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Climate Change Impacts on Water Resources Management

Adaptation Challenges and Opportunities in Northeast Brazil

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The Latin America and Caribbean (LAC) region has a unique mix of qualities and challenges when it comes to the environment. It is exceptionally endowed with natural assets, with globally significant biodiversity and valuable crops, and also harbors the world's greatest carbon sink in the Amazon. At the same time, however, the region registers the highest rates of urbanization in the developing world with pollution, overuse of its water and natural resources and detrimental impacts on the health of people, especially the poor, and the environment.

Over the past twenty years, the LAC region has made impressive gains in tackling these issues. It leads the developing world in biodiversity conservation and natural resource management and is at the forefront in reducing urban pollution. The World Bank has often been the partner of choice for those countries in the region that have had the initiative to pioneer innovative policies for environmental protection and natural resource management, strengthen institutions responsible for environmental management, enhance environmental sustainability, and introduce new approaches to water resources management. Such initiatives include fuel and air quality standards in Peru, carbon emission reduction in Mexico, payment for ecosystem services in Costa Rica, participatory and integrated water resources management in Brazil, and new approaches to irrigation management in Mexico.

The *Environment & Water Resources Occasional Paper Series*, is a publication of the Environment and Water Resources Unit (LCSEN) of the Sustainable Development Department in the World Bank's Latin America and the Caribbean Region. The purpose of the series is to contribute to the global knowledge exchange on innovation in environmental and water resources management and the pursuit of greener and more inclusive growth. The papers seek to bring to a broader public – decision makers, development practitioners, academics and other partners - lessons learned from World Bank-financed projects, technical assistance and other knowledge activities jointly undertaken with our partners. The series addresses issues relevant to the region's environmental sustainability agenda from water resources management to environmental health, natural resource management, biodiversity conservation, environmental policy, pollution management, environmental institutions and governance, ecosystem services, environmental financing, climate change and their linkages to development and growth.

In this particular paper, we present you the findings of an innovative approach which evaluates the implications of climate change for water management in the Northeast Region of Brazil. The project has contributed to raising awareness of the drought conditions that are expected to intensify in Northeast Brazil and the stress that climate change, combined with population growth and changes in patterns of demand for water, might place on the water systems in this region. This publication is the shorter version of the full report highlighting some of the main findings of the project towards steps to address these issues.

We hope that this paper, just as the entire series, will make a contribution to knowledge sharing within the LAC Region and globally.

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Climate Change Impacts on Water Resources Management

Adaptation Challenges and Opportunities in Northeast Brazil

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Water Management in a Warmer and Drier Northeast Brazil

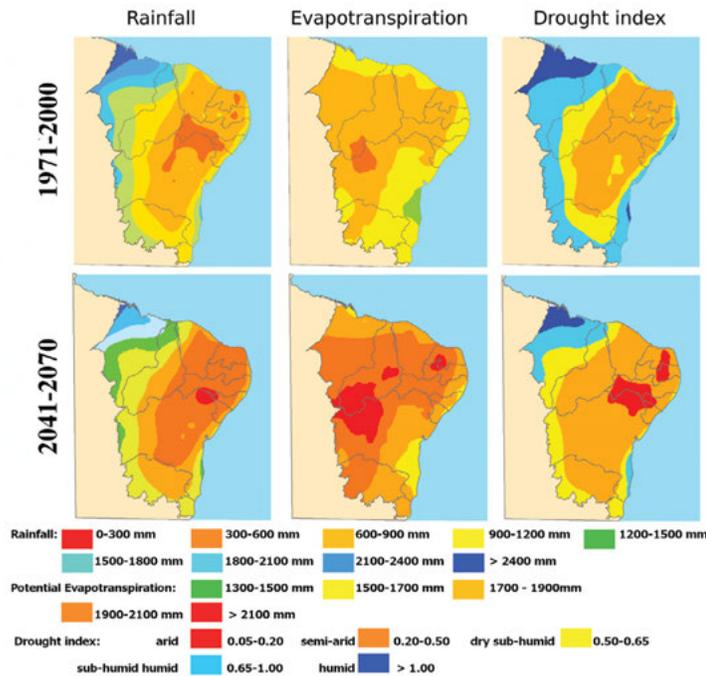
Most of Northeast Brazil is located in the semi-arid 'sertão', an area that receives less than 800 millimeters of rainfall per year on average. In addition to low precipitation, rainfall variability in the region is among the highest in the world. Reservoirs were the traditional response to droughts for more than 100 years, but were operated with insufficient attention to institutional arrangements for water resources planning and management.

