N & NE Brazil

Contents

General Climate

North and northeast Brazil experiences a largely semi-arid climate, which is characterised by a wet season that occurs between January and June and a dry season that accounts for the rest of the year, July to December (Silva, 2004). Rainfall is driven predominantly by the movement of the tropical rain belt (also known as the Inter-Tropical Conversion Zone, or ITCZ), which reaches its most southernmost position between February and May (Harzallah *et al.*, 1996). Variations in its movements can cause large variations in the rainfall received from one year to the next. Rainfall occurs primarily between March and May (MAM), with annual rainfall totals varying from around 1800mm at the hot and humid coast to 400mm in the hot and day centre of the region (ibid). Annual temperatures average between 20 and 27°C and the region experiences high levels of evapotranspiration (up to 10mm/day), and combined with highly variable rainfall (both spatially and temporally), drought is a major problem (Silva, 2004).

In addition the ITCZ, rainfall in the region is also influenced by southern cold fronts, upper air cyclonic vortices known as cold lows, land-sea breeze systems, the position and intensity of the South Atlantic Convergence Zone (SACZ), and the Madden-Julian Oscillation (Harzallah *et al.*, 1996). These systems act differently and their timing, structure and intensity all have an influence on the region's rainfall episodes (ibid).

Rainfall in Brazil is highly correlated with seas surface temperatures in the tropical Pacific and Atlantic Oceans (Harzallah *et al.*, 1996) and is therefore affected by the El Niño-Southern Oscillation (ENSO). The warm phase of ENSO, known as El Niño, is associated with periods of drought in the region (e.g. March to December 1972), while ENSO's cold phase, La Niña, brings periods of heavy rain in the North (e.g. May and September to October 1989 respectively) (Glantz, 2001).

Key climate vulnerabilities: Drought; food security; energy security; biodiversity loss; flooding.

Observed Climate Changes

A general warming trend of around 0.25°C per decade has been observed recently in lowland tropical areas (Mahli & Wright, 2004). The general trend in precipitation is less certain; however, there has been an increase in dry events observed over southern Amazonia between 1920 and 1999 (Li *et al.*, 2008) (See Figure 1).

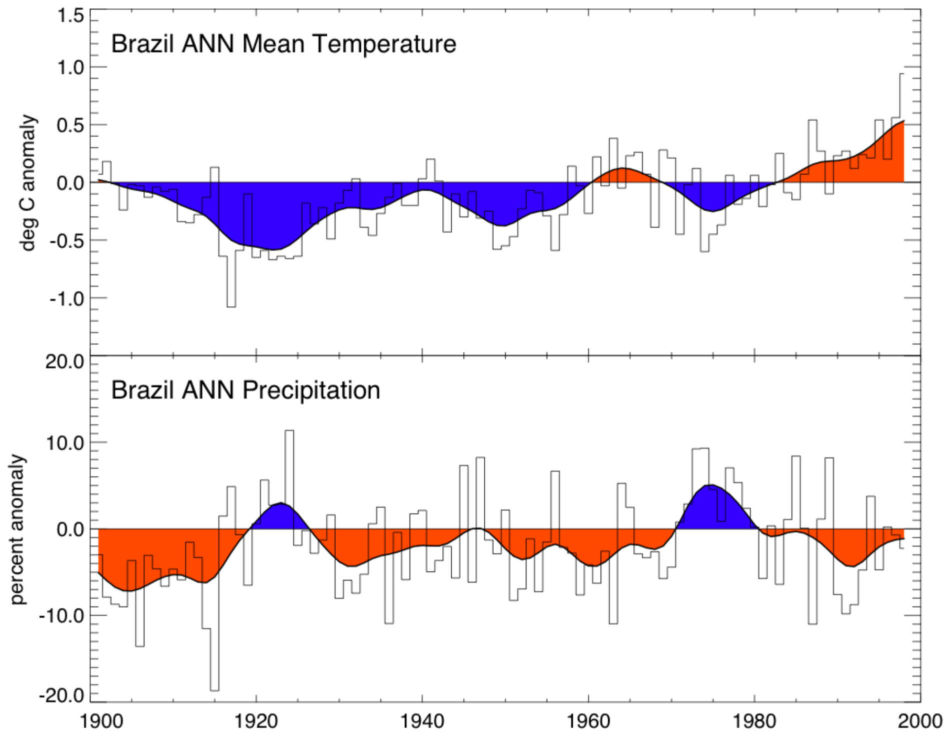

Figure 1 – Changes in annual mean temperature, 1901-1998 (top), and annual rainfall, 1901-1998 (bottom), across Brazil, respect to the average 1961-90 climate values of 25.0ºC and 1780mm respectively (Hulme & Sheard, 1999).

