

# Climate Vulnerability and Adaptive Strategies Along the Rio Grande/Rio Bravo Border of Mexico and the United States

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**Abstract:** Climate change and growing populations are dual stresses that are particularly challenging to communities along the US/Mexican border where adaptive capacity is limited, infrastructure is lacking, and economic resources are scarce. Although regional precipitation projections vary significantly in both timing and amount, projections of temperature changes produce a more robust signal of raised temperatures. A summary look is provided that highlights the climatic changes that are projected, identifies key systems and sectors that are vulnerable to climate change, describes and summarizes the role of adaptation and the development of adaptation strategies. A promising look at binational co-adaptation is highlighted and illustrates the potential for building regional adaptive capacity.

**Keywords:** *Climate change, adaptation, Rio Grande, U.S. Mexico Border*

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Populations along both sides of the Rio Grande/Rio Bravo border between Mexico and the United States are likely to be increasingly challenged by the compounding dual effects of population growth and climate change. Growing populations heighten competition for water in an already water-scarce region, where water is most commonly used to grow food. Regional climate change projections vary significantly with respect to precipitation change but are generally consistent in predicting higher temperatures and the drying effects they will have on crops, surface storage, and natural vegetation. Not only is climate change expected to bring more frequent, severe, and enduring droughts, but sea level and the frequency and intensity of storms, including hurricanes and floods are also expected to rise (Parry et al. 2007; Solomon et al. 2007). Although both sides of the border share exposure to water scarcity, population growth, and changing climate, resiliency may be lower and vulnerability higher in Mexico. Relative to U.S. border communities, adaptive capacity in Mexico's border communities is constrained by fewer economic and institutional resources, limited capacities for restoration and

disaster-relief, and greater risk-exposure by disadvantaged communities (Ibarrarán et al. 2008; Martínez 2007).

## Population Growth and Climate Change: Drivers of Vulnerability Along the Border

The climatic changes expected for Mexico over the mid-to-long-run are likely to compound the social, economic and other environmental stresses it faces. For example, rising temperatures will increase consumptive water-use requirements of urban and agricultural users at the same time that supplies are likely to decline as streamflow falls, evaporation losses increase, and both reservoir and ground water levels diminish. Scott et al. (2012) provide a comprehensive assessment and discussion on the water-sensitive region of the Arizona and Sonora border region along the Santa Cruz River and the transboundary Santa Cruz aquifer. There they observe the challenges of meeting the water needs of agriculture and urban water users, where the local population growth

