# The Impact Of Climate Change On The Brazilian Northeast's Electricity Supply

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***Abstract:***

*By the end of this century higher temperatures and significantly reduced rainfall are projected for the Northeast (NE) region of Brazil due to Global Warming and this will negatively impact the hydroelectric potential in the region. This study examines the impacts of climate change on the Brazilian Northeast's long term hydroelectric and wind energy resources. The hydroelectric output potential in the NE region by the end of this century is estimated by analysing long term rainfall reduction projections as a result of climate change, together with historical rainfall and streamflow data for the São Francisco river basin. Various studies that use a number of different IPCC models are examined in order to estimate the percentage of average rainfall reduction by 2100 in comparison to baseline data from the end of the 20th century. It was found that average annual rainfall in the São Francisco basin could decrease by approximately 25-60% depending on the emissions scenario. Due to the "elasticity factor" between rainfall and streamflow and because of increased amounts of irrigation and evaporation, the average reduction in the São Francisco's streamflow in the coming decades could be almost double the predicted decline in rainfall. Therefore, by 2100 (or decades earlier) the NE's average hydroelectric output could drop by more than 60% in comparison to its average output at the beginning of this century. Conversely, it is estimated that by 2100, wind power potential in the Brazilian NE will more than double the 2001 baseline reference. Additionally, the decline in rainfall projected for the NE region due to climate change could also cause a significant increase in the region's average annual solar radiation levels. Therefore both wind and solar power will need to be significantly exploited in order for the NE region to sustainably replace lost hydroelectric availability.*

**Introdution**

While Brazil overall has the world's largest water resources, Brazil's Northeast (NE) region receives only a fraction of the total annual national rainfall (DE JONG et al, 2013). The interior of the NE region is mostly semi-arid and suffers from frequent droughts, which can also affect the region's hydroelectric power supply. This is because the large majority of the NE's hydroelectric dams are located in the lower middle São Francisco basin (one of the driest regions in the country). The total installed capacity of hydroelectric plants along the course of the São Francisco River is approximately 10,400MW (ANEEL, 2015), as can be observed in figure 1 (RHS). However, as a result of a drought in the region which began in 2012, in 2014, 2015 and 2016, hydroelectricity only generated 38%, 31% and 25%, respectively, of the NE's total electricity demand. The effect of the drought on hydroelectric generation is illustrated in figure 2. In 2014 this shortfall was mostly substituted by fossil fuel thermal power, but more recently wind power in the NE region has replaced lost hydroelectricity. Moreover, in November 2015 the water level in the São Francisco basin fell to only 5% of the total capacity in terms of stored energy (its lowest level since all the dams were completed in 1994) (ONS, 2017). However, higher temperatures and significantly reduced rainfall are predicted for the NE and North regions of Brazil due to Global Warming and these climatic changes will threaten hydroelectricity and biomass production in these regions to an even greater degree. According to Marengo (2008) and Lucena et al (2010) the most vulnerable areas to climate change and climatic extremes in Brazil are the Amazon and the Northeast (NE).