Current Climate Vulnerability

Table 1 lists the natural hazards that have affected Brazil (as a whole) over the past 20 years. Insufficient and unreliable rain is a huge problem in northeast Brazil, particularly in rural areas where there is not sufficient capacity for support in drought years (Krol *et al.*, 2006). The regions of Ceará and Piauí, for example, are semi-arid areas that receive around 500-900 mm of rainfall per year, but experience evaporation of around 2000 mm/year (ibid). With crystalline bedrock geology, rivers in these regions are intermittent and suffer from frequent drought – often the result of El Niño events, which can cause a devastating effect on water resources in north-eastern Brazil (ibid). An El Niño in 1877-79, for example, brought a widespread drought and the resulting famine caused 500,000 deaths in the region – 4 percent of Brazil's population at the time (Lemos, 2003). More recently, a drought in 1979-1983 affected 18 million people and cost approximately US$1.8 million in emergency programmes (ibid).

Flooding is also a major problem for northern and northeastern areas of Brazil; floods in the states of Alagoas and Pernambuco in June 2010, for example, killed at least 38 people and left approximately 97,000 homeless (Phillips, 2010). Heavy rainfall and flooding also directly causes landslides, which causes loss of life and destruction to homes and transport infrastructure.

Hazard	Number of Events	Deaths	Total of Population Affected
Drought	7	-	12,000,000
Average per event		-	1,714,286

Hazard	Number of Events	Deaths	Total of Population Affected
Earthquake	1	1	286
Average per event		1	286
Epidemic (unspecified)	1	3	235
Average per event		3	235
Epidemic (bacterial)	2	196	15,616
Average per event		98	7,808
Epidemic (viral)	7	218	959,373
Average per event		31	137,053
Extreme Cold Event	3	7	-
Average per event		2	-
Flood (unspecified)	9	112	84,000
Average per event		12	9,333
Flood (flash)	4	128	205,026
Average per event		32	51,257
Flood (general)	39	1,059	4,361,422
Average per event		27	111,831
Landslide	13	540	159,444
Average per event		42	12,265
Storm (unspecified)	7	25	10,384
Average per event		4	1,483
Storm (tropical cyclone)	1	4	150,060
Average per event		4	150,060
Forest Fire	2	1	12,000
Average per event		1	6,000

Table 1 – Natural Hazards in Brazil (as a whole, not just N & NE) (1991-2010) (CRED, 2010)

Climate Change Projections

Annual Temperature

Brazil is likely to warm more slowly than the global average. Temperature increases will be more substantial during the drier JJA season (0.2-0.6°C per decade) than the wetter DJF season (0.1-0.4°C per decade). Figure 1 shows projections under a high emissions scenario for the 2050s, by which time, JJA temperatures are projected to have risen by 2.4 to 5.2 °C across northern Brazil. (Hulme & Sheard, 1999). Warming is likely to be more rapid over the Amazon rainforest compared to the south-eastern coastal areas.