Until the early 1990s, water distribution and integration within and between states' river basins was also lacking. Water use was uncontrolled and free, and primary users participated minimally in water management decisions. Until recently, recurrent droughts regularly resulted in major migrations out of the Northeast. Although poverty persists, there are significant efforts under way to bolster economic and social development throughout the region and to improve water management options and decisions.

After the adoption of a new National Water Law in 1997, the federal government of Brazil, along with several Brazilian states, started water sector reforms, which included decentralizing water management at the river basin level, initiating bulk water use charges, and emphasizing stakeholder participation processes in planning and allocation decisions. Despite these and other reforms (for example, new water storage and conveyance projects), droughts throughout the 2000s, and most recently in 2010 and 2012, have shown that the region still remains vulnerable.

Projections from global climate models have broadly indicated increases in drought for the Northeast. However, few if any studies have detailed the potential impacts of a warmer world specifically on the climate, hydrology, and socioeconomic conditions of Northeast Brazil. Within this context, the World Bank worked with the government of Brazil to improve understanding of what the future might hold for this rapidly growing region. Additionally, the project sought to identify what opportunities might exist for increasing flexibility within water management in the face of population growth and climate uncertainty.

Figure 1. Northeast Brazil Climate Change Projections, 1971–2000 and 2041–2070



Note: Figure shows mean annual precipitation, mean annual evapotranspiration, and drought index (precipitation divided by evapotranspiration) for the periods 1971–2000 and 2041–2070 (projected) using the MIMR climatic model under the B1 emission scenario. Evolution to more reddish color corresponds to increased drought, due to reduced rainfall and/or increased evapotranspiration.

Increased Droughts and Exploring Potential Trade-offs

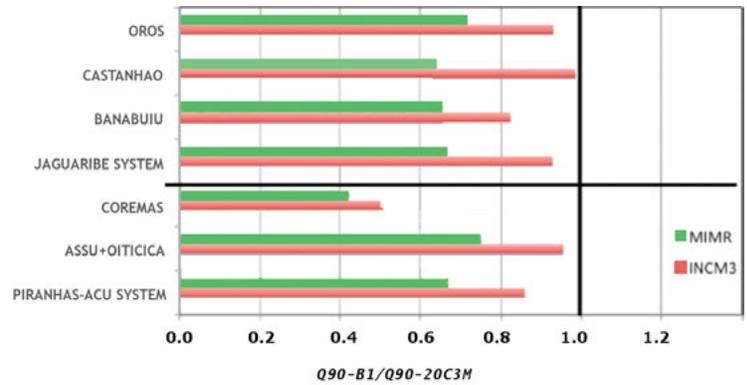
The project looked specifically at climate change and water demand impacts, as well as adaptation options in two river basins, the Jaguaribe (state of Ceará) and Piranhas-Açu (states of Rio Grande do Norte and Paraíba). To build sustained capacity and train professionals in the region, a multidisciplinary group of six Brazilian experts from different universities and research agencies helped develop the project approach, and a group of roughly 50 professionals from different institutions and additional experts from abroad participated in and benefited from the project

Table 1. Changes in Precipitation, Evapotranspiration, and Flow for Reservoirs

Reservoir	P [%]		ETP [%]		Q [%]	
	INCM3	MIMR	INCM3	MIMR	INCM3	MIMR
Banabuiu	-0,04	-0,24	0,02	0,12	-0,20	-0,73
Castanhão	0,01	0,00	0,03	0,13	-0,07	-0,26
Orós	0,01	0,00	0,03	0,13	-0,05	-0,21
Armando Ribeiro Gonçalves	-0,05	-0,06	0,04	0,11	0,06	-0,13
Coremas Mãe d'Água	-0,13	-0,07	0,04	0,12	-0,44	-0,47

Note: Table shows changes (%) in average annual precipitation (P), potential evapotranspiration (ETP), and flow (Q) for the five main reservoirs in the river basins of Jaguaribe (Banabuiu, Castanhão, Orós) and Piranhas-Açu (Armando Ribeiro Gonçalves and Coremas) under the B1 emission scenario and using the INCM3 and MIMR climatic models. The blue-rimmed items correspond to significant projected changes compared to the 1971-2000 period.