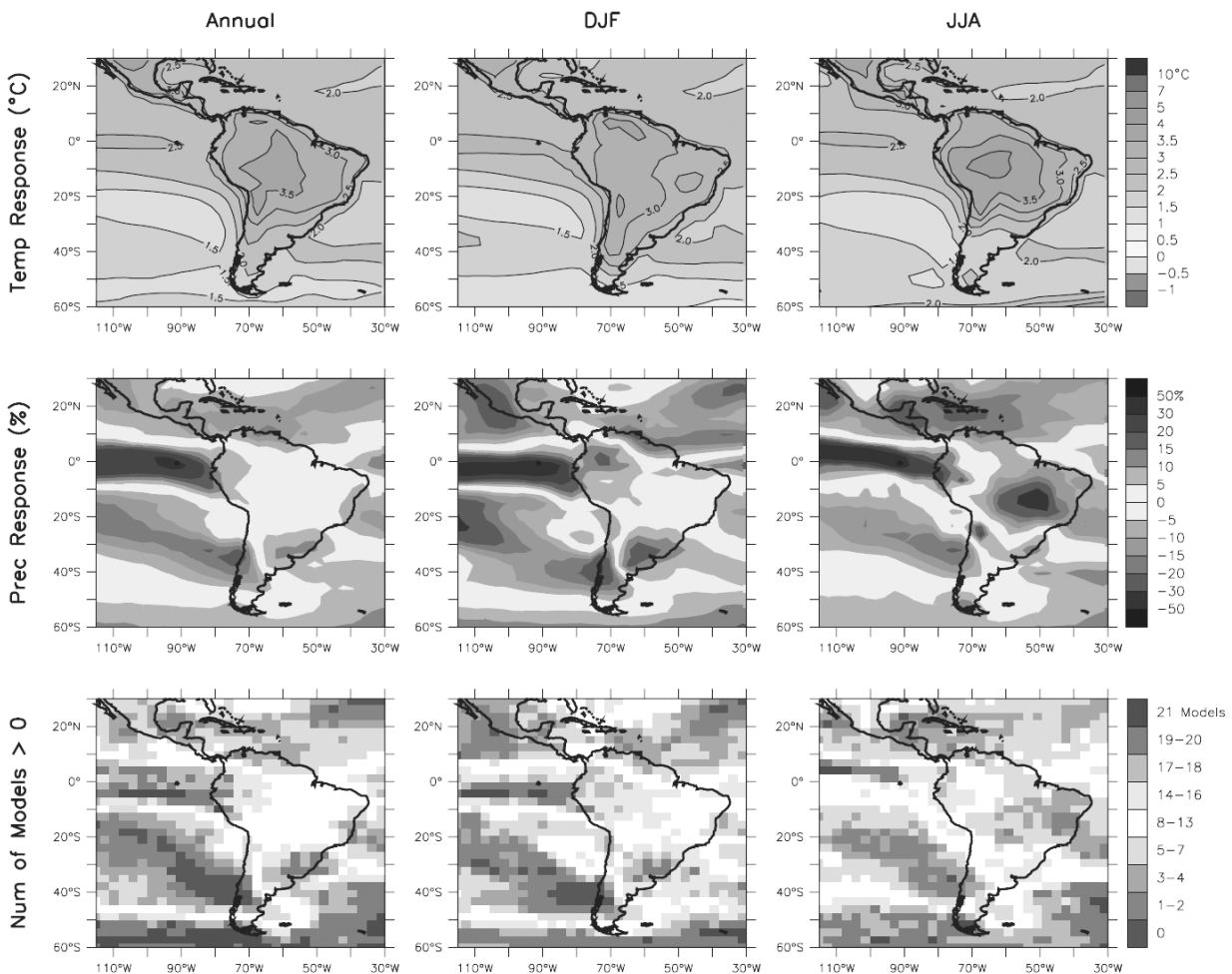
rate is about 1.3 percent per year, and where aquifer pumping often exceeds rates of recharge – a condition that Scott et al. (2012) suggests could be worsened under drier projections of climate change.

### Climate Change Projections

Climate change assessments from the Intergovernmental Panel on Climate Change Fourth Assessment Report under the A1B emissions scenario project temperature warming of between 2.6 °C and 3.6 °C over the coming century (Solomon et al. 2007; Parry et al. 2007). Under this same A1B emissions scenario, the estimated change in annual precipitation ranges

from -16 percent to -5 percent (with a median of -9 percent). Although projected temperature changes are relatively consistent across emissions scenarios, projected precipitation changes are not. Scott et al. (2012) include A1B, B1 and A2 emissions scenarios in their analysis and using the HadCM3 Global Climate Model show change of annual precipitation ranging between -20.9 percent and +19.9 percent.

Figure 1 reproduces the figure from the Intergovernmental Panel on Climate Change showing the effects of the A1B scenario across Mexico, Central America, and South America. The top panel shows likely temperature changes annually and for the winter and summer months,



**Figure 1.** Summarizing temperature and precipitation changes over Central and South America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation (Source: Intergovernmental Panel on Climate Change, Figure 11.15, Solomon 2007).

respectively. Temperature increases from 3 °C to 5 °C projected over the coming 70 to 80 years are more pronounced in the summer than winter over much of Mexico. Although with less consensus, precipitation is projected to fall significantly on an annual basis from 5 percent to 15 percent, with winters becoming much drier across most of Mexico (as much as 30 percent in some areas) and summers drying, with a bit less intensity in the north but very significantly in the south. The bottom panel shows the number of GCM models out of the 21 in the assessment that project an increase in precipitation. For Mexico, less than one third of the projections show an increase.