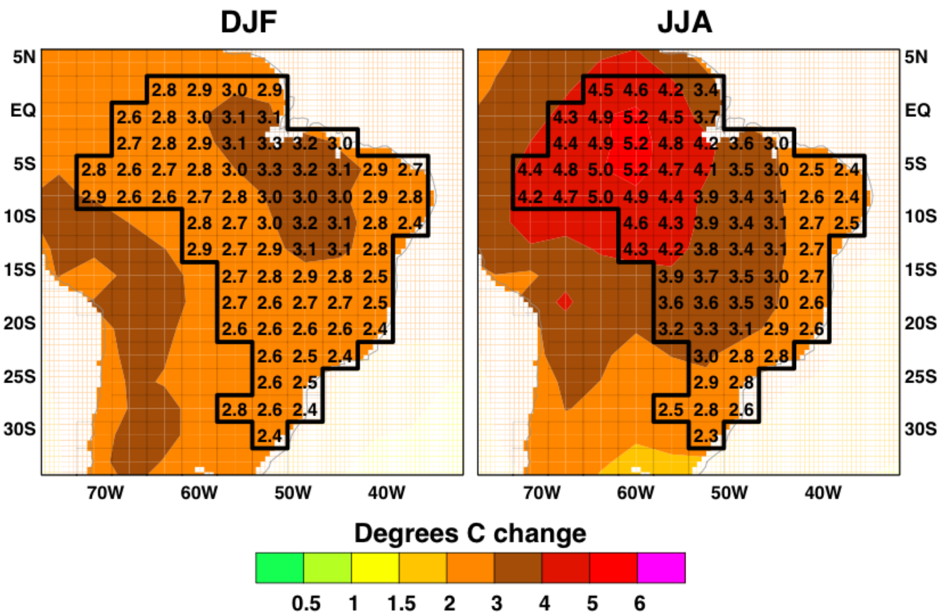

Figure 2: Change in mean annual temperature (deg Celsius from the average 1961-90 climate) for the 2050s, for December-January-February, or 'DJF' (left) and June-July-August, or 'JJA' (right), for the 'A2' SRES scenario (see Nakićenović & Swart (2000) for more details on emission scenarios). The printed numbers show the estimated change for each land gridbox over Brazil (Hulme & Sheard, 1999).

Annual Precipitation

In general, model projections show a drying trend for northern areas (see Figure 2), particularly during the MAM season for inland areas. The most easterly part of Brazil meanwhile will experience differing trends – becoming wetter between December and May and becoming drier from June to November (Hulme & Sheard, 1999). The Amazon delta has the largest drying trend and the southern state of Rio Grande has the largest wetting trend (ibid).

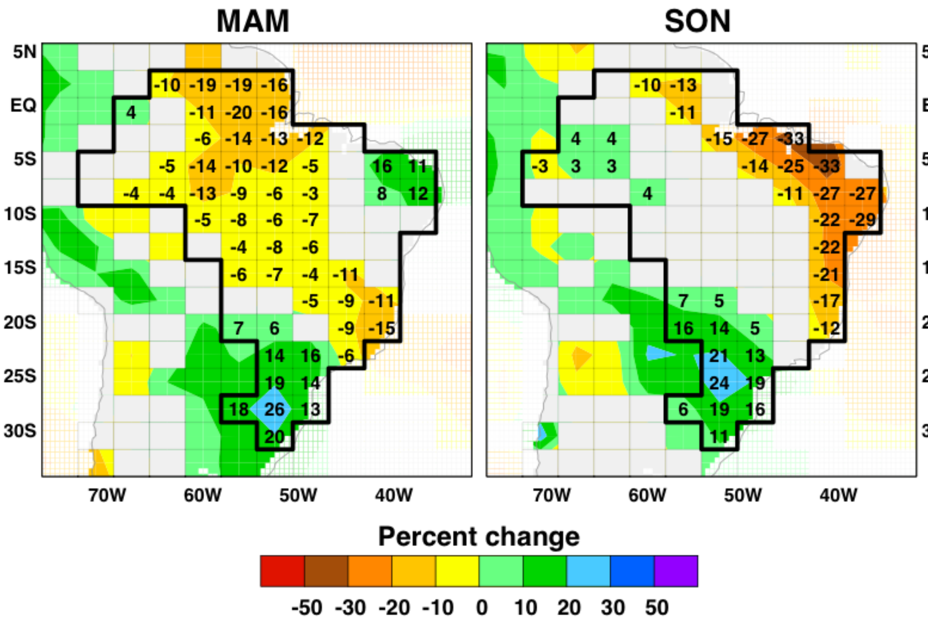

Figure 3: Change in mean annual precipitation (% from the average 1961-90 climate) for the 2050s, for March-April-May, or 'MAM' (left) and September-October-November, or 'SON' (right), for the 'A2' SRES scenario (see Nakićenović & Swart (2000) for more details on emission scenarios). The printed numbers show the estimated change for each land gridbox over Brazil (Hulme & Sheard, 1999).

