change is that related to the conservation and more efficient use of electricity in the household, service and industrial sectors (Schaeffer and Cohen, 2007):

• Electricity prices should be set so that they reflect the consumer's real willingness to pay, which would raise the price paid by high income consumers. Since electricity waste tends to be higher among these and since they face lower discount rates when buying new electric appliances, this measure would improve the economic viability of electricity conservation in the residential sector[9] .

• Low-interest loans for conservation programs and equipment substitution given by Government financial institutions (e.g. the National Bank for Social-Economic Development – BNDES). The high interest rates practiced in Brazil are an important economic barrier to improving electricity conservation.

• Rebates paid to consumers that switch to more efficient equipment may be an interesting option for utilities when the marginal cost of supply expansion exceeds the rebate program costs.

• Similarly, by directly running efficiency programs or providing efficient equipment, utilities could avoid high supply expansion costs, as well as help develop the market for new and more efficient technologies. However, this is a high cost option for the utilities, which should be used when final consumers do not respond to other demand-side management measures. This would be the case, for example, of low income communities, where the means to improve efficiency are scarce and electricity theft is costly to avoid.

• One other way to develop a market for energy efficiency is the creation of energy saving companies (ESCO's), which can perform audits, install new equipment and run conservation programs within firms. ESCO's can also benefit from energy efficiency auctions.

• Finally, the creation of even more stringent, and more broadly applied to a wider range of equipment, energy efficiency standards for electric appliances can be an interesting measure alongside labelling programs.

The consumption of electricity in the residential sector basically occurs in four major end uses in Brazil: lighting, water heating, air conditioning and food conservation (refrigeration and freezing). Market barriers to electricity saving in the household sector could be minimized with more direct policies, aimed at each specific end use, such as (Schaeffer and Cohen, 2007):

• In water heating, incentives to the substitution of electric showers for gas-fired heaters (the most economically viable alternative) or, even, solar panels. In many cases, the direct implementation of solar panels in low income communities by the utilities can be beneficial for the latter since: low income consumers pay a lower electricity tariff, being more profitable for the utility to sell that energy to consumers that pay more; by lowering the electricity bills of low income consumers utilities tend to face lower default rates; electricity theft can be costly/difficult to reduce, being easier to reduce demand.

• In the case of air conditioning and food conservation, incentives to a broader substitution of inefficient equipment for more efficient models. Utilities face lower discount rates than those faced by final consumers, which may change the feasibility of investment in efficient equipment.

[9] *Price incentives, however, are not sufficient to fully promote energy efficiency. There are several non-economic barriers which should also be considered.*

As for the services sector, there are areas in which electricity conservation measures could be successfully introduced. Silva (2006) carried out a survey of the Brazilian public lighting system from the energetic and institutional point of view and concluded that there is room for improvements that would lead to the conservation of electricity. Actions to obtain better efficiency in public lighting include not only equipment substitution (mostly lamps), but also better designed lighting systems. In addition, the application of simple conservation measures in hospitals can lead to the saving of great amounts of electricity. Vargas Jr. (2006) estimated that the substitution of air conditioning equipment, better lighting and air conditioning arrangements in smaller hospitals would lead to savings of 1157GWh/year. Given that the proportion of these in the total number of hospitals in Brazil is around 28%, the amount of electricity saved can be substantial. In commercial buildings or shopping malls, demand side measures, such as cold storage systems, can be an economically interesting option to reduce the electricity consumption of air conditioning systems when tariffs are higher. These systems allow the shift of the load curve away from peak hours, generating and storing cold during off peak hours of the day. Architectural designs that make better use of natural lighting and ventilation are also options that can help reducing the electricity consumption in new buildings.

There is a great possibility of achieving energy savings in the industrial sector, particularly by increasing the efficiency of industrial processes. In general, the gains from conservation of electricity can be attained through some low-cost measures[10], such as (Garcia, 2003; Garcia, 2008):

• Use of more efficient lighting, such as high pressure sodium (HPS) or mercury vapor lamps;
• Substitution of oversized (overpowered) motors[11];
• Substitution of old motors with more efficient ones, that is, replacement of a standard motor in operation by another with higher yield, with adequate power for the load driven.
• Substitution of overloaded lines;
• Adjustment or replacement of overloaded transformers;
• Correction of the low-power factor;
• Correction of irregular current at different phases;
• Reduction of load peaks;
• Supply of adequate protection systems as a safety measure;
• Improvement of the transmission systems between motors and the equipment driven.
• Reducing and/or controlling the speed of motors. The use of adjustable speed actuators (ASAs) applies mainly (but not only) to centrifugal loads, including pumps, fans and compressors with this characteristic, which need a variation in the flow provided. Since the power is proportional to the cube of the rotation speed, the gains are great.

Supply-side policies

The second set of proposed policy options to reduce the vulnerability of the Brazilian power sector to possible impacts of climatic changes is the expansion of power generation through different alternatives. To ensure a reliable expansion of the electric power system, the additional electricity generating capacity should guarantee electricity supply considering the worst-case hydrologic scenario at the lowest social cost. On the other hand, the operation of the hydroelectric system should be closer to the average hydrological condition, since the critical hydrological period does not happen all the time. This means that the additional installed capacity would operate mostly as a back up, staying idle most of the time.

Using an integrated demand-supply optimization approach to calculate least-cost adaptation alternatives to climatic impacts, Schaeffer et al. (2009) showed that the additional electricity generation capacity necessary to compensate for the loss of reliability of Brazil's hydropower generation system, amongst other impacts, would be mainly based on natural gas, but also advanced sugarcane bagasse burning technologies, wind and, to a lesser extent, coal or nuclear power technologies.

The results of optimization models, however, reflect economically optimal solutions, not accounting for market barriers that may obstruct the adoption of the projected least-cost adaptation options. Nevertheless, economically optimal results are an important way to identify and help direct energy policies reduce market barriers.

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[10] Measures with an average return on investment of up to two years.
[11] This measure seeks to avoid oversized motors in relation to the load driven. The sample of motors in Brazil analyzed by Schaeffer et al. (2005) showed that 1/3 of them worked below 50% of their nominal load, 1/3 between 50 and 75% of that load and 1/3 in the ideal range, above 75%.

Amongst the additional electric power generation capacity technologies projected in Schaeffer et al. (2009), wind and sugarcane bagasse are the ones most affected by market barriers in Brazil. Although conventional energy sources may not need policy incentives to guarantee their implementation, this may not be the case for sugarcane bagasse and wind power.

Sugarcane bagasse is a co-product of the ethanol and sugar production process, which can be used to increase the energetic use of sugarcane through combined heat and power generation or, alternatively, as an input to ethanol production through hydrolysis. The availability of sugarcane bagasse is directly dependent on ethanol and sugar production, since these are the main products of a mill. However, the possibility of selling electricity as a by product to the power grid can act as an incentive for the expansion of the sector. Presently, power generation in the sugar and ethanol production sector uses mostly a simple 22-bar backpressure steam turbine, in which electricity generation is a co-product of the ethanol production process.

This technology generates an electricity surplus (in addition to the ethanol plant's own consumption) of around 10 kWh/ton of sugarcane, and only during the harvest season. The use of more sophisticated technologies, however, can substantially increase the power generation from bagasse in the sugar and ethanol production sector. The easiest alternative to increase the power surplus of ethanol and sugar mills is improving the simple backpressure Rankine cycle steam turbine by increasing the boiler pressure up to 82 bar. An intermediate alternative is the use of Condensing Extraction Steam Turbine (CEST). This technology is not only more efficient, due to the introduction of the condenser that increases the power surplus, but it is also capable of generating throughout the year, which improves the reliability of the electricity production by ethanol and sugar mills. Finally, the breakthrough technology in power generation from biomass is the Biomass Integrated Gasification/Gas Turbine Technology (BIG-GT). In this technology, the residual bagasse and waste (leaves and tops) is gasified and the syngas fuels a gas turbine (open cycle or higher-efficiency combined cycle turbines) attached to a power generator.

TABLE 1 - Technological Alternatives for Surplus Power Generation in Sugar/ Ethanol Mills

Technology	Power Generation[1]	Process Steam Consumption[1] kg/TC	Surplus Power[1] kWh/TC	Potential Generation in Brazil: EPE (2007)[a] TWh/year	Potential Generation in Brazil: Agr. Frontier[b] TWh/year
22 bar/ 300° C backpressure ST	Season	500	0 — 10	0 — 11	0 — 66
82 bar/ 480° C backpressure ST	Season	500	20 — 40	23 — 46	132 — 263
82 bar/ 480° C CEST[c]	Year Round	340	80 100	91 114	526 658
BIG-GT[c, d]	Year Round	<340	150 — 300	171 — 342	987 — 1974

(a) Given sugar cane production projected to 2030
(b) given the estimated agricultural frontier (MAPA, 2006)
(c) Supplementary fuel required
(d) Technology not commercial yet
(1) Source: IEA (2004)
TC = tons of sugar cane; ST = steam turbine

Table 1: compares the different technological alternatives for power generation from residual sugarcane biomass and estimates the surplus power generation that can be added to the grid given the sugarcane production projected by EPE (2007a)'s reference study (1.14 billion tons using 13.9 million hectares of land) and a conservative[12] upper limit estimated by the full use of Brazil's agricultural frontier for sugarcane production[13] (MAPA, 2006). Given that the total electricity production in Brazil was 455 TWh in 2008 (MME, 2009), Table 1 shows that the potential for electricity generation with more advanced technologies is substantial even without the full use of the country's agricultural frontier.

[12] *This can be considered a conservative upper limit because it assumes that pasture land in Brazil will remain as it is. However, an increase in pasture land productivity could free extra land for agriculture in Brazil.*

[13] *This top limit does not account for social-economic issues such as competition with other crops, labour displacement, economic feasibility, product transport infrastructure, etc.*

A summary of possible policy options for electricity generation in the ethanol and sugar sector is presented below (Szklo and Geller, 2006):

• Utilities could be required to purchase excess power from sugar mills at avoided generation, transmission and distribution costs via long term contracts.

• Incentives to interconnect the utilities to the power grid without excessive delay or unreasonable technical requirements.

• Incentives to research and development of breakthrough technologies such as bagasse gasification and combined cycle power generation in sugar mills.

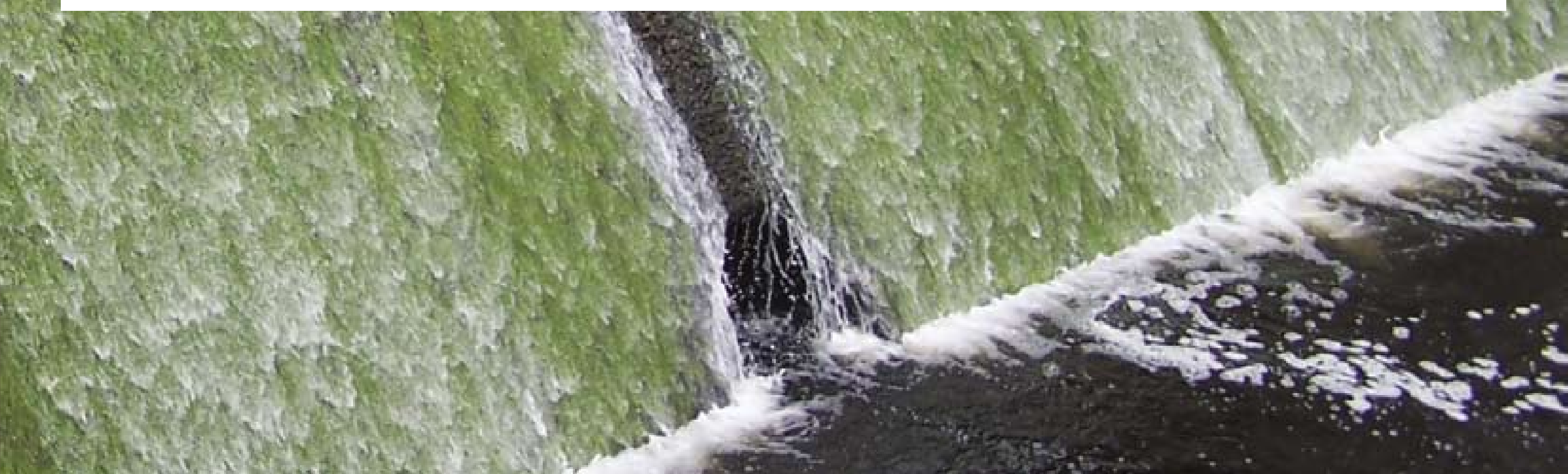
• The Government could reduce the information barriers on the newest technologies (such as the development of demonstration projects), as well as provide long term loans at attractive interest rates to sugar mills that adopt more efficient technologies.

Finally, expansion of wind power generation is also a possible way to increase the country's supply of electricity. In fact, the Brazilian natural endowment provide interesting complementarities between wind and hydraulic resources in some regions of the country (Szklo and Geller, 2006; Dutra, 2007), which would help optimizing the operation of the SIN. Given the projected wind velocities in the north-northeast coast of Brazil, off-shore wind power generation may be an attractive opportunity for the Brazilian power sector. Although off-shore wind power technologies have higher transport, installation and maintenance costs, it is an interesting option as the on-shore potential becomes more scarce as a result of environmental restrictions and competition with other land uses. As such, although wind power, in some situations, may still not be cost competitive with more conventional alternatives, in terms of private costs, in Brazil, the promotion of wind power generation in the country would help to achieve different objectives. Using different policy options, a long-term wind power generation incentive program in Brazil could have three different targets (Dutra and Szklo, 2008):

• firstly, it could help reducing GHG emissions from electricity generation. In the case of partially replacing of fossil fuel fired-thermal plants, an incentive program based on quotes and permits would install a wind capacity hovering between 18.7 and 28.9 GW;

• secondly, it could assist the optimization of SIN by helping in the operation of the country's hydropower reservoirs. A feed-in tariff based program would result in an installed capacity of 15.5 to 65.4 GW, depending on the project selection criterion; and

• thirdly, a program aiming at promoting wind power generation in Brazil could help fostering a domestic wind technology industry. Incentives based on feed-in tariffs to stimulate wind power turbine manufacturers to invest in the country would help installing a capacity that would vary between 29.1 and 217 GW for feed-in tariffs ranging from 60 US$/MWh up to 75 US$/MWh, respectively.



5. TOPICS FOR DISCUSSION AND INSTITUTIONS INVOLVED IN COPING WITH THE VULNERABILITY OF THE BRAZILIAN ENERGY SECTOR TO GLOBAL CLIMATE CHANGE

Climate change impact assessments lie at the end of a cascading chain of uncertainties. The climate projections are based on the results of GCMs, which, in turn, are based on scenarios of greenhouse gas emissions and concentrations. At the regional level, downscaling techniques are necessary to reduce the spatial and temporal resolution of GCM results to enable local impact assessment. On top of that, sectoral analysis applies its own modeling tools to project the impact on human or natural systems. Finally, these results should provide the basis for adaptation policies that aim at reducing the vulnerability to climate change. A layer of uncertainty is added at each stage in this process, so the discussion about vulnerability has to be addressed throughout this chain.