**Background and Materials**

By 2070, temperatures in the interior of the NE are projected to increase approximately 4–5°C and rainfall could decline approximately 25–50% in semi-arid areas of Bahia and up to 80% in coastal areas. This will cause a reduction in streamflow rates of 60–90% for various rivers in the NE (TANAJURA et al 2009). Climate change mitigation will increase the demand for emissions free electricity generation such as the use of more hydropower (SCORAH et al, 2012). However, another effect of climate change is that the hydroelectric potential in the São Francisco basin will be reduced due to more frequent and intense climate induced droughts (DE JONG et al, 2013 & LUCENA et al, 2009). By 2100, rainfall is projected to decrease by 19% in the Amazon, 35% in São Francisco basins and 20% across Brazil as a whole considering the IPCC B2 (≈RCP6.0) emissions scenario (MARENGO et al, 2012). The IPCC A2 (RCP8.5) high emission scenario shows a more alarming reduction in rainfall and temperature increase in the North and NE regions of Brazil which can be observed in figure 3. Considering the A2 high emission scenario, the estimates for 2100 are particularly severe for the eastern Amazon and the NE's semi-arid region, where temperatures are projected to increase up to 8°C and rainfall is projected to drop by 40-60% (MARENGO, 2008 & CPTEC/INPE, 2007). By the end of the century much agricultural land could be severely damaged and desertification will occur in the NE's semi-arid region which could result in water and food shortages, and famine on a massive scale (MARENGO, 2008). Nevertheless, while the majority of the IPCC climate models predict a drastic decrease in rainfall, a few models predict an increase in rainfall in the eastern Amazon and the Northeast region (MARENGO, 2008) which demonstrates that there is a large degree of uncertainty when it comes to predicting long term changes in rainfall patterns. Historical data from 1961-2017 for the spatial average of accumulated monthly rainfall within the São Francisco basin area (see figure 1, LHS) was provided by CPTEC/INPE (Centro de Previsão de Tempo e Estudos Climáticos / Instituto Nacional de Pesquisas Espaciais). This data is compared to monthly streamflow data for the São Francisco River, sourced from the ONS (Operador Nacional do Sistema Elétrico). It can be observed from the linear trend-line in figure 4 that average rainfall and streamflow have already declined by 25% and 33%, respectively, relative to the 1961-90 baseline.

**Results and Conclusion**

The São Francisco basin is already irrigated extensively for agriculture (SILVA, 2004 & CBHSF. 2016) and with the transposition of the river, it is expected that in the future its water resources will be increasingly used for irrigation (MARENGO, 2008). Additionally, more reservoir water may be lost to infiltration and evaporation as a result of lower humidity, more frequent droughts and higher air temperatures predicted for the future. Therefore, relative to any projected decline in average rainfall, the drop in average streamflow is likely to be even more drastic. Saft et al (2015) explain that due to non-linear hydrologic processes, the reduction in streamflow can be magnified 2-3 times relative to the decline in rainfall. This ratio of proportional changes between precipitation and streamflow is known as the elasticity factor and the phenomenon can be observed in figure 4 and 5 during the drought period from 2012-2017. An elasticity factor of 1.71 was estimated for the São Francisco basin considering that the average decline in streamflow each year during the last 4 years of drought was approximately 1.71 time more than the drop in rainfall. Therefore, a future reduction in average rainfall of 35% would see a reduction in streamflow of up to 60%. Furthermore, it is assumed that the NE's annual average hydroelectric production will be roughly proportional to the annual streamflow through the São Francisco basin. Therefore, it is estimated that the projected decline in rainfall of 35% by 2100 could result in a reduction of 60% in the annual average hydroelectric generation from the NE's São Francisco basin.

However, linearly extrapolating historical rainfall data in the São Francisco basin would see a reduction of approximately 34% and 47% by 2030 and 2050, respectively. Assuming an elasticity factor of 1.71, it is estimated that the corresponding reduction in average streamflow would be 58% and 80%, respectively. This means the rainfall projections for 2100 based on IPCC B2 and A2 scenarios could actually eventuate as early as 2030 and 2050, respectively. In summary, the deficits in rainfall and streamflow experienced during the last 4 years of drought could become the norm by 2030.

This loss in electricity generation will be largely supplemented by wind power in the NE region, which is expected to contribute approximately 57% of the NE's electricity by 2020 (DE JONG et al, 2017). Furthermore, by the end of the 21st century the wind energy potential in the region is projected to increase substantially as a result of stronger average wind speeds (LUCENA et al, 2010). Nevertheless, more research needs to be conducted on short term and long term solutions to water shortages which are projected for semi-arid regions. Specific solutions for the NE region might include more efficient water distribution and irrigation techniques, treatment of sewerage for agricultural use, tree intercropping (agroforestry), crop switching, silvopasture, water use education, afforestation and revegetation of riparian zones and reforestation in water source areas.