Sea Level Rise

Sea level rise projections are taken from the Intergovernmental Panel on Climate Change 4th Assessment Report (IPCC AR4)[1]; projections are given as a range (lower and upper bounds) for the 2090s:

- Low scenario: 0.23 to 0.43m
- Medium scenario: 0.26 to 0.53m
- High scenario: 0.28 to 0.56m

Climate Change Impacts

Flooding

While projections show a decrease in rainfall totals, the risk of flooding will continue in the region. Rainfall is likely to be more erratic with climate change, and so when rainfall does occur, it is more likely to fall in heavy events. In addition, La Niña events will continue to be a cause of extreme rainfall, although how their strength and frequency may be affected by climate change is not clear.

Water Resources

As highlighted earlier, sparseness of water is a major problem in this region of Brazil. Climate change projections have shown a general warming and drying trend across the northern half of the country, this has the potential to make droughts more common. The potential impact of climate change on ENSO events is not well understood, but a strengthening of El Niño events would cause more regular and more serious droughts for the region.

[1] Taken from the IPCC Working Group I (The Physical Science Basis): Chapter 10 (Global Climate Projections) (Meehl *et al*., 2007). Regional sea level projections are estimated by applying regional adjustments (Fig 10.32, p813) to projected global mean sea level rise from 14 climate models.

Coastal Areas

Sea level rise, combined with increasing intensity of tropical storms, will increase the risk of storm surges in coastal areas (IPCC, 2007).

Mangroves around Brazil's coasts will be at risk from sea-level rise; the IPCC state this is 'very likely' under the worst-case scenario for sea-level rise (IPCC, 2007). Coastal areas of northeast Brazil are also home to an array of stabilised and active sand dunes; these are affected by changing wind patterns, which are in turn affected by precipitation patterns and are therefore also at risk from a general drying trend (Tsoar *et al.*, 2009).

Agriculture & Food Security

Land use in the region consists predominantly of cattle holdings and subsistence farming (Krol *et al.*, 2006). Soils are generally shallow and poor in quality (40-60mm) (Silva, 2004). Main crops include beans, dry rice, cassava, maize and cashew nuts (ibid). A decreasing trend of rainfall and corresponding increase in temperature and evapotranspiration (Mean annual evapotranspiration can exceed 3000mm in semi-arid northeast Brazil (Silva, 2004)) will put increasing pressure of water available for irrigation. Residents currently rely on small reservoirs and interconnecting canals for water for irrigation – there are over 7,000 reservoirs as of the early 21st century in the state of Ceará alone (Tompkins *et al.*, 2008).

Recent advances in the understanding of ENSO now allow some degree of seasonal prediction for impending El Niño events. Droughts in the region were successfully predicted six months in advance in 1986 and 1991 (Lemos *et al.*, 2002).

Public Health

Northern Brazil is affected by malaria – particularly in the Amazon region, and numbers of cases have risen steadily in the last few decades (Hudson, 1997). Other diseases that are common in the region include cholera, American trypanosomiasis, yellow fever, schistosomiasis, and dengue fever, although their prevalence is also a reflection of poor sanitary conditions (ibid). The impact of climate change on mosquito-borne diseases in the region is uncertain – indeed the IPCC reported few disease outbreaks that were climate-driven (McMichael *et al.*, 2003). A general drying trend may reduce the amount of standing water available as breeding habitat, but this will also be affected by changing land use and the heavy rainfall events caused by La Niña.

With increasing pressures on water resources and food security, there will be an increased risk of drought-induced malnutrition that in turn causes increased susceptibility to infection (McMichael *et al.*, 2003).

Housing & Communities

The stress of insufficient water will intensify for northeast Brazil, increasing competition for resources and forcing internal migration. The current population of the region is about 11 million, increasing at a rate of 1.4 percent per year, although this is offset by rural–urban migration that compensates the rural birth excess (Krol *et al.*, 2006). Migration is largely towards urban centres in Brazil's South or to land reclamation areas in the Amazon area, and is strongly driven by drought (ibid).

Biodiversity & Conservation

For Brazil, a substantial aspect of its biodiversity relates to the Amazon rainforest. The rainforest is under threat from cattle ranching, timber extraction, biofuels, settlements, forest fires, and changing climatic conditions. Deforestation causes the loss of millions of hectares of Brazilian Amazonia each year; 1995, for example, saw 2.9 million ha lost – an area the size of Belgium (Laurance, 1998). Climate change will bring an increased risk rainforest being replaced by savannah, and of semi-arid vegetation being replaced by arid (IPCC, 2007). There are several variables that will affect how rainforest copes with a changing climate, such as leaf stomata using water more efficiently under higher atmospheric CO_2 concentration, but also being at risk from increasing transpiration under higher temperatures (Mahli *et al.*, 2009). A study by Mahli *et al.* (2009) found that the a medium-high emissions scenario had a high probability of intensifying dry seasons in the eastern Amazon, and a medium probability of this drying trend being sufficient to change rainforest into seasonal forest. However, vulnerability of the Amazon to dieback is likely to be a function of human activity and response to climate change.