The vast majority of recent climate change impact assessments are based on greenhouse gas emission scenarios produced in the IPCC SRES (IPCC, 2000). Several GCMs have been run for the Fourth Assessment Report of the IPCC (IPCC, 2007). In Brazil, however, few of these models have been downscaled for the national territory. The CPTEC/INPE has been undertaking a continuous effort to improve the availability of possible climate outcomes necessary to produce a more comprehensive understanding of climate impacts in the country. The availability of downscaled climate projections, however, still needs to be improved.

Besides the uncertainty about the alterations in climate itself, the analysis of the impacts that these changes may have on human and natural systems also needs to be improved. Universities and other research institutions (both private and public) have been working with CPTEC/INPE to produce sectoral impact assessments. Nonetheless, these studies are relatively recent and the development of specific sectoral methodologies is a continuous effort that requires constant improvement. So, parallel to widening the range of climate outcomes, methodological developments in sectoral analysis still have to be undertaken.

In the energy sector specifically, the uncertainty created by GCC has not yet been incorporated into long-term energy planning. In this sense, the climate change impact[14] discussion needs to be further incorporated into the agenda of institutions, such as the Empresa de Pesquisa Energética (EPE – the Brazilian energy research company of the Ministry of Mines and Energy) and the Ministry of Mines and Energy (MME) itself. For that to happen, better understanding of the vulnerabilities of the energy sector has to be achieved, through an increased number of studies, both general and site specific.

The energy sector is intertwined with all economic sectors. Therefore, vulnerability has to be addressed in an integrated analysis that takes into account the possible second order impacts that GCC may cause through its impacts on the energy system. This raises the point that impact assessments need to be addressed in a coordinated, multidisciplinary and interdisciplinary research effort.

Finally, the most important measure to reduce vulnerability to GCC in general is to improve the availability of data in Brazil. Studies can only be as good as the database available allows them to be. This means especially, increasing and sharing the meteorological database, as well as making a long-term effort to follow climate variables as GCC occur. Among the national institutions that can take the lead in this are the Agência Nacional de Águas (Brazilian Water Agency - ANA) and the Instituto Nacional de Meteorologia (Brazilian Institute of Meteorology - INMET).

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[14]Although the discussion about mitigation has already been incorporated to some extent in the energy sector agenda, impacts of GCC still need to be addressed in long-term planning.

6. CONCLUDING REMARKS

Given the heavy reliance of Brazil's economy on renewable sources and the dependence of these sources on climate conditions, this work has endeavored to analyze the vulnerabilities of the Brazilian hydropower system to GCC. However, in the light of the uncertainties related to the GCC models and scenarios, the findings of this study should be viewed as a possibility rather than as a future projection. Indeed, the results of this study are heavily dependent on the quality of the climate projections on which it is based. Probably, the most important results portrayed here are the general conclusions for observed vulnerabilities to GCC of the hydroelectric power system in Brazil, rather than the quantitative figures presented. In fact, studies that investigate possible effects of GCC on the energy sector are extremely important to assess the adaptation capacity to possible, although not yet certain, impacts on the production and consumption of energy.

The greatest uncertainties in this study are the projections of the general circulation model. In fact, different models have distinguished climate projections, especially in the Amazon and the Northeast region, where the impacts seem to be most accentuated. There are no consensual projections among different general circulation models to the future climate in Brazil (INPE, 2007) and climate projections are, indeed, the ultimate driving force behind all the results found in this study.

It is worth stressing that this study is an attempt to quantify a very complex issue. Several assumptions and simplifications had to be made. For instance, the increasing competition for water resources in a scenario of growing scarcity in some water basins (competition between water for power generation and irrigation for agriculture, for instance) was not considered.

Nevertheless, this paper concludes that the supply of hydropower in Brazil can be negatively impacted by GCC, contributing to the understanding of what are the vulnerabilities and uncertainties to which the Brazilian energy system is exposed in a GCC scenario. Furthermore, this study proposes a set of energy policies aimed at reducing market barriers to nonconventional sources of energy that might help the country's energy system adapt to those vulnerabilities.

Finally, maybe the most significant vulnerability identified in this study is the poor availability of historical meteorological data in Brazil. This is especially crucial for rainfall data. If Brazil, as well as other countries, wishes to be better prepared to face GCC, it must improve the understanding of the present climate situation and its evolution, especially through better information gathering.

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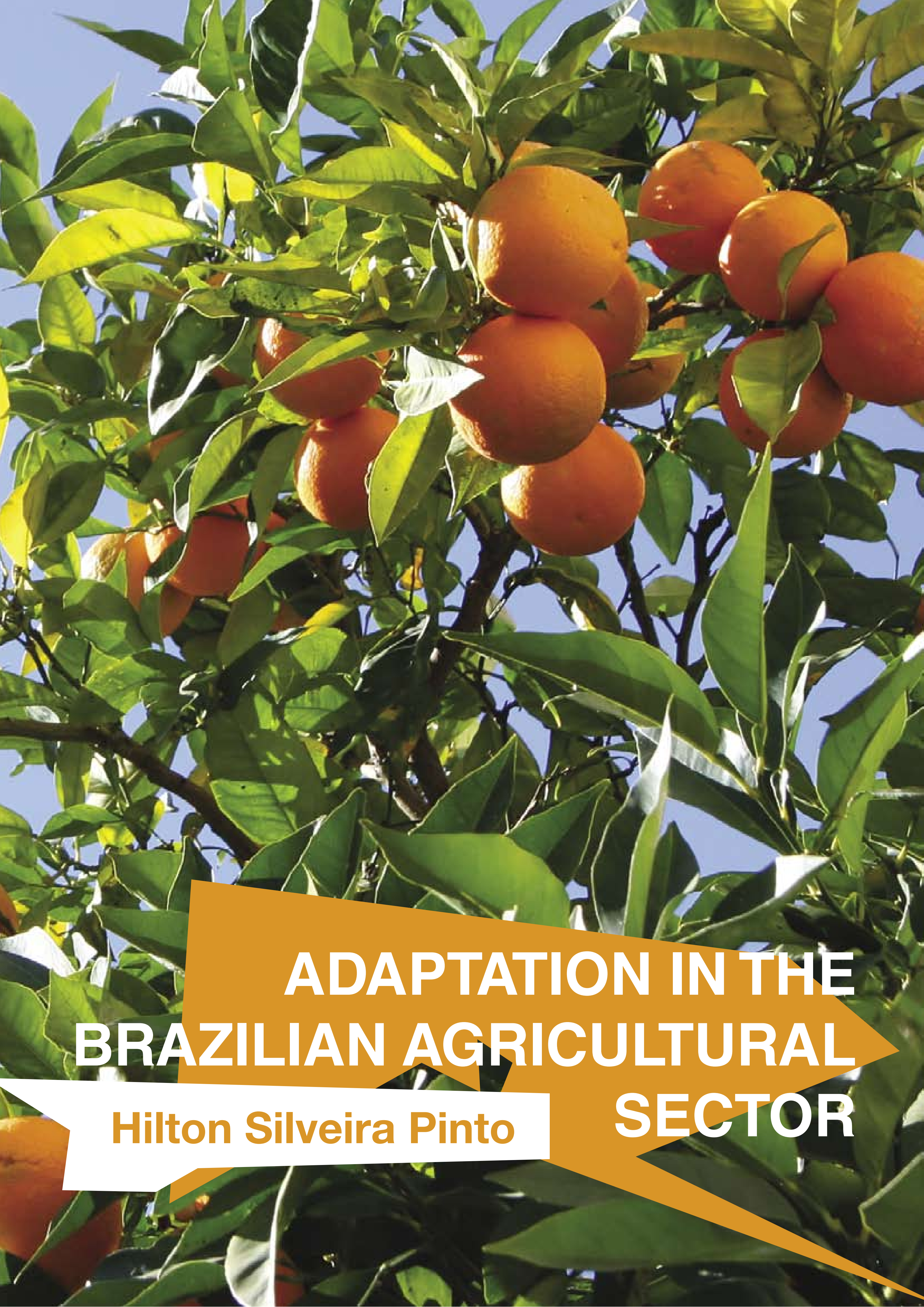


ADAPTATION IN THE BRAZILIAN AGRICULTURAL SECTOR

Hilton Silveira Pinto

SUMMARY

The objective of this paper is to demonstrate the need for adaptation of Brazilian agricultural production, in light of the changes in climatic conditions predicted over the next few decades. The paper looks at the geography of current agricultural production in Brazil and how future regional climatic conditions such as temperature, precipitation and the intensity and frequency of extreme weather events will affect this. The future climate scenario presented in the paper comes from the Hadley Centre and it was adapted for use in Brazil by INPE.

Agriculture in tropical areas is one of the economic activities most vulnerable to global warming. Crops that are already adapted to the climate in these areas will suffer from higher temperatures and changes in the rain distribution over time. Hundreds of millions of farmers around the world (mostly in Africa and Asia but also in Brazil) will face both economic and health risks. Migration is likely to be another consequence of the impact of global warming on agriculture.

In Brazil, agricultural activity is responsible for around 30% of Gross Domestic Product and variations in environmental conditions could have important implications for productivity of different crops.

There are several extreme weather events associated with global warming that could affect the agricultural sector. These include:

Heat Waves: In the State of São Paulo in Brazil, the average temperature for the month of September 2004 (32.1°C) was 4.4°C above the historic average (27.7°C), causing a loss of approximately US$50 million in animal husbandry due to the premature death of animals. Heat waves with maximum daily temperatures above 32°C are responsible not only for the death of animals, but also for a drop in agricultural production.

Short Summers (Veranicos): An increase in warm and dry days during atypical seasons (autumn and winter) would result in an increased demand for irrigation. Soybean cultivation would become increasingly difficult in the South of the country and some states in the Northeast could lose between 70% and 80% of their agricultural land.

Intense rains and winds: An increase in the frequency of intense rains and storms in the Southeast and part of the South of the country could bring problems for agricultural mechanization due to flooding of cultivated areas. Sugarcane, wheat and rice may also suffer from drooping as a result of the strong winds.

Nine cultivated plants are collectively responsible for 85% of the Brazilian agribusiness gross domestic product, namely: rice, cotton, coffee, sugarcane, beans, sunflowers, cassava, corn and soybeans. This report highlights research by PINTO and ASSAD (2008) which shows the impact of increased future temperatures on these agricultural products. By 2050, for example, without technological innovation, only sugarcane would increase its potential area for cultivation. All other crops analysed would lose around 15% of their potential cultivation area, with soybean presenting the worst case with a possible loss of 35% of its cultivation area.

In response to the predicted climatic changes, the paper suggests mitigation measures that could be adopted in the agricultural sector. These include: integration of animal husbandry with planting, or animal husbandry with both planting and forestry, in a defined rotational logic, to enable a reduction in erosion and greater efficiency in carbon sequestration. The paper also highlights the benefits of the direct planting system which is highly efficient in carbon sequestration.

The paper also highlights that genetic improvements offer one of the most promising alternatives to enable the main agricultural crops to adapt to future climatic changes. Developments in biotechnology would enable the introduction of new genes to provide plants with greater tolerance to dry spells and higher temperatures, as well as identifying tolerant genes in the plants of Brazilian biodiversity.

In terms of the agricultural sector, insurance companies could help their clients by providing access to information about climate risks, and technology to manage these risks, as well as information on crop selection and cultivation times in relation to the clients' farmers location. The education of client through workshops or reading materials to prevent losses and the provision of appropriate insurance products to small farmers are key instruments in the fight against the worst impacts of global warming on agriculture.

As one of the biggest industries in the world, the insurance industry could reallocate some of its assets to green investments, contributing to the transition to a low-carbon economy. Renewable energy projects, green-buildings and energy-efficient technologies are some examples of investments that can generate good financial returns and also contribute to mitigating the effects of climate change and thus the impacts on the agricultural sector.

ABSTRACT

The reports from the Intergovernmental Panel on Climate Change consider that, by maintaining the present rates of CO^2 and other greenhouse gas emissions, by the end of the 21st Century, the temperature of the planet Earth will be between 1.4°C and 5.8°C higher than observed in 1990 (IPCC 2001), or between 1.2°C and 6.4°C according to the IPCC (2007). The rainfall in the Southeast and South of Brazil should be between 5% and 15% more than observed during the same period. In Brazil, agricultural activity is responsible for around 30% of the Gross Domestic Product, and therefore, any variation in the environmental conditions could alter the productivity of the farms and, consequently, the economy of the country. A climatic risk zoning program for Brazilian agriculture, which indicates "what to plant, where to plant and when to plant" has been under development by the Federal Government since 1995, with the objectives of rationalizing plantations and obtaining the maximum productivity for the principal agricultural products in the country, among which are coffee, rice, beans, corn, soybeans and wheat. This work aims at establishing the scenarios of the principal Brazilian agricultural crops for the years 2020, 2050 and 2070, taking into account future alterations in the temperature and rainfall, according to the Precis RCM model, which was developed by the Hadley Centre in England. The future scenarios were modeled taking the present climatic risk zones as a basis.

1. GLOBAL CLIMATE CHANGE

Concern about global climate change as early as the 19th Century, was demonstrated by some researchers who tried to forecast the climate in terms of both natural and man-made causes. UPPENBRINK (1996) highlights some of these works, such as that of J. TYNDAL (1861) and S. P. LANGLEY (1884), both referenced in NASA (2002a and 2002b). The authors, at that time, evaluated the importance of atmospheric gases in the absorption of heat, preventing excessive cooling of the Earth's surface so as to allow the existence of life as it was known. It was, perhaps the first attempt at defining the greenhouse effect. ARRHENIUS (1896) utilized the data from LANGLEY (1890) and analyzed the effect of CO2 on the behavior of the climate, concluding that the duplication of world concentration of carbon dioxide would promote an increase in the global temperature of between 5°C and 6°C, which is very close to the present day estimations.

During the 1970s, the institutions increased their concern as to the possible climate alterations and their consequences. A meticulous study, with results based on consistent statistical analyses was coordinated by the NATIONAL DEFENSE UNIVERSITY (1978). The fundamental doubt consisted of knowing if the world tendency would be for the increase or decrease in temperature, having reached the conclusion that, over the coming 25 years (i.e. up to the year 2000), there would be an equal 10% probability that the temperature would rise to 0.6°C above, or fall to 0.3°C below the average for 1970.

During the 1990s, work by DUPLESSY (1992), and LE TREUT and KANDEL (1992) indicated the possibility of astronomic causes for the alterations in climate in prior years. The origin of these variations was based on the arguments of the geophysicist MILUTIN MILANKOVICH (DUPLESSY 1992). Temperature and total rainfall variations associated with the variations in the number of sunspots or magnetic activity were analyzed by PUGASHEVA et al. (1995) and GUSEV et al. (1995). Work developed by the WMO (1992) shows an increase in temperature in the Northern Hemisphere to the order of 0.6°C; not continuous, but concentrated principally in two periods, from 1920 to 1940 and after 1976, with a rapid warming that culminated in 1990. Another aspect refers to a possible climatic variation due to the fluctuations in insolation or other natural phenomena, as presented by GUYOT (1997) and STOZHKOV et al. (1995 and 1996).