Figure 2. Ratio of Projected Future versus Current Guaranteed Flow Rates for River Systems and Reservoirs



Note: Figure shows ratio of projected future (2041-2070 period) and current (1971-2000) guaranteed flow rate (Q90) for the Jaguaribe river basin system and its three main reservoirs (Orós, Castanhão, Banabuiu) and the Piranhas-Açu system and its two main reservoirs (Coremas, Assu + Oiticica) under the B1 emission scenario using the INCM3 and MIMR climatic models. Q90 corresponds to the flow that is exceeded 90 percent of the time and is generally used for granting water rights in Brazil. All values are below the 1.0 mark and thus indicate a decrease of the projected future guaranteed flow rate compared to the current situation.

through a stakeholder engagement process. These institutions included the National Water Agency (ANA), the water resources administrations from the three Northeast states covering the two river basins (Ceará, Rio Grande do Norte, and Paraíba), and other water users and members of civil society represented through the two river basin committees. The project implemented a series of two-day workshops from May 2011 to April 2012, during which the participants developed findings, widened knowledge, and shared insights through several iterative steps.

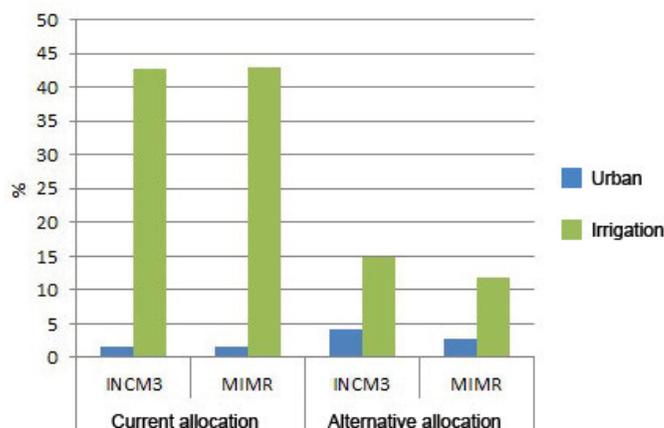
First the group evaluated the extent to which climate change would impact the Northeast, particularly the effects on the hydrology of the river basins and water availability. Regression models were used to downscale temperature and rainfall projections from three climatic models, each forced with the A2 and B1 emission scenarios of the IPCC Fourth Assessment Report.² The time periods used for the present and future scenarios were 1971–2000 and 2041–2070 respectively. The evaluation showed that broadly, the Northeast Region would experience reductions in mean annual precipitation combined with increased mean annual evapotranspiration (the water loss through evaporation and plant transpiration), ultimately suggesting an increased likelihood of droughts over the coming decades in the region (figure 1). More specifically in the river basins, the changes would represent an average increase in mean annual evapotranspiration of 5–15 percent and significant increases in interannual rainfall variability. These increases would lead to reductions in surface runoff and flow (table 1). Across the board, these findings show greater future water scarcity in these basins, with important impacts on water allocation, as highlighted by percentage reduction in guaranteed flow rates (figure 2). The impacts were found to be somewhat greater in the Piranhas-Açu basin than in the Jaguaribe basin.

Next, the group estimated current and future water demands in the two river basins. Future demand was based on several projections, including population growth, water management approaches, and potential evapotranspiration. Evaluating these factors

illustrated that water demand is projected to increase over the coming decades, mainly due to population growth. Moreover, the marginal impacts of demand projections on water allocation are greater than those corresponding to climate scenarios. However, increased evapotranspiration from climate change will serve as an overlying stress on the basins' water resources.