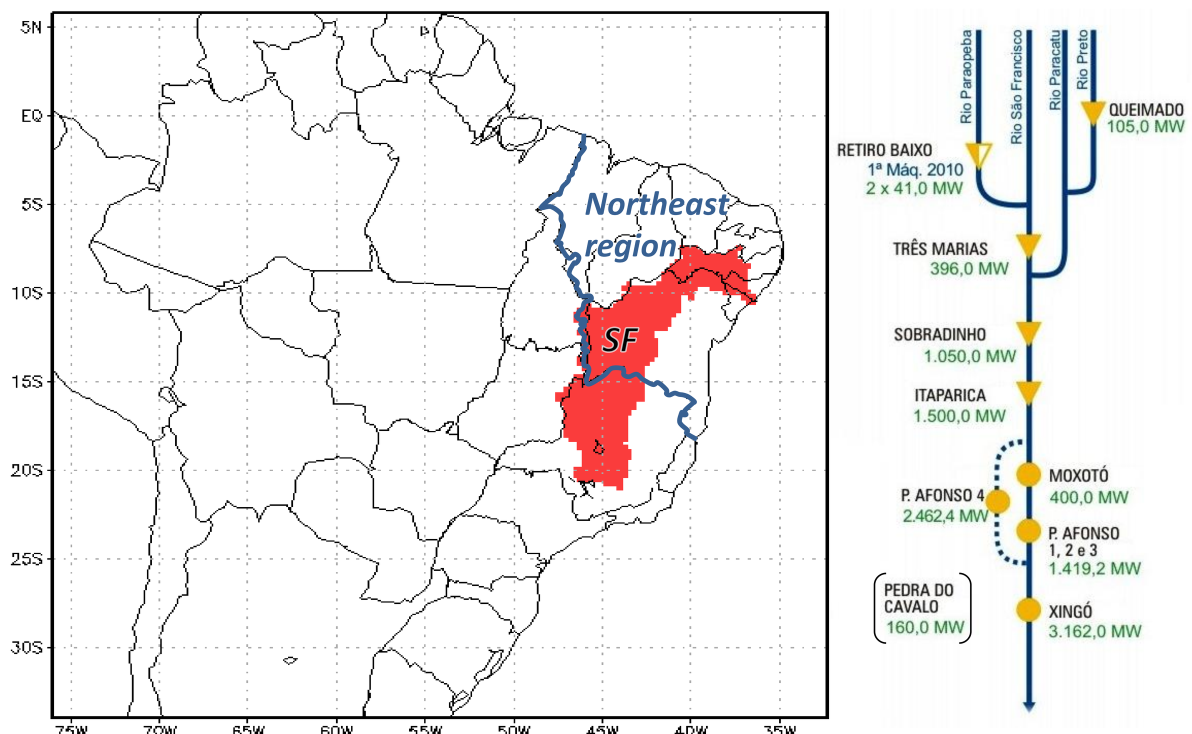


*Figure 1: NE region, São Francisco (SF) River basin (LHS) & schematic of hydroelectric plants (RHS).*