The reports of the "Intergovernmental Panel on Climate Change" (IPCC) indicate an unquieting situation as regards the increase in temperature on the planet. The forecast is that the global temperature should increase by between 1.4°C and 5.8°C over the next 100 years, considering the 1990 average as the threshold. By clearly and objectively confirming the previous arguments, the IPCC Reports (2007a and 2007b) ratify the results of the IPCC-2001, indicating a truly disturbing situation as to the increase in the temperature of the planet and its effects on future human activities. Considering both the natural and man-made causes, the forecast is that the global temperature should increase between extremes of 1.2°C and 6.4°C by the end of the twenty-first century, taking the average of 1961-1990 as a threshold. It is admitted that any increase in temperatures in the different regions of the Earth's surface will lead to alterations in agricultural behavior, provoking a change in the frontiers of economic exploitation or subsistence.

The objective of this work is to demonstrate, based on the geography of current agricultural production, the necessity to adapt this production to the future regional climatic conditions, thereby structuring a new agricultural geography in the country. The basic parameter adopted in the simulations of future scenarios has taken the Climatic Risk Zoning for Agriculture as a reference. This is a program of public policies placed in operation by the Federal Government to rationalize the financing of Brazilian agriculture. The scenarios for the years 2020, 2050 and 2070 were established by the Precis RCM model, developed by the Hadley Centre in England, and adapted for Brazilian conditions by CPTEC/INPE (MACHADO and MARENGO, 2006 and MARENGO and AMBRISI, 2006), with a resolution to the order of 50 x 50 Km. Founded on the basic climatic demands for regional adaptation, and taking as a basis the climatic parameters from the present climatic risk zoning, future climatic data have been recalculated for nine agricultural products that represent around 85% of the Brazilian agribusiness gross domestic product: rice, cotton, coffee, sugarcane, beans, sunflowers, cassava, corn and soybeans. Accordingly, municipal maps and tables have been prepared demonstrating the possible migration of agricultural products in future due to the increase in temperatures, and which allow the evaluation of variation in areas appropriate for cultivation in the present and future scenarios.

2. CLIMATE IMPACTS ON AGRICULTURE

Each plant has its own adaptation to the climatic conditions predominant in its habitat. Thermal or hydric conditions, when modified excessively, cause the death of these plants, in general due to extreme incidents. This is the case of frosts or heatwaves. In these cases, the survival of the species could occur through migration in search of new locations with climate conditions similar to those before, the mitigation of environmental conditions or a beneficial genetic mutation.

The knowledge of current agricultural geography in the country through climatic risk zoning has enabled the development of simulation work into future agricultural scenarios. The models allow the recalculation of variables that condition the vegetal adaptation to the different types of existing climate, by attributing the values of expected temperatures in accordance with the world or regional climatic models. These values are utilized in the simulation of the hydric balances and the possible meteorological extremes in the indication of the new conditions for the adaptation of the crops to the new climate considered.

Up to the year 2000, few studies of this type had been carried out to simulate the scenarios for climatic change in agriculture. ASSAD & LUCHIARI JR. (1989) evaluated the possible alterations in productivity in soybean and corn crops due to scenarios of increasing or decreasing temperatures. SIQUEIRA et al. (1994 and 2000) demonstrated, for some areas in Brazil, the effects of global changes on the production of wheat, corn and soybeans. A first attempt at identifying the impact of the climate changes on the regional production was made by PINTO et al. (2001), who simulated the effects of the rises in temperature and rainfall on the climatic risk zoning for arabica coffee in the states of São Paulo and Goiás. The results of the simulations show a significant reduction in the areas having agroclimatic aptitude.

Considering the scenario of rising temperatures, it may be assumed that, in the regions climatically bordering those that limit the adequate cultivation of agricultural plants, the positive anomaly that arises will be unfavorable for the development of the crop. The greater the anomaly, the less appropriate the region will become, to the maximum limit of biological tolerance to heat or drought provoked by the thermal increase. On the other hand, other crops more resistant to high temperatures or longer dry spells will probably be benefited, up to their own limit of tolerance to thermal or hydric stress. In the case of low temperatures, regions that are presently limiting for the development of crops susceptible to frost will acquire conditions of lower risk for the development of the plants with the rise in temperature due to global warming. This is the typical case of coffee production, which could be transferred from the Southeast to the South of the country in the future.

3. CLIMATE AND VEGETAL BEHAVIOUR

The principal aspect that conditions the biological adaptability of crops to the climate refers to the direct effect on the plants of the increase in temperature and the concentration of carbon dioxide (CO_2) in the atmosphere, which significantly alter the behavior of the stomas, and consequently the photosynthesis. The concentration of CO_2, being close to 300 ppm, is well below the saturation for the majority of plants. Excessive levels, close to 1,000 ppm start to cause phytotoxicity. Generally, within this range the increase of CO_2 promotes greater biological productivity in the plants, as demonstrated by ASSAD and LUCHIARI (1989) and COSTA et al. (2008). By the same token, the increase in temperature of the air conditions an increasingly less efficient biological behavior as temperatures reach 34°C. When the temperatures exceeds 33°C, the arabica coffee in the flowering phase loses its flowers due to aborting, which transforms the flowers into “estrelinhas”, a popular term that indicates failure in the pollination and consequent drop in production (Figure 1). To the extent that temperatures increase above 22 or 23°C, the photosynthesis tends to diminish in intensity causing a reduction in the vegetal growth that is interrupted with values close to 40°C.

Figures 1a and 1b: Coffee branch showing: a) Left – Normal flower buds; b) Right – Aborted flower buds or "estrelinhas", due to the occurrence of raised temperatures. (IAFFE et al., 2003).

The plants denominated type C4 (Sugarcane) tolerate the higher temperatures much better than the plants called C3 (Coffee) and for this reason survive easily in environments with higher temperatures or higher levels of CO2.

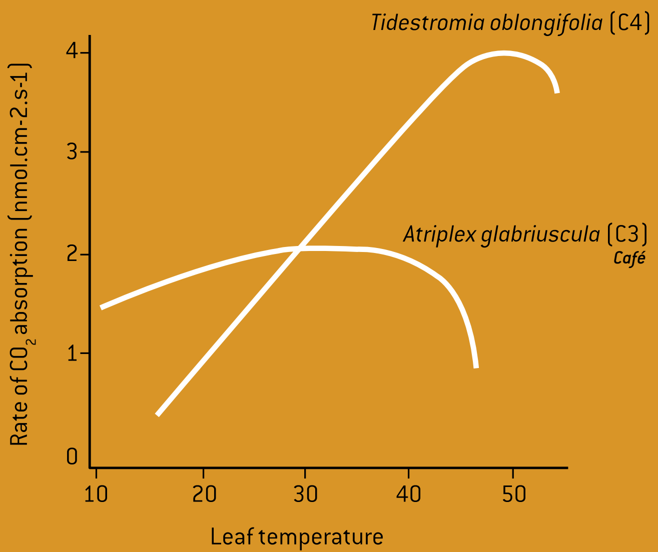


Figure 2: Effect of temperature in the photosynthesis process of plants type C3 (coffee) and C4 (sugarcane). Source: http://www.herbario.com.br/cie/universi/teoriacont/1003fot.htm.

Adopting the definition of the IPCC and the 4th United Nations Convention on Climate Change, and considering only the increase in climate change, it is possible, according to AYOADE (2001), to identify some alterations/limitations in vegetal behavior. These are:

1. Temperatures of the air and the soil affect all the processes in plant growth; i.e. all crops have minimum, optimum and maximum thermal limits for each of their stages of growth;

2. The upper lethal temperatures for the majority of plants are between 50°C and 60°C. Above 40°C the photosynthesis is interrupted.

3. Prolonged cooling of plants, with temperatures above the freezing point of the plant tissue, will hold back the vegetal growth and could kill the plants adapted only to higher thermal conditions;

4. Excessive heat could destroy the vegetal protoplasm, because it has a drying effect on the plants and the rapid rates of transpiration could lead to wilting.

4. ZONING OF CLIMATIC RISKS FOR AGRICULTURE

The Zoning of Climatic Risks for Agriculture is a tool presently utilized as public policy by the Federal Government with the purpose of rationalizing the use of resources for financing plantations and rural insurance. In a simplified form, it signifies indicating to the government itself and the farmers “what to plant, where to plant and when to plant” with the economic loss of production occurring being 20% or less.

Since 1996 in Brazil, by determination of the National Monetary Council (CMN), rural credit and insurance are only made available to farmers from municipalities that opt for plantations of a determined crop, which is defined as appropriate by the zoning of climate risks (PINTO et al., 2000). The basic study of zoning has allowed the researchers, and the government itself, to understand in detail the distribution of agricultural crops in the country; that is to say the Brazilian agricultural geography. For the purpose of zoning, the climatic potential of a region, in general, has its basis in the temperature variations and the availability of water for the plants according to that established by CAMARGO et al. (1977), CATI (1977), PINTO et al. (2001), SILVA et al. (2000 and 2001) and ASSAD et al. (2004, 2007). Areas with annual average minimum temperatures lower than 15°C are considered high risk due to the high probability of frosts and areas with temperatures above 23°C are also high risk due to the persistence of heatwaves with temperatures above 30°C during the blooming phase, which causes the aborting of the flowers (IAFFE et al., 2003).

The process for the creation of zoning, according to PINTO et al. (2000) is based on a simulation of growth and development of the crops, from a database of climate and soil, using decision analysis techniques and geoprocessing tools. Thus, the development of simulations is based on methods of rainfall frequency analysis and the Index for Satisfying the Water Needs of Crops - ISNA – which is the relationship between ETR (true evapotranspiration) and ETM (maximum evapotranspiration), shown in Equation 1.

5. EXTREME CLIMATIC EVENTS AND LOSSES IN AGRICULTURE

Increase of carbon dioxide in the atmosphere:

The functioning of photosynthetic activity due to the concentration of atmospheric carbon dioxide in the growth of plants is well known. When close to 300 ppm it is well below the saturation level for the majority of plants and when close to 1,000 ppm, it becomes phytotoxic. Photosynthetic activity is greater in the plants classified as type C3 (leguminous) than in C4 (gramineous). In the same way, transpiration that is directly related to temperature tends to be more reduced in C4 plants than in C3 plants, which is evidence of the greater water efficiency in C4 plants than in C3 plants.

ASSAD and LUCHIARI (1989), utilizing simplified physiological models, have shown that these variations are significant in Brazilian pastures. For example, the average temperature during the rainy season in these regions - from October to April - is 22°C, having a maximum of 26.7°C and a minimum of 17.6°C. Considering the hypothesis that an increase in the concentration of CO_2 in the atmosphere provokes an increase in the temperature, the authors have simulated two scenarios: the first supposing an increase of 5% in the average temperature, when the C4 plants such as corn and sorghum experienced a potential increment of at least 10 Kg/ha/day of dry grain in average productivity. For the type C3 plants (soybeans, beans and wheat) this increase would be less, to the order of 2 to 3 Kg/ha/day of dry grain. In the second scenario, which simulates a drop in average temperature of 5°C, the loss in productivity in type C4 plants would be to the order of 20 Kg/ha/day and in the C3 plants the loss would be to the order of 10 kg/ha/day. SIQUEIRA et al. (1994), utilizing this type of model and working with several different scenarios in 13 locations that range from low latitudes (Manaus) to high latitudes (Pelotas), encountered responses very close to and more exact than those proposed by ASSAD and LUCHIARI (1989). As a result of the rise in temperature, shortening in the corn and wheat growing cycles and increases in the productivity of corn, soybeans and wheat are foreseen, due to the increase in concentration of CO_2, which will vary from the present 330ppm to 550ppm. In some cases gains greater than 500 kg/ha for corn and wheat, and more than 1,000 kg/ha for soybeans are foreseen. More recent work (COSTA et al, 2008) shows with more detail the consequences of the increase of CO_2 in the increase in productivity of agricultural plants due to the effect of fertilization.

Heatwaves

According to the IPCC (2001 and 2007) the increase in the world's temperature is unequivocal. Eleven of the last twelve years (1995 to 2006) have demonstrated rising temperatures. The linear trend for thermal increase over the last 50 years has been 0.13°C per decade, which corresponds to almost double the last 100 years.
In recent years, two waves of extreme heat have affected the southeast of Europe, values of extreme temperatures have been surpassed with indices to the order of 45°C in Bulgaria; in general, the countries of Europe, Asia, and the Americas have observed extreme meteorological phenomena considered unlikely.

In the State of São Paulo, Brazil, the average temperature for the month of September 2004 (32.1°C) was 4.4°C above the historic average (27.7°C), causing a loss of approximately US$50 million to animal husbandry due to the premature death of animals. Heatwaves with maximum daily temperatures above 32°C are responsible not only for the death of animals, but also for a drop in agricultural production, given that they interfere significantly with phases of the phenological cycle of the crops and in the development of the vital organs of the plants. Figures 3a and 3b below show the lethal effect of only one day with a maximum temperature of 33°C on arabica coffee flowers.

In the State of São Paulo, the occurrence of heatwaves has increased significantly over recent years, as shown in Figure 4 below. In the beginning of the twentieth century, there were around 12 days on average with maximum temperatures higher than 32°C in the region of Piracicaba and this number has presently risen to 17 days.

Figures 3a and 3b. Arabica coffee plants showing, on the left branches with flowers, and on the right, a branch with flowers damaged by maximum temperature of 33°C observed on only one day. Courtesy of P. Caramori IAPAR.