### Understanding Climate Change Vulnerability

Climate vulnerability is a concept that expresses the risks and consequences of failure of systems that are both sensitive and exposed to climatic factors and their changes (e.g., temperature and precipitation changes). Easterling et al. (2004) describe how vulnerability is assessed and measured in both physical and economic dimensions, including threats to public health, important economic industries, communities and settlements, economic developments, infrastructure, and environmental and ecological resources and services. Building adaptive capacity can reduce vulnerability, mitigate the adverse effects, and enhance system restoration and resiliency. A useful way to understand and assess climate change vulnerability is through its three interactive components: sensitivity, exposure, and adaptability or adaptive capacity.

**Sensitivity.** Conceptually similar to the notion of elasticity, sensitivity describes how much a system and its functionality are potentially affected by changes or events. Without some sensitivity, no vulnerability would exist. In agriculture for example, some crops cannot tolerate hotter and drier conditions, and when such conditions occur, crop performance is significantly diminished. One important example for Mexico is corn, which is much more physiologically sensitive to hot and dry conditions than wheat.

**Exposure.** Though a system may have high sensitivity, if it is not likely to experience or be exposed to such changes or events, then vulnerability is minimal. Exposure is a critical element affecting vulnerability, and is a factor that institutions and policy can often affect. The vulnerability of coastal communities to sea-level rise and storm surges, for example, rises with the size of population and development, as people are drawn to aesthetic and recreational opportunities. In these cases, updating zoning and building codes may be possible mechanisms whereby development occurs in a less vulnerable fashion.

**Adaptability.** With systems that are both sensitive and exposed to adversity, adaptability becomes relevant. Adaptability refers to changes that can be made to the design, function, or behavior of a system that can strengthen its ability to withstand and/or recover from adversity, for example, through limiting sensitivity or exposure, or by enhancing robustness and resilience.

**Vulnerable Populations, Sectors, and Resources.** Several sectors in Mexico are potentially vulnerable to climatic changes, including agriculture, water, energy, and even health and tourism to lesser degrees (Ibarrarán et al. 2008).

**Agricultural Resources and Food Security.** Arable land in Mexico is relatively scarce, amounting to about 11 percent of its land base. Many important growing regions depend on irrigation. In terms of net economic returns, the most important crops include corn, tomatoes, sugar cane, dry beans, and avocados. Livestock is also important, particularly beef, poultry, pork, and dairy. Whereas, agriculture accounts for 3.8 percent of GDP, it provides 15 percent of the jobs. In 2009 Mexico accounted for 15.9 percent of U.S. agricultural imports, valued at nearly \$11 billion (U.S. Department of Agriculture Foreign Agriculture Service 2011).

Corn is the foundation for food supply and food security in Mexico. It is the basic staple grain and energy source in the diet of much of the Mexico's population, and more importantly for the most vulnerable populations. Climate change can adversely affect corn production by limiting

growing seasons, grain quality and quantity, and through limited rainfall and irrigation water supplies. Martínez (2007) and Martínez and Adrian (2004) assess the regional effects of climate change on maize production within Mexico, identifying both regions of production increase and decrease. Under the A2 emissions scenario they show net production falling. With the exception of a few small regions in central Chihuahua, maize production in northern Mexico is diminished under the A2 scenario.

**Water Resources.** Mexico's water resources are also highly vulnerable to changes in both temperature and precipitation. Surface and ground water supplies are often overexploited and stressed by pollution. As in the Western U.S., agriculture accounts for the majority of water use, in 2009 was nearly 77 percent (Conagua 2011). A recent study along the Arizona and Sonora border, where communities are heavily reliant on a transboundary aquifer for water, indicates that continued population growth in the region will likely require enhanced use of transfers of surface waters and increased use of recycled waters to meet growing demands. Climate change trends, the study indicates, are highly variable in their projected effects on ground water flows and aquifer levels. Under drier climate scenarios, aquifer recharge would add considerably to the water stress faced by the region.

Along the Rio Grande, another recent study shows that even under scenarios where precipitation may significantly increase, the resulting losses from evaporation more than offset any gains, resulting in much lower runoff and streamflows in nearly all scenarios (Hurd and Coonrod 2012). In Mexico's arid north, decreasing runoff and streamflow threaten not only regional irrigation and food production, but also threaten treaty-obligated deliveries to the Rio Grande and to south Texas farms. In particular, the regionally important Rio Conchos basin supplies the majority of the river flow in the lower Rio Grande and to south Texas farms.