The analysis of future water demands was then merged with the climate and hydrology results to identify potential impacts on water supply and availability for particular sectors of the economy (irrigation and urban water supply). Several strategies combining different water allocations and user priorities were developed to investigate potential opportunities to mitigate the impacts. For example, some strategies had water allocated and prioritized differently across urban supply, irrigation, and reservoir storage. The analysis also took into account the possibility of increased water supply through water transfers from the São Francisco river basin under the São Francisco Integration Project, which is currently under implementation.

Figure 3. Impact of Different Water Allocation Strategies on meeting the water demands of irrigated agriculture and urban consumption



Note: Figure shows percentage of unmet water demand for irrigation (green color) and urban consumption (blue color) in the Piranhas-Açu river basin under the current water allocation strategy and an alternative strategy, using the climatic models INCM3 and MIMR, for a scenario of future water demand.

Figure 3, for example, compares the current practice of water allocation (i.e., with absolute priority for urban demands, and always keeping a minimum level of reservoir storage at 30 percent capacity) with a more flexible alternative (i.e., keeping the highest priority to urban demand, but giving priority to irrigation and industry over reservoir storage). The results show that the more flexible alternative strategy would strongly reduce the water scarcity that is experienced by the irrigated agriculture sector, with no or negligible impact on the urban demand. This result indicates the potential for improvement in the current system of water management in the river basin with benefits for all users.

The impact evaluation also included an economic component that looked at the effects and trade-offs between the urban supply and irrigation sectors. The analysis for the Piranhas-Açu river basin found that, in economic terms, maintaining the current water allocation strategy (highest priority to urban demands and lowest to irrigation demands) under climate change could negatively

impact irrigated agriculture by as much as US\$24 million per year on average, or a 41 percent reduction in the economic return of the irrigated agriculture, with little or no additional benefits to the urban supply sector. On the other hand, placing higher priority on irrigated agriculture (but still less so than urban supply) could result in a US\$6 million per year on average gain for irrigated agriculture, with little or no losses to urban supply services.

Taken together, the results from this process indicate that while real future trade-offs will likely exist and should be negotiated and discussed between water users, more flexible allocation strategies could make the water sector in Northeast Brazil as a whole less vulnerable to demand and climate change impacts. For irrigated agriculture, there may be a reduction in the uncertainty if more flexible water management rules are adopted. Furthermore, there are potential benefits from improving demand management and structuring the allocation process in a way that still prioritizes urban use, but grants irrigators greater access to the water in the reservoirs, water that is often currently (and conservatively) stored for urban supply.

The associated trade-offs and impacts in the urban and irrigated agriculture sectors for any situation wherein allocations are not met could be so significant that these issues need to be further investigated for proper identification of feasible solutions involving alternative water allocation in the basins.

Overall, the challenges are greatest in the Piranhas-Açu basin. First, the marginal impacts of climate change in the Piranhas-Açu basin are greater than those identified in the Jaguaribe basin in all climate scenarios. This is not only due to the differences in climate between the two basins, but also due to the substantial investments in infrastructure made in the Jaguaribe river basin from the late 1980s until now, compared to the Piranhas-Açu. Similarly, the combined climate change and demand impacts in the Piranhas-Açu basin are greater than those in the Jaguaribe; this implies an urgent need for investment in infrastructure and development of institutional and legal frameworks in this basin. Using flexible reservoir operation rules, along with water transfers within and between basins, might help mitigate such impacts.

Pilot Adaptation Actions at the Local Level

In addition to the analyses at the river basin level, the project evaluated two examples of adaptation to future water scarcity at the local level. Since adaptation to climate risk occurs to a great extent at the local level, the project sought to analyze the vulnerabilities to current and future climate, as well as the socioeconomic and institutional constraints to making such adaptations. The first case, Cruzeta (located in the Piranhas-Açu river basin), highlights adaptive strategies for improving reservoir management in a changing climate. The second case, Águas do Vale (in the Jaguaribe river basin), describes the real case during the extreme drought of 1998–2001 where the introduction of flexible water allocation and economic compensation mechanisms amongst irrigators proved to be a useful and illustrative drought management strategy.