Figure 3a

Figure 3b

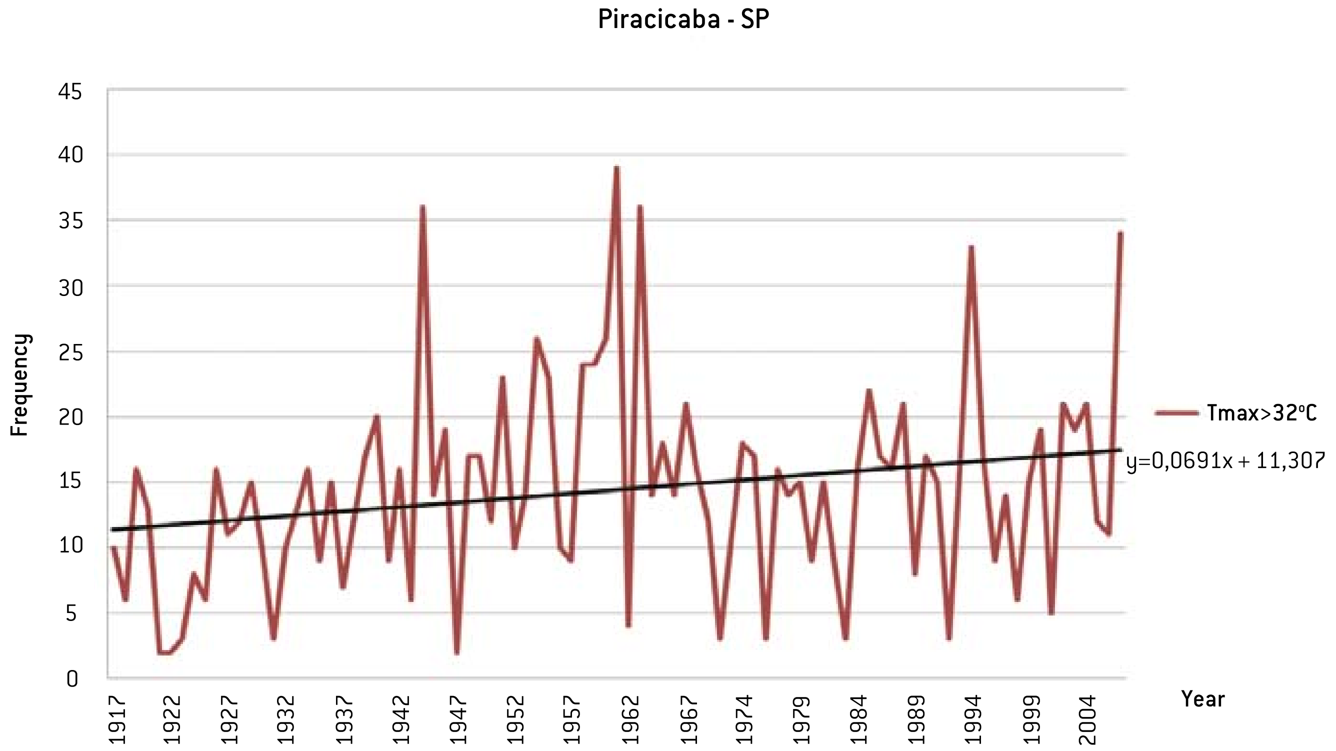


Figure 4. Variation in the frequency of the number of days per year with maximum temperatures higher than 32°C in the municipality of Piracicaba, S. P.

Considering the evolution of the global temperatures and the scenario foreseen by PINTO and ASSAD (2008), with the exception of sugarcane, it is expected that around the year 2050, the greater part of the agricultural crops in Brazil will have suffered a noticeable decline in productivity due to the excess of heat.

Frosts

In general, the farmer defines frost as the condition where ice forms on grassland or pastures when there are low temperatures during the early mornings in winters. Studies on the subject (PINTO, 2000) show that these conditions are observed when the temperature measured in the standard meteorological shelter reaches around 5°C; that is zero degrees in the leaves, or the temperature of the grass. However, in agriculture, when considering the death of plant tissues, the denomination frost will depend on the crop that suffered the low temperature. Thus, for coffee or sugarcane, the temperature lethal to the leaf is –3.5°C, for the tomato it is –1.0°C and for the rubber plant it is –7.7°C.

The occurrence of frosts in perennial plants in general has diminished substantially in the north of Paraná, in São Paulo and in Minas Gerais over recent years. Until the 1990s, light agricultural frosts were observed approximately every four years with heavy frosts every eight years. Updated data show that since the year 2000 there have been no further frosts causing significant damage to agriculture. Figure 5 shows the sharp decrease in the number of days with the temperature below 10°C observed in the Campinas region, which declined from approximately 40 at the beginning of the century to around 10 in recent years. This fact proves the reduction in the frequency of frosts in the tropical area, due to a noticeable increase in temperature, which can be demonstrated by data observed in about 120 weather stations. Considering the scenarios of rising temperatures up to 2050, it is observed that the South of Brazil could have a significant diminution in the occurrence of the phenomenon, allowing the cultivation of tropicalized plants even in Rio Grande do Sul. This is the case of arabica coffee crops, whose displacement to the south of Paraná, Santa Catarina and Rio Grande do Sul is foreseen over the coming years (PINTO et al, 2008).

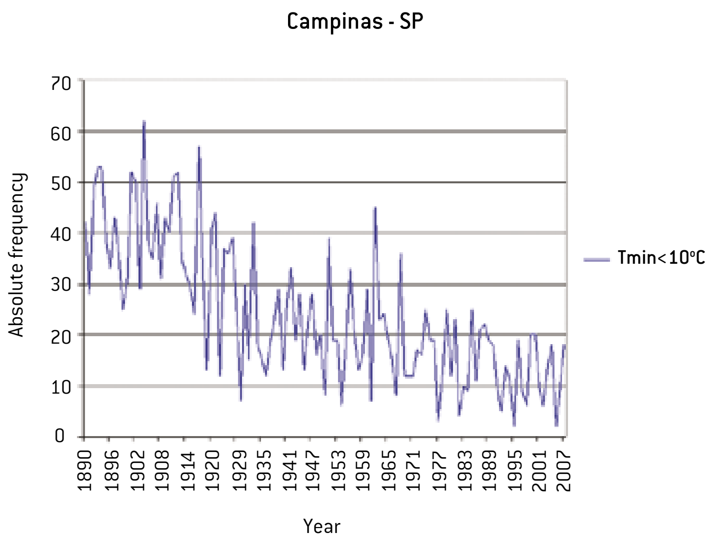


Figure 5. Variation in the frequency of days with temperatures below 10°C in Campinas, São Paulo, between the years 1890 and 2007. (Data: IAC/Apta).

Short Summers

Based on the work of PINTO and ASSAD (2008), with the exception of Amazônia, the possible increase in the periods of dry weather should cause problems for the productivity in practically every annual and perennial crop in Brazil. Soybeans will lose the conditions to be cultivated in the South of the country, sugarcane should increase the demand for the so called "salvage irrigation" in its expansion towards Central Brazil and the subsistence crops such as beans, corn and cassava should suffer sharp drops in productivity in the Northeastern areas. According to Alisson Barbieri da Cedeplar/UFMG and Ulisses Canfalonieri from Fiocruz, in a work to be published by the British Embassy in Brazil, some states in the Northeast such as Ceará and Piauí should lose between 70% and 80% of their agricultural land due to the increase in dry period indices there between the years 2010 and 2050. Agricultural plants need water in certain critical phases during their development, such as blooming, when the dry period causes the loss of flowers and consequent decline in productivity.

The use of irrigation to compensate the increases in short summers in Central Brazil and the Northeast is not recommendable in view of the increase in competitiveness between water for human consumption and agriculture. On the other hand, some areas in the east of Amazônia, with a reduction in rainfall, could develop circumstances for the cultivation of cassava and sugarcane due to the easier traffic conditions for machinery, which would enable mechanized harvesting.

Intense rains and winds

The forecast from most climatic models for an increase in the frequency of intense rains and storms in the Southeast and part of the South of the country, could bring some problems, principally for agricultural mechanization due to flooding of the cultivated areas, which would impede access to agricultural machines for the continuous management of the crops. Effects like the drooping in strong winds of plants such as sugarcane, wheat and rice may also occur significantly more often. Agricultural treatments against plagues and diseases could be made more difficult due to the impracticability of spraying with pesticides due to the strong winds or heavy rains.

Humidity of the air

The increase in temperatures and the consequent water vapor content in the atmosphere should increase the index of disease in agricultural plants by providing better conditions for the formation of dew in the leaves and thermal comfort for the fungi. Increases in temperature induce a shortening in the reproductive cycle of fungi and insects due to a shorter period of incubation, which allows a larger number of generations of the microorganism. On the other hand, the incidence of longer intervals of dry periods, with a drop in the humidity in the air, could increase the incidence if plagues in the farms given that insects adapt themselves better to dry conditions with higher temperatures.

6. MITIGATION AND ADAPTATION OF CROPS

Vulnerability is the degree of susceptibility or incapacity of a system to overcome climatic effects adverse to its remaining in the environment where it subsists. In agriculture, it may be considered that vulnerability is responsible for crop failure in food production species. Mitigation is the manner of conducting processes that attempt to minimize the effects of high temperatures or increases in dry periods on plants. Adaptation refers to the capacity that the living being has to adjust itself to the new climatic conditions or their consequences. In agriculture, the adaptation may be forced through so-called genetic improvement; either conventional or genetic engineering.

In Brazil, the future agricultural scenarios may be analyzed in more detail due to the new studies by PINTO and ASSAD (2008). Starting with all the panoramas analyzed, the effects of global warming will be felt intensively by Brazilian agricultural production. However, it is possible as of now, to propose solutions that will control and/or mitigate these effects. Basically, the minimization of the consequences depends on three fronts for action: i) Reduction of greenhouse gas emissions (GHGs), ii) Mitigation and iii) Increase in research into biotechnology.

Brazil presently occupies fourth place in the world ranking for emission of greenhouse gases given that deforestation is responsible for 75% of the total. The adoption of a serious and efficacious public policy that controls and inhibits the burnings could promote a drastic reduction in the rate of emissions, reclassifying the country to eighteenth or nineteenth position in the world pollution ranking.

In addition to the reduction in burnings, the second aspect is mitigation. To invest in more efficient and cleaner agricultural systems would help to improve the atmosphere. Ambiguously, there is criticism relative to agriculture, alleging that this activity contributes to an increase in global warming, principally due to the practices of burning and opening new frontiers in Amazônia. However, in the agricultural activity, there is sufficient scale to reduce the concentration of greenhouse gases in the atmosphere. With extensive areas cultivated using more efficient and cleaner systems it is possible to sequestrate the carbon from the atmosphere with agility and efficiency.

The third aspect foresees the work of adapting the species, and investing in genetic improvement for this purpose, be it conventional or with the use of biotechnology. With these investments there will be the guarantee that different cultivated varieties would be created for adaptation to the higher temperatures or shortages of water.

Reduction in greenhouse gas emissions

For it to be possible to promote a reduction in GHGs, it is necessary to guarantee that there are agricultural actions and programs that contribute towards continuous reduction of these emissions, giving incentives to more efficient and cleaner agricultural production, and investing in research into the adaptability of species to the new climatic panoramas. Considering this, it is necessary to formulate efficient public policies that guarantee:

a) the reduction of burnings, leading to their elimination;
b) the substitution of fossil fuels with biofuels;
c) investment in research into alternative energy sources;
d) the creation of efficient systems of carbon storage;
e) continuous activities of forestation and reforestation;
f) the adoption of conservationist practices, such as the reduction of erosion, the adoption of direct planting techniques and efficient coverage of the soil.

Figure 6. Illustration of the different stages of the animal husbandry/planting/forestry system.
(Photo: Geraldo B. Martha Jr. Embrapa Cerrados)

In parallel with these actions, it is necessary to invest in studies that enable us to define detailed scenarios about the new geography of the Brazilian agricultural production. It is necessary, therefore, that these studies are thorough to identify, municipality by municipality the agroclimatological conditions, and study at a local level the possible climatic and agricultural scenarios in ten, fifty or 100 years time.

In the Cerrados region, Brazil presently owns around 40 million hectares of degraded pastureland, characterized for its low support capacity, around 0.5 animals/ha/year, given that they are not subject to agronomic techniques or sustentation. Solutions such as the implantation of techniques to integrate animal husbandry with planting or animal husbandry with both planting and forestry in a defined rotational logic, would follow a sequence of substitution of pastureland with grain and forests initially, and return to pastureland subsequently. Such practice would enable a reduction in the erosion, the cycling of nutrients, an increase in the production of biomass, greater efficiency in carbon sequestration and, at the end of the cycle of forest/pasture installation, an increase in the annual support capacity from 0.5 animals/ha to 2.5 animals/ha.

This would be a clean and efficient way to mitigate the effects of global warming, given that at the same time it would be possible to reduce the quantity of carbon present in the atmosphere, have a high capacity for the production of cellulose, help to fertilize the soil and practically quadruple the support capacity of the pastureland.

Still with the possibilities of mitigation offered by agricultural systems, we may cite in the case of soil management, the benefits found in direct planting. Brazil is one of the few countries in the world to practice this type of planting, with a present area of around 23 million hectares. This type of planting is highly efficient in carbon sequestration. Firstly, because it reduces the quantity of implements required, demanding for example, less fuel and machinery for the application of manures, fertilizers and agricultural pesticides. Secondly, because only one stage is sufficient to effect the planting. Machinery adapted for direct planting is already able to effect sowing over the residues of the previous crop without the necessity of turning over the strips between furrows, ploughing the land or grading. Thirdly, because it increases the production of biomass.

Several studies in Brazil have demonstrated that in the North, Central-west and South regions, the utilization of the direct planting system, ensures the sequestration of approximately 500 Kg/ha/year of carbon, which signifies that 12 million tons of carbon per hectare are absorbed in one single agricultural practice in the country. In the case of integration between animal husbandry/planting/forestry, there is carbon sequestration to the order of 2.5 ton/ha/year, according to the

P58 (BR-16 with gene)
2,5% soil moisture

BR-16 without gene
2,5% soil moisture

Figure 7. Soybean with genes tolerant to dry spells. The four plant pots on the left contain the tolerance gene and the other four on the right correspond to common soybeans. Courtesy: Dr. Alexandre Nepomuceno, researcher at Embrapa Soja, Londrina, Paraná.

data from Embrapa Cerrados.

Genetic improvement

Independent of the environmentalist concept about the cultivation of produce with the use of transgenic seeds, parallel to conventional genetic improvement, this is one of the most promising alternatives for the adaptation of the principal agricultural crops in the future. For better adaptation it is necessary to use plant breeding techniques that enable the introduction of new genes into the plants, providing tolerance to dry spells and higher temperatures.

Biotechnology may also contribute towards the mapping of genes tolerant against heat or dry spells, making the process independent of genes mapped abroad, given that it is completely possible to find these tolerant genes in the plants of Brazilian biodiversity. Thus, to preserve the biodiversity, in addition to being a practice absolutely necessary and important for the environment, could also be fundamental for the maintenance and sustainability of agriculture.

Brazilian Institutions have already developed, and continue to develop, work based on the genetic improvement for tolerance against dry spells and high temperatures. Embrapa Soja, in Londrina, has made available a variety of soybean tolerant to dry spells on an experimental basis. The Agronomy Institute of Paraná – Iapar – has developed four varieties of bean with a good tolerance against dry spells and heat, and the company Empresa de Pesquisa Agropecuária e de Extensão Rural de Santa Catarina – Epagri – has demonstrated advances in this type of research

7. FUTURE SCENARIOS

with temperate climate fruits.

The summary of the second part of the IPCC 2001 Report (about impacts, adaptation and vulnerability) directed to those who formulate public policies was extremely vague on evaluating possible impacts of the global climate changes on the behavior of agricultural plants. In reference to the adaptation of crops located in the "middle latitudes" and the reflection on their productivity, the report only states that the climate change will lead to "positive general responses for variations lower than some degrees Celsius and negative general responses for more than some degrees Celsius". The IPCC 2007 Report, as well as recent works by ASSAD et al. (2006, 2007), PINTO et al. (2007, 2008) and NOBRE et al. (2008), are more specific as to the effects of the increase in temperatures on plants. Recently, ZULLO JR et al. (2008a and 2008b), COSTA et al. (2008), PINTO et al. (2008) and ASSAD et al. (2007) have demonstrated the effects of global warming on the future dislocation of the principal agricultural crops in Brazil. NOBRE et al (2008) analyzed the consequences of the warming in South America.