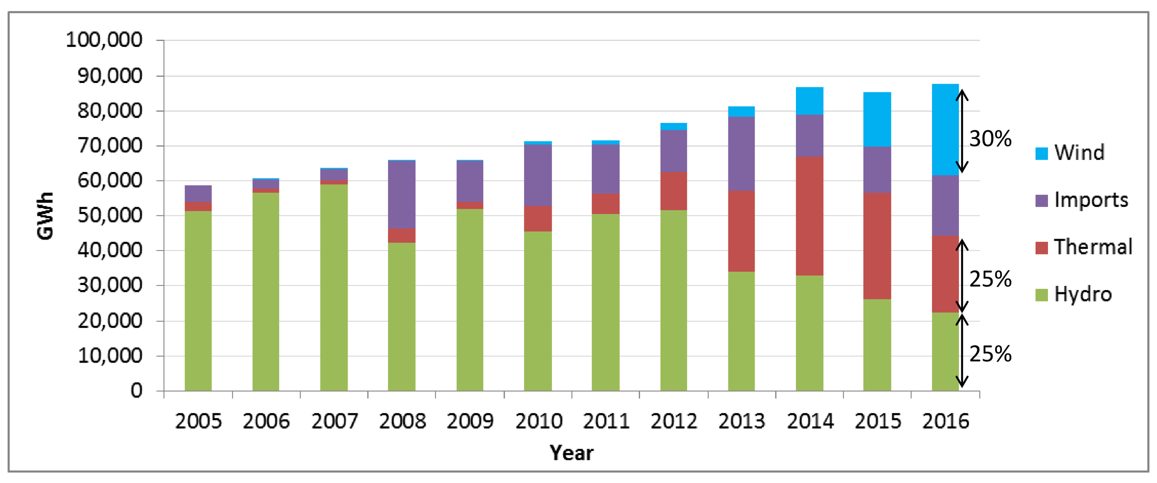


*Figure 2: Sources of the NE's Electricity. From 2005-2007 hydro was responsible for more than 87% of the NE's electricity supply, however, by 2016 this figure dropped to 25%. Source: ONS (2017).*

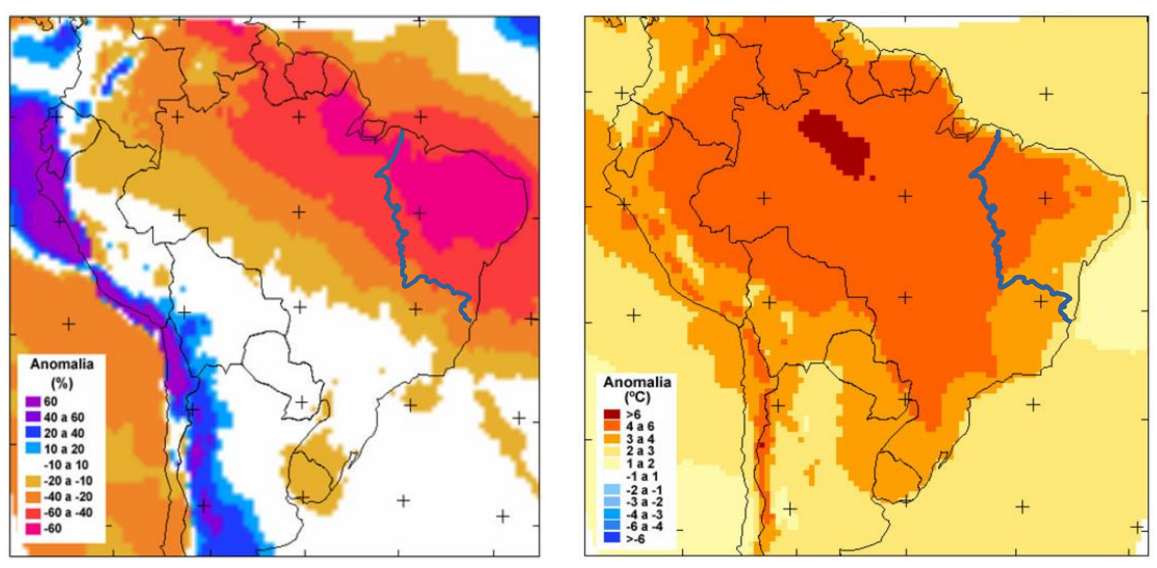

*Figure 3: Projections of annual rainfall (LHS) & temperature (RHS) anomalies for the A2 scenario for 2071-2100 relative to 1961-90. Source: CPTEC / INPE and Ministério do Meio Ambiente (2007).*