Livelihoods

The economy of north and northeastern Brazil relies predominantly on cattle farming and subsistence farming. Availability of water will continue to put pressure on the both these forms of income; Sanghi & Mendelsohn (2008), for example, found that climate change could cost Brazil's farmers up to US$7 billion annually by the end of the century.

Energy

Brazil relies heavily on renewable energy sources, accounting for 47 percent of all energy produced in 2007, with hydroelectric power the source of 83 percent of electricity produced in 2006 (Lucena *et al*., 2009). Biofuels also form an important source of energy – both for liquid fuels (particularly for transport) but also for electricity generation as well (ibid). Sugarcane is typically very tolerant of high temperatures, and assuming it is sufficiently irrigated, it is unlikely that climate change will negatively affect crop yields (ibid).

The viability of hydropower in the future will depend strongly on flow of water, and hence precipitation. Energy generation varies heavily with the seasons, so the national grid has an important role to play to ensure each region of the country has energy while in drier periods, bringing in energy from regions in a wet season (Schaeffer & Szklo, 2001). However, for the Tocantins–Araguaia Basin that supplies much of the northeast, for example, the projected reduction in rainfall for both the dry and – in particular – the wet seasons will result is less accumulated water in reservoirs and a smaller capacity for electricity generation (Lucena *et al*., 2009). Small-scale hydropower in rural areas will also be affected directly by changes in rainfall. For the regions of north and northeastern Brazil, this will result in a less reliable energy source in conjunction with a general drying trend.

Transport

North and northeastern Brazil will be affected by increasingly erratic rainfall events and associated floods, putting transport infrastructure such as roads, bridges and railway lines at risk from damage.

Government Response

Brazil was the first country to sign the UN Framework Convention on Climate Change (UNFCCC) in 1992, and has also been a strong supporter of the Kyoto Protocol (Puppim de Oliveira, 2008). Brazil receives a substantial amount of international funding through such environmental agreements; for example, it has been a leader in the number of projects within the Clean Development Mechanism (CDM), and is one of the largest receivers of resources through the Global Environment Facility (GEF) (ibid).

As a developing nation (non-Annex 1), Brazil does not have a specific target to reduce carbon emissions within the Kyoto Protocol. Brazil does have a number of initiatives for emission reduction, but these relate more to biofuels and other sub-national climate policies (ibid).

Likely Adaptation Options

- It is likely that existing and newly-planned water storage infrastructure will be come under increasing pressure. Addition to and expansion of current provision for stored water will be required to offset increasing vulnerability of rain-fed and irrigated crops (Krol & Bronstert, 2007).
- Assistance to subsistence farmers in choice of seeds and the best time of year to plant them, as temperature and rainfall changes throughout the growing seasons (Lemos, 2003).
- Promotion of irrigation and efficient use of water resources, including rainwater harvesting and development of small dams and other storage facilities.
- Improvement in drought forecasting and how it is communicated to farmers and other local people.

Useful Websites

- UNDP Climate Change Country Profiles: http://country-profiles.geog.ox.ac.uk/
- UNFCCC NAPAs from Non-Annex I Countries: http://unfccc.int/national_reports/napa/items/2719.php
- UNFCCC First Communications on Climate Change for Non-Annex I Countries: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php
- Adaptation Learning Mechanism: http://www.adaptationlearning.net/
- IPCC Reports: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm

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Note: This profile is designed to give a brief, non-technical overview of the current and future climatic conditions of Brazil. The key climate impacts are summarised by sector; however, this should not be taken as an exhaustive list, and the corresponding list of adaptation options are as a guide of likely or possible strategies.

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Written by Robert McSweeney

Edited by Mike Wiggins and Liu Liu

www.tearfund.org

100 Church Road, Teddington, Middlesex TW11 8QE

0845 355 8355 (ROI: 00 44 845 355 8355) enquiry@tearfund.org

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