PINTO and ASSAD (2008), in work developed with the support of the British Embassy in Brazil, have shown the financial losses and gains arising from the migration of crops in the country due to the increase in temperature.

Table 1 below shows the consequences on nine of the principal plants cultivated and responsible for around 85% of the Brazilian agribusiness gross domestic product.

By calculating proportionally the losses and gains in plantable areas using the crops considered in the table above, due to the migration caused by global warming, the results indicate an economic gain to the order of R$27 billion per year with sugarcane in 2020, in the worst scenario (A2). Soybeans should lose R$4.3 billion per year and corn around R$1.2 billion in the same period.

In scenario B2, the lowest warming forecast, the negative balance of production reaches R$6.7 billion per year and the positive, due principally to the increase in potential areas for sugarcane, reaches R$29 billion per year.

Recent data, collected by PINTO and ASSAD (2008) show that to obtain a new cultivated crop in agricultural plantations, necessarily takes ten years, in addition to three more for the multiplication of the seeds. The annual cost is to the order of US$500,000; that is US$6 million for each new crop. This fact shows the importance of beginning work on genetic improvement in search of plants tolerant against dry spells and higher temperatures, while under penalty of the obsolescence of existing cultures before the production of the new plants adapted to the future climatic conditions.

Crops	Present potential area (Km^2)	Year 2020 potential Model Precis A2 (Km^2)	% Variation relative to present area	Year 2050 potential Model Precis A2 (Km^2)	% Variation relative to present area	Year 2070 potential Model Precis A2 (Km^2)	% Variation relative to present area
Cotton	4,029,507	3,583,461	-11.07	3,449,349	-14.40	3,380,202	-16.12
Rice	4,168,806	3,764,488	-09.70	3,655,029	-12.32	3,577,169	-14.19
Coffee	395,976	358,446	-9.48	328,071	-17.15	265,243	-33.01
Sugarcane	619,422	1,608,994	159.76	1,477,816	138.58	1,351,441	118.18
Beans	4,137,837	3,957,481	-04.36	3,715,178	-10.21	3,587,559	-13.30
Sunflower	4,440,650	3,811,838	-14.16	3,709,223	-16.47	3,633,928	-18.17
Cassava	5,169,795	5,006,777	-03.16	5,886,398	13.48	6,268,634	21.26
Corn	4,381,791	3,856,839	-11.98	3,716,684	-15.18	3,624,487	-17.28
Soybean	2,790,265	2,132,001	-23.59	1,837,447	-34.15	1,635,239	-41.39

Table 1. Variation of the areas estimated by model Precis RCM, in Km^2, with potential for the plantation of the principal Brazilian crops in present climatic conditions (2007/08) and also in 2020, 2050 and 2070, in the scenario IPCC - A2.

8. THE NECESSITY FOR A BETTER UNDERSTANDING OF CLIMATE CHANGES AND MORE EFFECTIVE PARTICIPATION BY THE PLAYERS INVOLVED IN THE DEBATE

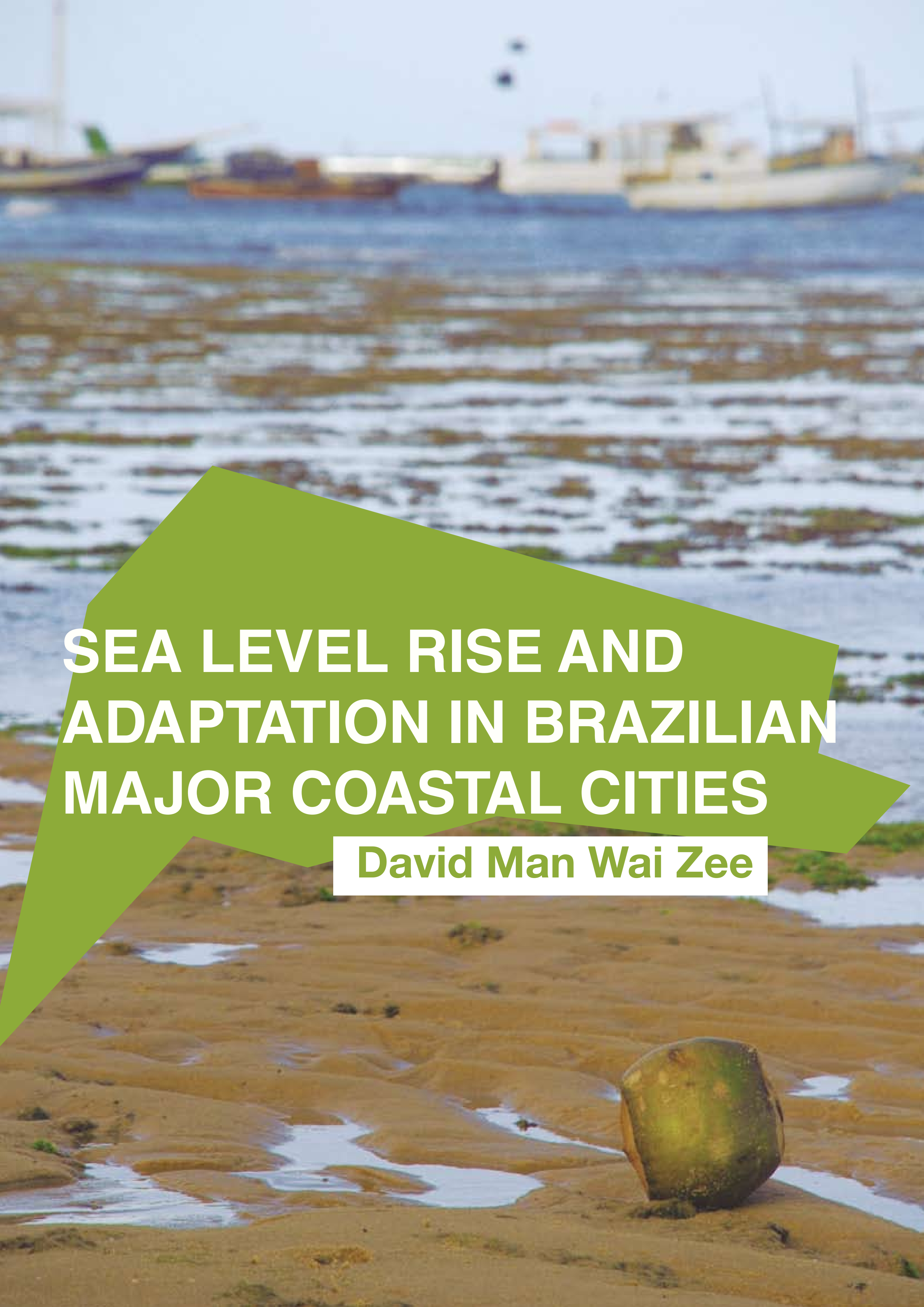
In general, around 98% of the world's climatologists agree that global warming is a developing phenomenon, and that in accordance with IPCC (2007), 95% of the causes are due to the activities of mankind. The contrary opinions of the remaining 2% of researchers, the so-called sceptics, are not based on scientific arguments that demonstrate the incorrectness of existing work. The only arguments presented are mostly based on astronomic phenomena, and are about the increase or diminution of $CO2$, about the variation in temperatures over millions of years and about the glacial eras, but they lack the scientific analysis that identifies the occurrence of warming scenarios over the next 10 to 100 years. For agribusiness, 10 years could signify substantial losses in terms of the economy, and principally in terms of the future security of food supply. A survey carried out by EMBRAPA, the Brazilian Company for Agriculture and Animal Husbandry and other official and private agricultural research institutions in Brazil, shows that, in order to obtain a single plant culture having tolerance to heat or drought, either by conventional improvements or transgenically, there is a delay of approximately 10 years and a cost of 10 to 12 million reais. The present climatic analyses show that within 10 to 20 years, a new alteration in the agricultural scenario will certainly have occurred, with migration of plants to the South or to higher altitude areas, with corresponding losses of production for the country. In this scenario, any lack of action today could have a high cost in the near future. With rare exceptions, the research financing agencies in Brazil delay around 10 years in taking a decision to support studies into climate changes, and even so, these resources are still, in part, more in promise than reality. In the agricultural area, only EMBRAPA and the British Embassy have shown themselves to be really interested in financing these studies.

The preliminary estimates of EMBRAPA show that there are presently around 150 million hectares of degraded pastureland in Brazil, with cattle rearing capacity to the order of 0.5 UA/ha (Units of Animal per hectare). The management effort for the recuperation of these lands through agricultural/silvicultural/pastoral management, in addition to enabling the capture of CO_2 equivalent to the order of 2 to 4 tons per hectare, could generate conditions for the pastures to support up to 2.0 UA/ha, with economic advantages from forestry production.

Good agricultural planning should be carried out at least 10 years in advance. One aspect that could contribute to a future for agriculture that is less prejudiced by global warming concerns forecasting the appropriate use of soil by the farmers, basing plantations on the climatic risk zoning indicators together with alteration forecasts.

Among the private companies dedicated to agribusiness, most of them have already been working with second-generation transgenic seeds; which is making the improvements necessary to obtain plants resistant to meteorological stress. In these companies, those responsible for the research areas have more positive evaluations as to the alterations in future climate than the directors of official institutions, probably due to a more up-to-date information flow, to less influence from the sceptics or to precaution against the bad economic performance that could be coming.

In the governmental area, the diversity of interpretation of climatic changes has made the establishment of a single coherent program for research difficult, even for the mitigation of already existing problems, without there being a more competent coordination to define how to establish an integrated program that meets national and international requirements. Brazil has already been the pioneer in research into global warming and agricultural development, and could lose positions in the world ranking shortly, if it does not establish a fully integrated program, with resources for basic experimentation involving laboratory and fieldwork with the principal agricultural crops.



SEA LEVEL RISE AND ADAPTATION IN BRAZILIAN MAJOR COASTAL CITIES

David Man Wai Zee

SUMMARY

Almost 60% of the world's population either lives or travels in areas close to the coast, so any rise in sea levels is a serious threat to the way humans live. According to the report of the Intergovernmental Panel on Climate Change-IPCC, Climate Change 2007, the world's temperature is projected to increase between 1.1º C and 6.4º C during the 21st Century, which will lead to a sea level rise of between 18 and 59 cm.

In addition to sea level rise, the frequency of extreme weather events will weaken the physical stability of the coastline. As water warms, it will evaporate more quickly, and we will experience, more rain and storms as well as winds, hurricanes or cyclones. Kinetic energy is transferred to the sea in the form of waves or storm tides which carrying sediments of erosion or silt hit the coastline.

The changing profile of the coastline, the impact of the storm tides and a rise in coastal sea levels can have a catastrophic impact on coastal urban areas and port facilities.

Risks to navigation become higher as more energy is absorbed by the sea - translating into waves and cyclones of higher intensity and frequency. Finally, the rising sea level compromises the drainage of the coastal cities, making the dispersal of urban effluents more difficult and, as a consequence, increases the pollution of the waters. The environmental degradation of coastal space means the loss of areas for tourism and leisure, the depreciation of property and an increase in insecurity for local residents. Such factors lead to economic losses and declining values for coastal properties.

This study presents the threats, vulnerability and exposure (i.e. the risk) for three different regions in Brazil: the State of Rio de Janeiro, the State of Santa Catarina and the metropolitan region of Recife in Brazilian Northeast region. Santa Catarina presents the greatest threats from global warming. The first hurricane observed in the South Atlantic happened within its boundaries, in 2004. Also, the State of Santa Catarina has experienced heavy rains for the last two years. The State of Rio de Janeiro suffers from the impact of frequent storm tides, but, over the last years presents a less destructive scenario than Santa Catarina. The Recife metropolitan area presents the lowest threat from global warming since it is located in a more stable climatic region than the others. This does not mean Recife is safe from climate change -. because Northeast Brazil is a less developed region, the vulnerability of Recife (even greater in Olinda) is still very high.

The study classifies these regions by risk and aims to estimate the economic loss that could be provoked by climate change. We have studied the built infrastructure, planned investment and the demographic density for each place. As a result, the report aims to estimate the primary regions which are likely to have a high demand for insurance.

The coastal zone can be adapted to reduce these threats by adopting preventive and reactive policies. Of course, preventive measures are more economical and effective than reactive actions, however this is not always possible due to lack of planning capacity, investment and public opinion. Some of these adaptation policies are:

• To increase requirements for new urban infrastructure projects;
• To strengthen public information about the potential risks of sea level rise locally;
• To protect natural barriers against sea level rise (e.g. mangroves and coral reserves);
• To create an investment plan to reduce vulnerability of critical areas (for example, construction of dykes and other artificial barriers).
• A more rigorous use of coastal land (e.g. definition of *non aedificandi* areas);

Lloyd's has already published as part of its 360 risk insight programme, a paper about sea level rise. This paper sets out the rising threat of climate change for three different regions of the world: the Caribbean, England and Southeast Asia. But it warns that every region will suffer more extreme events and greater losses with the progression of global warming.

It is the role of the insurance industry to encourage adaptation measures by given incentive to policy-makers and individuals. As described in Lloyd's 360 risk insight, insurance companies should set policy premiums at a level that more closely reflects the risk to which individual properties are exposed. If adaptation measures are not implemented, insurance will become more expensive and less available. Insurance companies could also allocate some of their assets to green investments as a strategy to mitigate global warming and reduce future losses.

1. INTRODUCTION

Coastal areas are permanently exposed to the struggle between the continental and oceanic forces that give rise to their constant transformation. The coastline becomes, therefore, an area of even greater risk with the influence from climate changes, whose most noteworthy collateral effect is the raising of the sea level.

It is in the oceans that the thermal energy absorbed by the greenhouse gases is accumulated, and this translates into an increase in the water temperature. Those waters warmed most from the tropical regions are transported by the currents to more distant locations such as the poles, and provoke the melting of the glaciers. The thaw causes differences in temperatures and salinities that provoke an alteration in the density of the seawater between oceanic regions, which in turn provide feedback to the currents that spread the heat concentrated in the tropical zone through the oceans. This chain of effects feeds the network to dissipate the energy accumulated on the planet.

The raising by 1°C in the oceanic water temperature gives rise to thermal expansion of an enormous volume of water contained in the oceans and consequently the level of the sea. If added to the combined effects of the melted water from the polar icecaps and the mountains, in addition to the meteorological tides (originated by meteorological phenomena), the potential to raise the sea level may be perceived. If the surging effect of stronger waves, due to the greater interaction of the energy between the atmosphere and the oceans arising from the greenhouse effect, were taken into account, it may be perceived that the oceans could reach continental regions that were previously unimaginable. Accordingly, the risks of a rise in sea level affecting coastal urban regions are greatly enhanced.