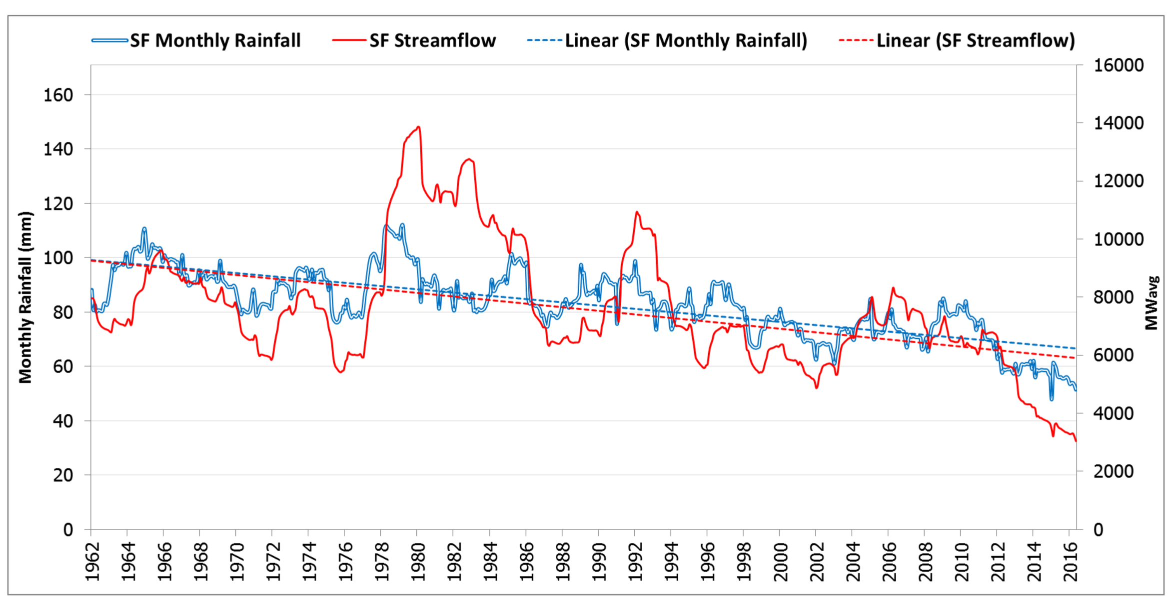


*Figure 4: 2 year rolling average of monthly rainfall (mm) and power/stream flow in the São Francisco (SF) basin from 1961-2017. Sources: CPTEC / INPE (2017) and ONS (2017).*

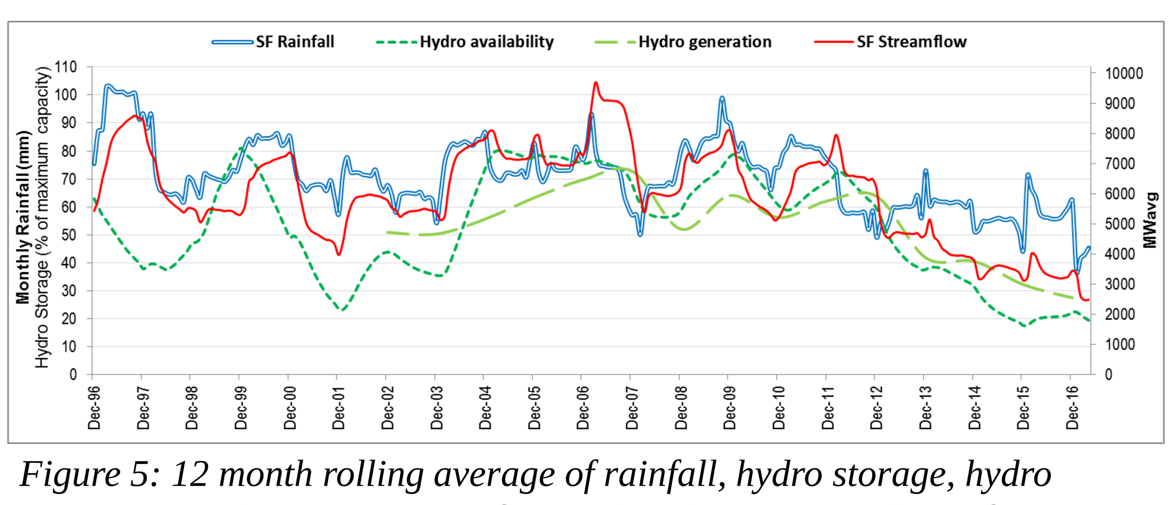


*Figure 5: 12 month rolling average of rainfall, hydro storage, hydro generation and average streamflow in the São Francisco basin from 1996-2016. Sources: ONS (2017) and CPTEC / INPE (2016).*

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