Cruzeta

The municipality of Cruzeta is located in the heart of the sertão. A surface reservoir provides water to its 8,000 inhabitants as well as to an irrigation scheme of about 125 hectares cultivated by 30 smallholder families. Under climate change, irrigated agriculture would see its water demand increase substantially and its water allocation guarantee diminish. As an adaptation measure, and to help supply the water demand for both human consumption and irrigated agriculture, investments are being made to improve efficiency throughout the irrigation canal system and at the level of the individual farm plots. Modernization efforts include new water-saving methods such as on-farm microsprinkler irrigation and improved operation of the canal system, which are estimated to reduce the water demand of the irrigation scheme by up to 40 percent. On top of this, understanding how the water storage reservoir performs under various climate change scenarios proved important for gauging the adequacy of current and future water and agriculture policies in Cruzeta and across the region.

This pilot case highlights that as with the region as a whole, the Cruzeta system will likely face increases in evapotranspiration, which could lead to substantial increases in irrigation water demands. However, irrigation modernization improvements, both in infrastructure and in management, would decrease this demand by up to 40 percent. The case also shows that water managers operating the reservoir system are extremely risk averse and assume zero flows in planning for future years. Here, using climate information could help improve decisions and ultimately free up more water for use during years of expected high rainfall, thus avoiding unnecessary rationing. Moreover, managing and transferring risk from high-priority uses (urban supply) to lower priorities (irrigation) could be more efficiently managed under future climate change, particularly with the modernization of irrigation.

Águas do Vale

Águas do Vale, also known as the Rationing Plan for Water Use in Irrigation for the Jaguaribe and Banabuiu Valleys, is an innovative water allocation program that was introduced in the state of Ceará during a particularly dry period (1998–2001). It consisted of emergency measures to mitigate water conflicts and damaging impacts of the drought on irrigation investments.

Essentially, the program instituted measures to increase irrigation efficiency by providing certain farmers with incentives through water payments to shift away from low-value but high-water-use crops (mainly rice) to low-water-use and higher-value crops (mainly fruit). The basic mechanism was to encourage certain producers to stop cultivating rice, and transfer some of the efficiency gains to those who were producing higher-efficiency and higher-value crops.

Overall, the Águas do Vale experience illustrates the potential for innovative adaptation and drought management strategies that focus on the reallocation of water through negotiated and participatory mechanisms, and also the value of institutionalizing a bulk water pricing and permit system for irrigated agriculture. This case was not without some challenges, however, such as resistance to changing irrigation methods and technologies, the need for a robust system of monitoring, enforcement of the market created by the program to improve its efficacy and success, and the need to increase the use of climate information in assessing future water supply and demand risks. Still, this initiative indicated a clearer perception of the economic value of water, which has shown potential to be further explored in water management instruments involving temporary and permanent water transfers, as well as water tariffs.

Conclusion and Next Steps

This project proved to be a critical first step in better understanding how climate change will translate to water scarcity, and how the drought-prone and rapidly developing Northeast Region of Brazil could adapt through more flexible water management and allocation strategies. The analyses helped build knowledge and awareness of the drought conditions that are expected to intensify in Northeast Brazil and the stress that climate change, combined with population growth and changes in patterns of demand for water, might place on the water systems in this region. The project yielded many useful products and tools, including a model process for facilitating more integrated water resources discussions, planning, and capacity building. The next step includes working with decision makers on how to take into account possible climate change outcomes and hydrological impacts in their investment plans and future choices. Given the significant amount of World Bank financed investments in Northeast Brazil and its commitment to climate change adaptation projects and investments globally, there are expectations among federal and state officials, as well as other project participants, that the lessons from this project should help shape future investments, knowledge building, cross-sectoral integration, cooperation, and institutional dialogue.

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The Environment and Water Resources Occasional Paper Series was developed under the direction of Karin Kemper, Sector Manager for Environment and Water Resources in the Latin America and Caribbean Region (LCSN) of the World Bank. The publications in this Series were designed and produced by GRC Direct under the supervision of Emilia Battaglini and Rachel Pasternack (LCSN).

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