2. CONCEPTUAL LANDMARK: THE RISING OF SEA LEVELS.

Global warming is both a physical and conceptual reality. The present challenge is no longer to prove its existence, but to know how we are going to adapt to this new situation.
Almost 60% of the world's population either lives or travels in areas close to the coast. A rise in the sea level is a serious threat to human living conditions in the immediate future.
According to the report of the Intergovernmental Panel on Climate Change-IPCC, Climate Change2007:The Physical Science Basis (IPCC, 2007), the principal conclusions inherent in the rising of sea levels are the following:

a) Warming in the climatic system is real.

b) The manmade origin of the warming and the rise in sea levels will continue to increase for centuries due to the timescales of climatic processes and the feedback, even with the maintenance of greenhouse gas emissions into the atmosphere at their present levels.

c) The world's temperature will tend to increase at between 1.1º C and 6.4º C during the 21st Century.

d) The sea level should rise by between 18 and 59 cm during the 21st Century.

e) There is more than 90% chance of further icecap melting.

f) There will be 66% more occurrences of tropical cyclones and rises in meteorological tides.

g) Both the emission of past and present greenhouse effect gases will continue to contribute to the rise in sea levels for a further 1,000 years.

Therefore the forecasts are significantly solid and disconcerting. Humanity is already on the road to another phase, which is the preparation to confront the consequences of climate change. The question of adaptability is the new order of the day, and as such we must understand better the potential effects that may result from the rising in sea levels in coastal and neighbouring regions.

2.1 CAUSES OF THE RISING IN SEA LEVELS

Around 70% of the earth's surface is covered by oceans. The vastness of the water table constitutes a location appropriate for encouraging the exchanges of energy between the atmosphere and the oceans. The greenhouse gases trap the thermal energy converted by the solar radiation arising from the planet in the atmosphere.

The thermal energy trapped in the atmosphere due to the greenhouse effect is converted into wind energy and an increase in water temperatures. The accumulated energy is transmitted in the form of waves and evaporation, which in turn is transformed into storm tides, rises in the sea level and tempests (hurricanes, cyclones etc...). This successive chain of oceanographic climate events is nothing more than the transmission of an enormous quantity of additional energy stored in the planet.

This additional energy is dissipated in the form of more severe storm tides, more intense hurricanes, cyclones in regions not previously contemplated, and more worryingly, reaching buildings totally unprepared to receive this type of impact.

The first resistance to the dissipation of energy accumulated in the oceans is the coastal area, which gives importance to the adaptation of these regions and protection against the immediate effects of climatic changes.

The rising of sea levels is due therefore to the static as well as dynamic phenomena (extreme events). The static nature of excess in the sea level is essentially due to the thermal expansion of the seawater, together with the contribution arising from the increase in volume of the oceans resulting from the melting of the polar icecaps and snowy mountains.

The dynamic nature of excess in the sea level is basically due to the following causes:

a) Differences in atmospheric pressure provoking winds that could cause the stacking of oceanic waters when meeting the coast, also called meteorological tides;

b) Water evaporation from the sea and land from winds capable of accumulating energy for the formation of cyclones and hurricanes that provoke deformation in the sea levels along their paths. This phenomenon may be called the storm tide and corresponds to an extreme event;

c) The formation of storm tides near to the coast causes a stronger attack from high energy waves having the capacity to surge or advance over the shoreline;

d) Possible alterations to the pattern of coastal current circulation may also bring about the stacking of waters in certain points of the coast due to their morphology. The alteration of the coastal circulation profile (direction and intensity) could also be a reflection of the climatic changes.

In addition to the question of the intensity of the rising of sea levels, the frequency of extreme nature event appearances is also relevant given that they weaken the physical stability of the coastline.

The transfer of thermal energy accumulated in the atmosphere occurs through the difference in distribution of temperature around the planet. Naturally, the heat accumulated in the tropics tends to spread providing equilibrium through the regions on earth. This distribution of heat is carried out via the air currents (winds) and the sea in ocean and coastal currents. The larger the differences, the greater will be the intensity and frequency of the thermal imbalances.

The transfer of heat to the oceans provokes thermal expansion of the waters and alterations in the marine currents. The transportation of warmer water to the poles melts the glaciers and increases the volume of the oceans thereby provoking the rise in sea levels.

The greater the warming of the waters, the faster will be the process of water evaporation, more rain and storms in addition to the formation of winds, hurricanes or cyclones. This kinetic energy is transferred to the sea in the form of waves or storm tides, which hit the coastline carrying sediments of erosion or silt. The alterations in the profile of the coastline, the impact of the storm tides and the consequent rising of the coastal seawater levels have caused brusque scenarios of energy dissipation able to provoke catastrophic impacts in coastal urban areas.

Figure 1 presents in schematic form the succession of potential events of a causal nature that provoke the rises in sea levels close to the coast.

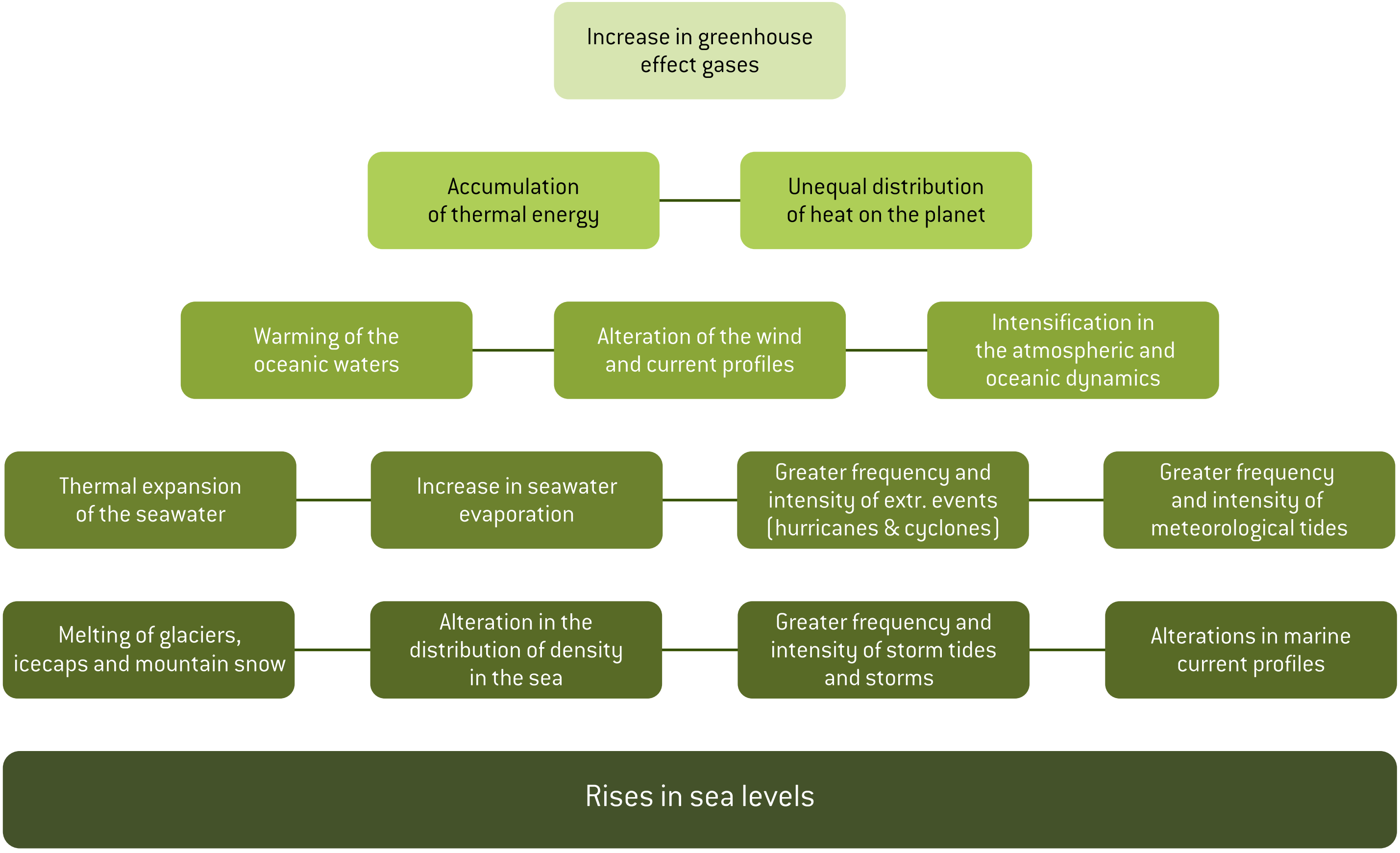


Figure 1: Causal sequence of the origin of rises in sea level

2.2 EFFECTS OF THE RISES IN SEA LEVELS

The coastal areas are sensitive because they suffer the first impacts from any rise in the sea level.

For coastlines having low declivity and a sedimentary nature, areas of extensive coastal plains and lagoons become more exposed to the invasion of seawater thereby altering their morphology, relief and bathymetry.

The greater accessibility of the waves, coastal currents, winds, saltiness (strong smell of the sea) cause more physical abrasion and movement to the coastal sediments. Accordingly, there is an alteration in the coastal morphology and the balance of sediments leading to the exteriorisation or collapse of the coastal and urban structures there. By the same token, the loss of sheltered areas and even saline intrusion into the coastal mangroves can be witnessed.

With the increasing rises in the sea levels, the inland waters become repressed, and the backwaters face problems with flooding in the low inland areas. The alteration to the quality of coastal water provokes the migration of certain biodiversity to more appropriate areas.

Extreme nature events (waves, meteorological tides, cyclones and coastal currents) supported by the static rise in sea level are without doubt serious threats to the collapse of coastal buildings and structures. Such a hypothesis is founded without considering the environmental burden coming from the climatic changes at the time of determining the size of these structures. In the same way, the risks to navigation become higher due to more energy being absorbed by the sea and translating into waves and cyclones of higher intensity and frequency.

Finally, the rising water levels compromise the drainage of the coastal cities, making the dispersion of urban effluents more difficult, and as a consequence increase the pollution of the waters. The environmental degradation of coastal space means the loss of areas for tourism and leisure, the depreciation of property and an increase in the sensation of insecurity.

Such factors result in economic losses and declining values for coastal areas.

Figure 2 demonstrates the sequence of events that depreciate the coastal urban zones arising from rises in the sea level.

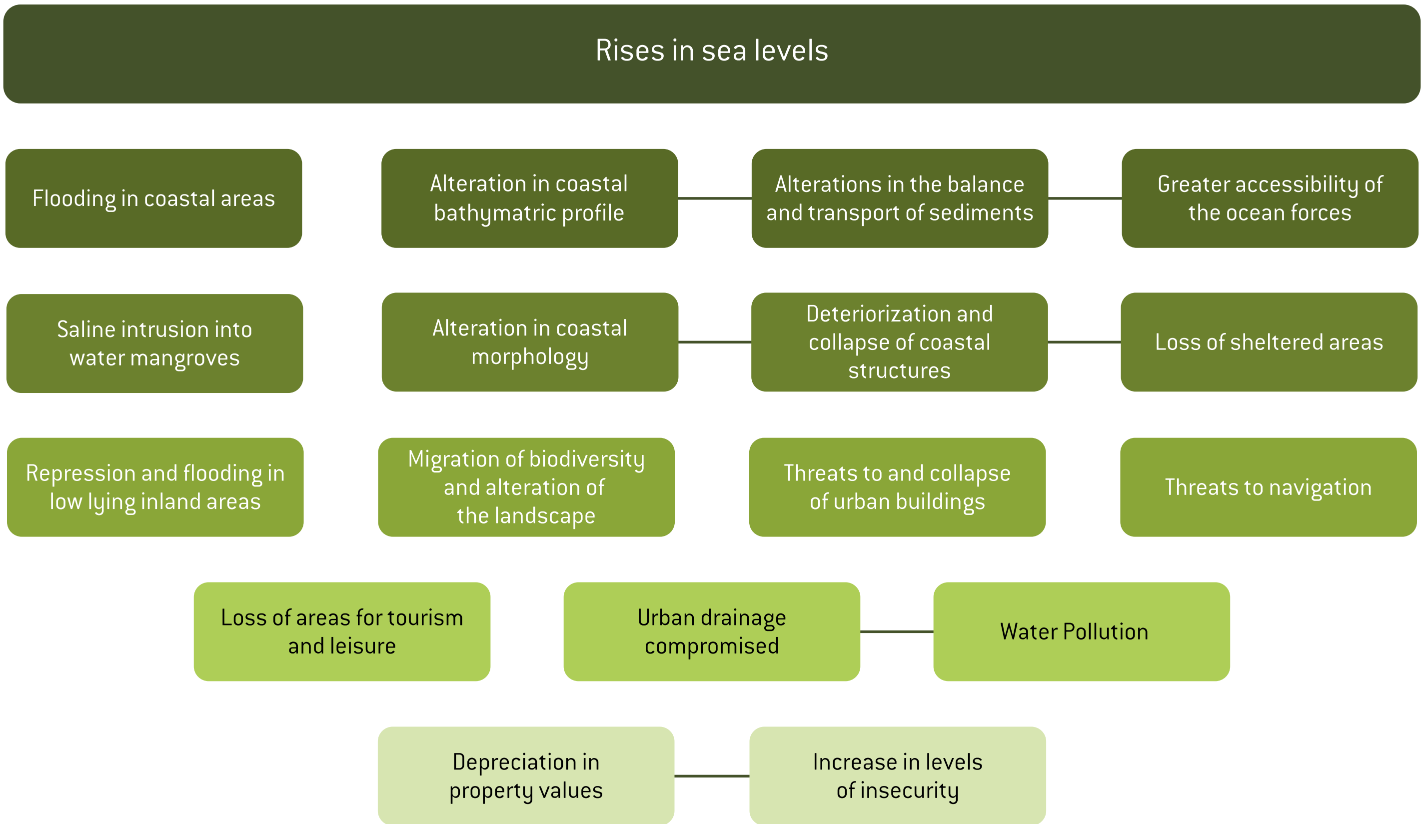


Figure 2: Diagram of impacts caused by rising sea levels.

2.3 LATEST EVIDENCE

The average temperature of the oceans reached 17º C in July 2009, which is the highest registered since the measurements began in 1880, according to the National Climate Data Centre – NCDC (http://veja.abril.com.br/noticia/ciência-tecnologia/temperatura-oceanos-bate-recorde-493298.shtml) on 07.09.09. This affirmation increases the pressure on the melting of the glaciers in the Arctic and Antarctic, strengthens the surging of more hurricanes and with greater intensity, in addition to the phenomenon of thermal expansion in the oceans. All of these factors individually or taken together cause an increase in the sea levels along the coastline.

The warming of waters in the oceans is inevitable and tends to be confirmed given that the seas respond extremely slowly to air temperature, which has already risen significantly over recent decades.

As for the melting of the glaciers, the Antarctic concentrates around 90% of all of the ice on the planet, and according to British and Dutch researchers, if all of this ice were to melt, there would be a rise of dozens of meters in sea levels.

The oceans cover more than 70% of the surface of the earth, and have an average depth of 4,026 meters. With these dimensions, it is possible to evaluate the enormous volume of water in the oceans that corresponds to approximately 97% of the water on the planet. Accordingly, it becomes easy to perceive the potential influence that an increase of 1º C in the temperature could provoke in terms of thermal expansion referring to the volume and the rise in sea levels.

Some projections in the rises in sea levels forecast a rise of 60 centimetres during the 21st Century. Accordingly, by 2030, the hypothesis of an increase to the order of 15 centimetres is perfectly reasonable in global terms.

As has been mentioned, the rises in the sea level and their capacity to impact certain regions of the Brazilian coastline depend on innumerable factors, such as morphology, the local bathymetry and the density of occupation, among others.

Accordingly, the forecast for the rise in sea level varies from location to location along the Brazilian coastline.

In Brazil, according to work carried out by the Oceanic Institute from the University of São Paulo (Instituto Oceanográfico da USP-IOUSP), an increase in the sea level off the coast of Cananéia (south São Paulo) to the order of 4.1 mm p.a. was confirmed between 1955 and 1990. The same institution found that the level off the Santos coast had risen by an average of 1.1 mm p.a. between 1944 and 1989.

These facts demonstrate the variability of average rises in the sea level at different locations. Overall, the tendency for rising sea levels is both evident and real.

Between 1946 and 1988, the port of Recife registered an average rise of 0.56 cm p.a. (Neves and Muehe apud Harari and Camargo, 2008), which corresponds to an increase of 23.5 cm over 42 years.

Analysis of the data from the tide-gauge station on Ilha Fiscal in Rio de Janeiro, from 1965 to 1986, indicates an annual rise of 1.26 cm p.a.(Silva, 1992). It is possibly due to being from the tide-gauge station located within the Guanabara Bay that there is a maximization of excess water level due to localized hydrodynamic effects.

It is for this reason that variations to the order of 15 cm for Recife and 30 cm for Guanabara Bay in Rio de Janeiro have been estimated for 2030.

Due to the extent of the Brazilian coastline, the factors that intervene in this narrow coastal strip (physical,

3. ADAPTABILITY

climatic, oceanographic, biological and man made) and affect the magnitude of the impacts from rising sea levels are diverse. The combination of these factors promotes several risk scenarios, and therefore potential demand on the insurance market.

Despite the countless uncertainties, the most evident certainty is that the climatic changes are real and have come to stay. Accordingly, it has become important to evaluate the risks, measure the potential losses and develop preventive measures. We are dealing with actions to adapt to a new reality that is already established.

The risk comprises three variables, i.e. vulnerability, exposure and threat (Roaf et al, 2009). This represents the potential that the rise in sea levels could unleash in a sequence of effects, causing countless impacts on the coastal areas in the near future. Losses arising from the advance of the sea could appear in several ways due to the local characteristics of vulnerability, their level of exposure and the potential threat of oceanographic-climate phenomena emanating from the greenhouse effect (Roaf et al, 2009).

Risk of impact = (Threat) x (Vulnerability) x (Exposure)

Fig. 3 Impact Risk Equation (Roaf et al, 2009).

From the impact risk equation (Fig. 3), it becomes easy to understand that, if it were possible to annul any of the variables, the risk would tend to disappear. Nevertheless, if it were possible to reduce to the minimum more sides of the risk triangle (Fig.4), the possibility of any impact in the coastal areas arising from the higher sea levels becomes much smaller.

Fig.4 Risk Triangle
Source: Crichton, D.C. The Implication of Climate Change for the Insurance Industry. Building Research Establishment, UK.

The exposure factor of the risk triangle is related to the geographic location and the level of interaction that exist between the coastline and the ocean. Areas that are more sheltered from the direct attack of the sea, such as the internal parts of estuaries and bays, tend to have less risk of suffering the consequences of rising sea levels. On the other hand, coastal areas that are open to the sea have a greater risk of suffering from the environmental impacts arising from the variation in sea level.

The vulnerability of the coastline is in respect of the physical characteristics (geology and morphology) of the coastal scenario. The better the conditions of coastal stability, the less vulnerable the coastal strip will be to climatic changes. Factors such as the availability of sediments, declivity, bathymetry, vegetal cover, relief, and level of human occupation, among others, constitute the elements that characterize higher or lower vulnerability of the coast.

The sharp alterations in the oceanographic-climate scenario arising from the climate changes and the risk of rising sea levels compose the nature of the threat. The threat considers the potential of the occurrence and the frequency with which the event could appear over the coming decades.

The explanation in the preceding section configures the importance of a localized and specific analysis for each of the countless scenarios that make up the Brazilian coastline, and face the threat of rising sea levels.

4. CASE STUDIES

Three coastal urban scenarios that are representative of the Brazilian coastline facing the impacts from the rising sea levels will be presented. The analyses will be wide-ranging and qualitative, and will consider the risks and the potential losses that the areas in question may be subjected to before 2030.
The cities selected were Recife (Pernambuco), Rio de Janeiro (RJ) and Itajaí (Santa Caterina) due to their regional importance, urban density, port area equipment and geomorphologic representation.

4.1 RIO DE JANEIRO

The coastal strip analysed extends from Itacurussá in the Sepetiba Bay to Macaé on the northeast coast of Rio de Janeiro state due to its economic and social importance.

Within the strip of coastline under analysis there are oil and mineral terminals, multifunctional ports (Sepetiba, Rio de Janeiro, Forno) in addition to the forecast installation of other port units, heavy industries, shipyards, sea outfalls and innumerable towns and cities with high rates of conurbation.

Geographically speaking, the area under study may be divided into two stretches, called the east coast (Macaé to Cabo Frio) and the south coast (Rosman et al, 2009). In oceanographic terms, it is possible to observe differences between these two coasts, bearing in mind the dynamic aspects (waves and currents) and the transport of sediments. Accordingly, the aspect of exposure, one of the elements of the triad that comprise the impact risk, becomes variable due to the situation of the coastline considering existing oceanic onslaughts.

The aspect of vulnerability, another variable in the impact risk triad, will fundamentally depend on the relief, both onshore and offshore, the geological characteristics of the coast and the composition of the coastal biodiversity.

Considering these aspects of exposure and vulnerability, it is possible to subdivide the coastline into six stretches according to Rosman et al (2009). These are:

Stretch a) The bay from Macaé to Búzios;
Stretch b) The bay between Búzios and Ilha de Cabo Frio;
Stretch c) Região dos Lagos, between Arraial do Cabo and Niterói;
Stretch d) The Guanabara bay, including Baixada Fluminense municipalities;
Stretch e) Baixada de Jacarepaguá, from Ipanema to the Pedra de Guaratiba;
Stretch f) Sepetiba Bay.

Figure 5 shows the location of the stretches and respective subdivisions.

Figure 5: Coastline of Rio de Janeiro and its six sectors analysed
Source: CIDE, 2004

Considering the six stretches, the exposure aspect may be ranked in six levels (1-6) where the most exposed stretch will have the highest value – 6. In terms of exposure to the rise in sea level, the stretch of coastline most exposed is Região dos Lagos (c), followed by Baixada de Jacarepaguá (e) and Búzios to Ilha de Cabo Frio (b). Due to the protection of the rocky Búzios peninsular, the bay between Macaé and Búzios (a), together with the shores of the Guanabara Bay (d) and Sepetiba (f) that are protected in internal waters, all have much lower levels of exposure.

As for the vulnerability aspect, Baixada de Jacarepaguá followed by Sepetiba Bay and Guanabara Bay are those with highest risk. This is due to the extensive low areas with smooth declivity, being densely populated and urbanized, in addition to their geological composition and sedimentary nature. The coast of the Região dos Lagos, the stretch between Macaé and Búzios, and principally between Búzios and the Ilha de Cabo Frio demonstrate the lowest levels of vulnerability due to their geological characteristics (crystalline outcropping), low populations and large quantities of sediment that provide equilibrium to the beach line.

As for the threat aspect, this has a regional nature and will be analysed in comparison with the other cities considered in the present study. For the State of Rio de Janeiro region, the threat of a cyclone passing directly through it is less than for the southern region, as for example Itajaí in Santa Catarina. Nevertheless, meteorological tides provoked by the passing of cold fronts that already reach excess heights to the order of 60 centimetres are frequent and common in the State of Rio de Janeiro, principally in stretches c, d and e. This is due to the East-west alignment of the south Fluminense coast, which receives the direct impact from the penetration trajectory of the cold fronts (southeast) that stack the oceanic waters meeting off the Fluminense coast.

The tendency is for an increase in intensity and frequency of the cold fronts entering from the southeast in the coming years, due to the higher availability of energy to be dissipated from the heat absorbed by the greenhouse effect. This represents the greatest threat, which, taken together with the greatest exposure, means that the south Fluminense coast has a far more worrying scenario than the east coast.

For the purpose of a comparative analysis in terms of threat, the southern region (Itajaí, SC) is that with the greater tendency to receive extreme events (cyclones and storm tides) that start to give potential to the rises in sea levels. This is followed by the Southeast region (Rio de Janeiro-RJ) in the occurrences of frequent meteorological tides and storm tides. Lastly, there is the Northeast region of Recife-PE, which in qualitative terms suffers the least potential greenhouse-effect threat in terms of regional rising sea levels. Accordingly, the comparative values for the threat factor that will be considered are 5 or 6 (greatest threat) for the southern region, 3 or 4 (medium threat) for the Southeast region, and 1 or 2 (least threat) for the Northeast region.

Table 1 represents a comparative analysis of the risk for the Fluminense coast in question (local). In the same way, regional aspects are also considered because, in terms of threat, three cities from the Brazilian coastline (Recife, Rio de Janeiro and Itajaí) are being compared given that they have wide-ranging, or regional, characteristics.
Table 1 demonstrates both qualitatively and comparatively the risk potential that the rises in sea level could bring to the Fluminense coast. The analysis considers the risk aspects (threat, vulnerability and exposure) and the demand for insurance protection. It provides a ranking of market potential for services and the demand for insurance to confront the rise in sea level on the Fluminense coast over the coming decades.

For the question of demand, the economic value of man-made works was considered on a comparative basis (1 to 6), which, when multiplied by the risk, also supplies the conceptual ranking for priority.

Rio de Janeiro coastline	A. Threats	B. Exposure	C. Vulnerability	Risk = A x B x C	Ranking of risk	D. Economic value	Demand = D x Risk	Ranking for demand	Market priority
Stretch a) Macaé to Búzios	3	3	2	18	4°	3	54	4°	B
Stretch b) Búzios and Ilha de Cabo Frio	3	4	1	12	6°	2	24	6°	C
Stretch c) Região dos Lagos	3	6	3	54	2°	1	54	5°	C
Stretch d) Guanabara Bay	3	2	4	24	3°	6	144	2°	A
Stretch e) Baixada de Jacarepaguá	3	5	6	90	1°	4	360	1°	A
Stretch f) Sepetiba Bay	3	1	5	15	5°	5	75	3°	B

Table 1: Risk and demand concept for stretches of the Fluminense coastline

4.2 SANTA CATARINA

Because of the morphological features on the Santa Catarina coastline, it may be divided into four distinct segments (Rosman et al, 2009), as follows:

Stretch a) Adjusted coastal area from the north to the Costa de Barreiras (from Passos de Torres to Cabo de Santa Marta).
Stretch b) Coastal plains area of Santa Catarina or coast with scattered rocky promontories and barriers (Cabo Santa Marta to Ilha do Papagaio).
Stretch c) Crystalline escarpment area from the south or coastal plains and rocky promontories (from Ilha dos Papagaios to Ponta do Vigia).
Stretch d) Coastal plains and estuary area (from Ponta do Vigia to Ilha de São Francisco).

Figure 6 shows the morphological divisions considered for the Santa Catarina coast.

Figure 6: Santa Catarina coastline and its four principal sectors. The shaded area in the figure represents Quaternary deposits (Pleistocene and Holocene) according to Horn Filho et al. (1994). Source: Rosman et al, 2009.

Stretch *a* is a sector with a rectilinear coastline, contrasting with the remainder of the Santa Catarina coast, which is interspaced with indentations. This shore is characterized by the presence of sandy crests skirted by lagoons (Rosman, 2009).

Stretch *b* has rocky promontories and curvilinear barriers. There are lagoon systems of various sizes in this stretch that connect to the ocean via small tidal canals (Rosman, 2009)

The port of Itajaí lies within stretch *c*, which is characterized by countless promontories, indentations and estuaries, providing sheltered bodies of water, thereby providing good port facilities.

Stretch *d* provides a coastline with an abundant supply of sediments providing the presence of frontal dunes spreading between the estuary systems (Rosman, 2009). The great quantity of sediments provides protection and maintenance for the coastline against any extreme events coming from the ocean.

As far as threats are concerned, and as previously discussed, when compared to Rio de Janeiro and Pernambuco, the Santa Catarina coastline received a score of 5 or 6 because there are real chances of cyclones passing through this region.

Since there are four distinct sectors in morphological terms, the values for vulnerability considered will be from 1 to 4, given that 1 indicates least vulnerability and 4 indicates the greatest vulnerability.

Stretch *a* will be considered the most vulnerable coastal feature (4) because it basically comprises sedimentary deposits without the presence of crystalline promontories.

In stretch *b* the existence of countless rocky promontories provides more effective protection for the coastline. These function as true markers in the establishment of the beach curves. This sector is considered vulnerable at level 2.

Stretch *c* will be considered the least vulnerable (1) due to the greatest presence of rocky promontories. The Santa Catarina Island is a crystalline barrier that protects the coast.

Finally, stretch *d* will take the classification 3 for vulnerability in comparison with the other sectors of the Santa Catarina coastline.

As for the exposure aspect, stretch a will be considered as having the greatest degree (4), while stretch *b* slightly less (3), for the historical reason that Cyclone Catarina passed through the region on 27/03/04. Stretches *c* and *d* will be considered as having exposure levels 2 and 1 respectively.

In terms of economic value, stretch *d* includes the port city São Francisco do Sul, which is responsible for the outflow of a large part of the industrial production, grains and mineral ores from the state. Accordingly, it will be considered level 4. On the other hand, stretch *a*, that runs from Torres to Cabo de Santa Marta, will be attributed the value 1 because there are very few relevant man-made installations there.

Stretch *c* will be awarded the economic value 3 because it has important cities such as Florianópolis, Camboriú and Itajaí.

Accordingly, the value 2 remains for stretch *b* in the question of economic value attributed.

The results obtained from Table 2 furnish high priority for stretch *a* despite the fact that it shows a markedly lower level of economic and social development relative to the other stretches, and is considered of less interest in the potential for adaptation services to confront the rising sea levels. It is recommended to concentrate the attention and efforts to meet the demands of sections *b* and *d*, given that they present final values much closer and higher, indicating that there is a true potential for business.

Santa Catarina coastline	A. Threats	B. Exposure	C. Vulnerability	Risk = A x B x C	Ranking of risk	D. Economic value	Demand = D x Risk	Ranking for demand	Market priority
Stretch a) Torres to Cabo de Sta. Marta	5	4	4	80	1°	1	80	1°	A
Stretch b) C. de Sta. Marta to I. Papagaio	5	3	2	30	2°	2	60	3°	A
Stretch c) I. Papagaio to Pta. Do Vigia	5	2	1	10	4°	3	30	4°	B
Stretch d) Pta. Do Vigia to I. S. Francisco	5	1	3	15	3°	4	60	2°	A

Table 2 Risk and demand concept for stretches of the Santa Catarina coastline

4.3 PERNAMBUCO

The seashore from the metropolitan region of Recife was chosen as the study area for the consequences of the rise in sea level due to climatic changes.
The vulnerability of this study area is basically due to three factors (Rosman et al, 2009):

a) High concentration of tall buildings and urban works close to the coastline (84% of the buildings in the strip 30 m from the shoreline);

b) Reduced average altitudes (between 2m and 4m) which characterize the implantation of urban areas on coastal plains where the drainage is a disconcerting factor;

c) Inappropriate human occupation that has, as a consequence, a chronic and increasing erosion problem along the coastline.

The metropolitan region of Recife incorporates the coastal strip including the municipalities of Jaboatão dos Guararapes to the south and Recife, Olinda and Paulista to the north.

The extent of the coastline studied is to the order of 47 km, comprising the rivers and estuaries. This extends over a sedimentary plain with an average altitude of around 4m (Rosman et al, 2009). We are dealing with the most densely populated area affected by mankind on the Pernambuco coast.

In the study area, the adjacent Jaboatão-Pirapama estuary system, the Pina Basin and the confluence of the rivers Capibaribe – Beberibe (Recife), the drainage area of the Paratibe river (limited from Olinda to Paulista) and the estuary of the Timbó (Paulista) river are highlighted (Rosman et al, 2009).

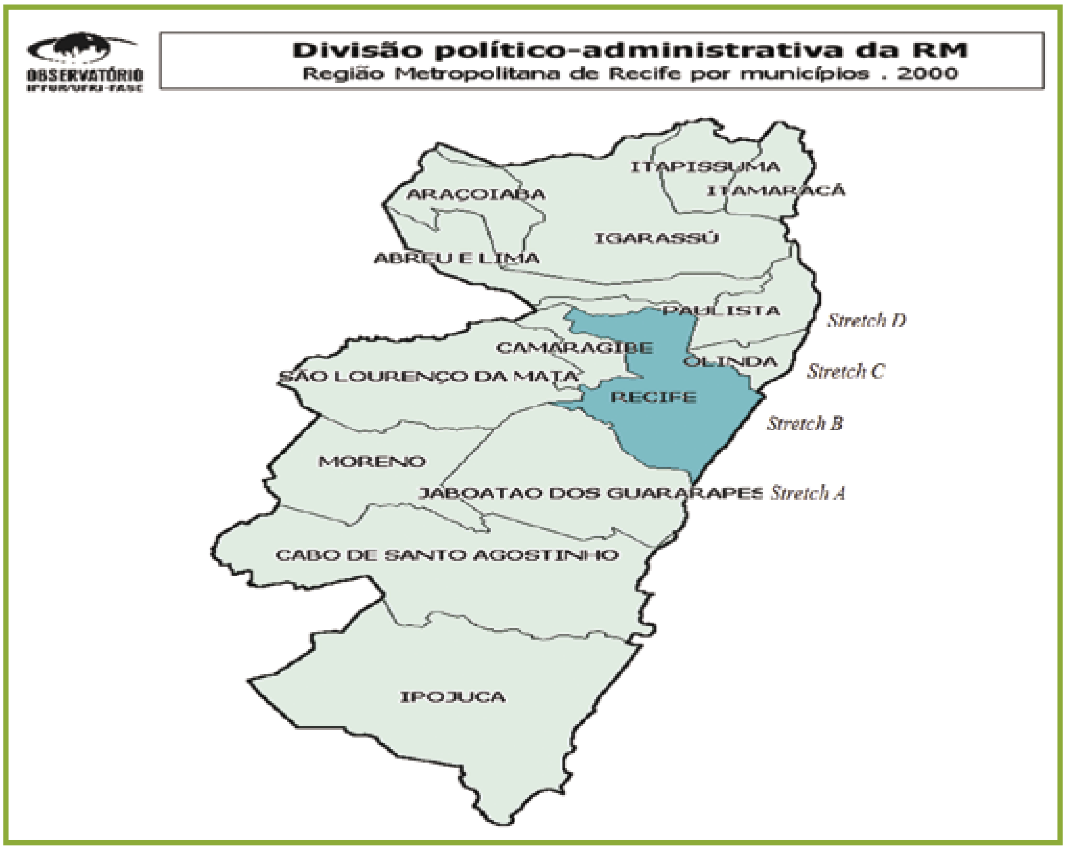


Figure 7: Pernambuco coastline and its stretches analysed
Source: Observatório de Políticas Urbanas e Gestão Municipal. IPPUR/UFRJ-FASE, 2002
Metrodata Team: Henrique Rezende, Paulo Renato Azevedo, Peterson Leal.

The areas previously described deal with zones of coastal plains with a high probability of suffering flooding following rises in the level of the sea.

The metropolitan centre of Recife is highlighted as one of the Brazilian coastal cities most vulnerable to any rises in the level of the sea; 81.8% of the urban constructions are within 30 m of the coastline (Rosman et al, 2009).

In Olinda, the situation is even more serious, because 59% of its coastline no longer has a recreational beach due to the intense erosion processes (Rosman et al, 2009).

The absence of a beach due to the approximation of the urban infrastructure represents the loss of the first line of the continent's defence against the destructive oceanic onslaught.

For the purpose of analysis, four stretches will be considered as follows:

Stretch a: Municipality of Jaboatão dos Guararapes
Stretch b: Municipality of Recife
Stretch c: Municipality of Olinda
Stretch d: Municipality of Paulista

Figure 7 presents the municipalities of the Recife Metropolitan Region

Within the same criteria for analysis contemplated for Rio de Janeiro and Santa Catarina, the aspects of threat, exposure, vulnerability and economic value will be approached.

For the question of threats, they are considered to be homogeneous for all the municipalities and will be awarded the value 2.

As for exposure, the coastlines of the municipalities in question have the same direction and therefore the same exposure characteristics. A value of 4 will be conferred on a scale of 1 to 5 for all municipalities, because they are all frontally exposed to the open sea.

The classification, in decreasing order of vulnerability as to the direct impact of oceanic onslaughts and areas subject to flooding following rises in sea level, was conferred as follows (Rosman et al, 2009):

a) Olinda (4) presents the most critical vulnerability scenario because 59% of its coastline no longer has a recreational beach, and the integrity of the urban works depends purely on the maintenance capacity;

b) Paulista (3) has 70% of its coastline committed and has high vulnerability despite having a lower population density;

c) The Jaboatão – Pirapama estuary system is subject to flooding and 56% of the coastline in the municipality of Jaboatão dos Guararapes (2) demonstrates higher vulnerability than Recife.

d) Recife (1) is vulnerable to flooding in the confluence of the rivers Capibaribe – Beberibe, where the port of Recife is located and 29% of its coastline is characterized as highly vulnerable to attacks from the sea.

As affects vulnerability, the municipality of Olinda, without the first barrier of defence (the beaches), has become the most vulnerable being given a grade 4 on a scale of 1 to 4. The low coastal declivity in the municipalities of Paulista and Jaboatão dos Guararapes, are factors giving potential to the vulnerability of these municipalities in addition to the coastal erosion, and values of 3 and 2 have been conferred respectively. Accordingly, for the purposes of comparison, the municipality of Recife will be awarded the value of 1.

The port of Recife, the banks of the rivers Capibaribe and Beberibe, move 2.2 million tons of solid bulk each year, including barilla. Recife also has the port of Suape with 8 million tons of product outflow each year. Added to a population of approximately 1,560,000 inhabitants (IBGE, 2007) and GDP of R$18.32 billion (IBGE, 2005), the municipality of Recife will be awarded the maximum economic value of (4) relative to the other municipalities analysed.

Jaboatão dos Guararapes, with a population to the order of 688,000 inhabitants (IBGE, 2007), constitutes the second largest nucleus of urban density in the region with GDP to the order of R$4.07 billion (IBGE, 2005). Jaboatão will be classified at level 3 for the purpose of economic value comparison.

Olinda, with a population of approximately 397,000 inhabitants, GDP of R$1.94 billion and world renown for historical and cultural heritage, will be considered in third place in terms of economic importance with an index of 2. Accordingly, Paulista (1) will be given the least economic value grade, comparatively speaking.

It may be seen from Table 3 that the stretch including Olinda has the highest priority for the demand of adaptation services against the effects of the rising sea level. Then follow Jaboatão dos Guararapes and Recife due to the high density of constructions.

Pernambuco coastline	A. Threats	B. Exposure	C. Vulnerability	Risk = A x B x C	Ranking of risk	D. Economic value	Demand = D x Risk	Ranking for demand	Market priority
Stretch a) Jaboatão dos Guararapes	2	4	2	16	3°	3	48	2°	B
Stretch b) Recife	2	4	1	8	4°	4	32	3°	B
Stretch c) Olinda	2	4	4	32	1°	2	64	1°	A
Stretch d) Paulista	2	4	3	24	2°	1	24	4°	C

Table 3 Risk and demand concept for stretches of the Pernambuco coastline

5. COASTAL ADAPTABILITY

Adaptation is the response offered to the potential impacts arising from climate changes with a view to mitigating any possible damage, in addition to making the most of possible opportunities.

Based on the concept of risk, the best strategy for adaptation would be to encourage a reduction in the vulnerability and exposure, in addition to monitoring the progress of the threat over time. All of these factors (vulnerability, exposure and threat) vary due to geographic location and time. As for the vulnerability factor, this depends on the interference of mankind, given that any urban expansion on the coast makes it more fragile. By the same token, the exposure factor can, for example, alter over time due to the angle of penetration of the waves. The direction of the incidence of high-energy waves in the mouth of the Guanabara Bay has altered in recent years. Previously, the predominant direction of the higher-energy waves was from the southeast, nevertheless the increasing incidence of wave formations emanating from the south and southeast has provoked problems for navigation and destructive impacts on the turning area of the Santos Dumont Airport runway.

Despite being reality, the rising sea level (RSL) is not homogenous and varies in accordance with local characteristics (oceanographic, meteorological and geomorphologic conditions).

Adaptability in the coastal area could be developed by adopting either proactive or reactive policies. Naturally, the proactive measures are much more economical and effective than the reactive measures, although they are not always possible due to lack of planning, investment capacity or the prevailing public opinion as to the RSL risks.
The directing of the monitoring efforts and the accompaniment of the evolution in risks and effects of the RSLs along the high visibility coastal cities, such as Rio de Janeiro, Recife and Itajaí, would advance increased divulgation, in addition to moulding public opinion more favorable to prevention. One of the important aspects of prevention is the arrangement of insurance by the private sector, which would in turn stimulate the development of measures by the public sector to combat the coastal vulnerability.

Among the preventive measures to increase coastal protection are cited (Tal et al, 2008):

a) Increase the demands on criteria for sizing urban infrastructure;
b) Increase flexibility in vulnerable urban systems (e.g. change of location, reductions of useful life, etc.);
c) More proactive criteria for the use of coastal land (e.g. definition of strip *non aedificandi*).
d) Intensify social communication aiming at participation and awareness of the potential local RSL risks.

Proactive adaptation measures are actions undertaken before the impacts, whereas reactive adaptation actions are those carried out due to the impacts of RSLs. In natural coastal areas, adaptation has a reactive nature, but on the other hand, in those coastal areas affected by mankind, interventions tend to have both proactive and reactive characteristics (Tal et al, 2008). The greater the communication and consequent participation of society, the greater will be the pressure for interventions by the public authorities.

Table 4 seeks to exemplify the principal types of adaptation and their classification (Table adapted from Tal et al, 2008).

Areas		Proactive Adaptations	Reactive Adaptations
Natural		Do not occur	Alteration of vegetal cover. Migration and/or recuperation of damp areas Creation of natural protection areas.
Urban	**Private sector**	Arrange insurance. Be more flexible in construction projects. Alteration of industrial and port projects.	Alteration of insurance premiums. Modification to economic use of the coastline. Development of new services and technologies to confront rsl.
Urban	**Public sector**	Contingency plans. Monitoring programme. Alter construction specifications; Alter technical norms. Alter plans for urban land use. Coastal macrozoning.	Subsidies and compensation measures. Building of coastal protection structures. Beach widening. Construction of sea walls and barriers. Reinforcement and reconstruction of Urban infrastructure.

Table 4: Summary of the principle actions to RSLs in adapting the coastal zones

6. SOCIAL MOBILIZATION

Effective environmental solutions necessarily pass through the phase of social approval and participation. Political articulation will always be an important factor in the transformation of society and in overcoming collective challenges.

Nevertheless, it is necessary to recognize that social mobilization requires wide-range planning that considers thematic priorities, time limits, investments and principally a strategy to stimulate the self-sustainability of the process once it has begun.

Adaptation of the urbanized coastal zones, in an efficacious and rapid manner, against the rising sea levels (RSLs), depends on the effective participation of the society that will be benefitted by the planned interventions. Society only participates if it recognizes the potential impacts of the RSLs, identifies the vulnerability, perceives the threats and recognizes the available means of combat. This list of information should be made available for public information aiming at forming public opinion as close to reality and local necessities as possible.

The principal communication agents and public opinion formers are the environmentalists, NGOs, professors, researchers and journalists specialized in the specific environmental theme.

The principal monitors of environmental alterations in the coastal zone are the fishing community, surfers, fire brigade, life guards, coastal inhabitants and researchers who study or enjoy the sea shore.

It is natural that the beginning of any actions in socially high profile cities, such as Rio de Janeiro, Salvador, Florianópolis or Fortaleza would raise the potential to communicate information and concern as to the consequences of RSLs.

Actions that promote greater visibility for the problem cause the diffusion of knowledge within society. Among the most relevant actions are:

a) Spontaneous media, through press officers scheduling the mass communication vehicles, such as TV and the newspapers;

b) Debates and cycles of talks sponsored by newspapers, magazines and companies;

c) TV programs debating with and interviewing researchers and environmental leaders;

d) Leaders of communities, collective groups, and politicians calling attention to the problem;

e) Parliamentary advisors with the objective of promoting new norms, legislation or pronouncements aimed at bringing forward preventive planning actions and restrictions to bad use of urban land;

f) Identification and strengthening of NGOs and collective groups, civil associations, yacht clubs, port systems, and research and teaching centres that work directly with the question of RSLs.

Finally, there must be an entity that coordinates and stimulates actions on an integrated basis, in addition to promoting, monitoring and evaluating the results of the social mobilization along the Brazilian coastline.

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Credits

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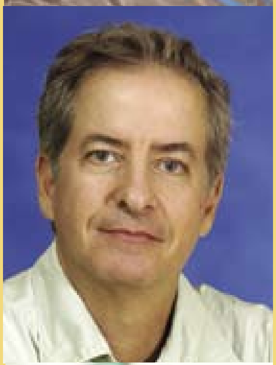

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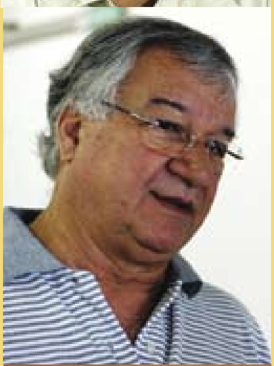

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