**Oil and Energy.** Mexico is one of the world's largest producers of crude oil and the second-largest supplier of oil to the U.S. Oil and gas revenues provide more than one third of all Mexican Government revenues and are the country's largest source of foreign currency. The nationally-owned oil company, Pemex, is a

constitutionally established monopoly controlling the exploration, production, transportation, and marketing of oil. Experts suppose that Mexico's primary known oil reserves are in decline. To avoid declining economic production, decisions about developing deep water reserves might need near-term attention (globalEDGE™ 2011). The energy sector has moderate climate change vulnerability derived primarily from exposure of offshore oil facilities to damaging storms and from the potential loss in hydropower production from low rainfall and resulting storage conditions, primarily in the south. Hydropower produces about 20 percent of Mexico's electricity and is concentrated in the south. The largest hydro plant in Mexico – and fourth-largest in the world – is the 2,400 MW Manuel Moreno Torres Dam in Chicoasén, Chiapas, on the Grijalva river. Additionally, electricity production capacity could be stressed by load strain from higher temperatures and drought.

**Tourism.** Tourism is an important economic sector, responsible for over 10 percent of Mexico's GDP and foreign currency. Located principally in the resort communities along the Pacific, Gulf and Yucatan Peninsula coastal areas, these regions are vulnerable to both sea-level rise and to damaging storm events. Sustained disruption and loss of these economic areas could exacerbate poverty and employment stress.

## Climate Change Adaptation Strategies

Climate adaptation strategies are a challenge to develop and implement successfully, particularly where economic resources are limited as is common within a developing economy. Except for the exceptional “no-cost” or “low-cost” adaptation, most climate adaptations are evaluated within a broader context of need or desirability. For example, a dam may be primarily intended for managing variable water supplies and flood events, but adjustments or adaptations in the design could enhance its performance in the event of climate change. Climate adaptation is generally articulated within a broader context of economic development, and it is often

difficult or impractical to distinguish the two, notwithstanding the need to do so for funding purposes. It is also important to understand the often variable and scalable nature of adaptation. Uncertainty regarding severity and timing of climate change might give rise to alternative strategies regarding the timing of planned investments, or whether or not to make anticipated or planned investments at all.

### Understanding Reactive and Proactive Adaptation

In many cases, strategies to build adaptive capacity can include a mixture of activities. Responses and actions that are taken once climate changes are realized (and recognized as such) are commonly referred to as reactive adaptation. In contrast, responses and actions that are enacted in advance or with the anticipation of climate changes are commonly considered proactive adaptations (Easterling et al. 2004; Hurd 2008).

One of the key differences between reactive and proactive adaptation strategies concerns the timing of investments in adaptive capacity building. Reactive adaptation can result from two situations. First, no consideration is given at all to changing conditions or events; simply adapt when and as conditions warrant. Second, a deliberate decision to delay or postpone investment is taken, owing to inherent uncertainty, and results in adaptation actions that were anticipated but otherwise taken too late to do as much good as they otherwise might have. Proactive adaptation tries to anticipate changing conditions and

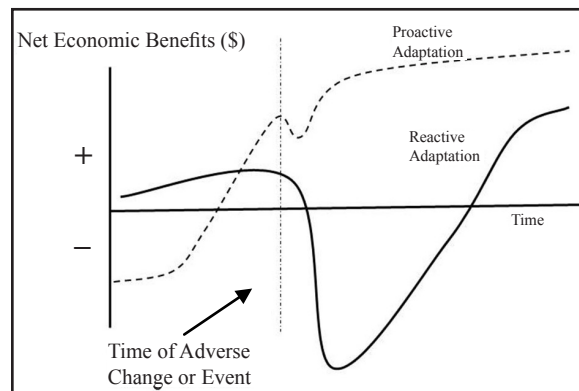
preparing for them well in advance.

Figure 2 compares two hypothetical and stylized time paths depicting the net economic benefits for both cases. In the case of reactive adaptation, net economic benefits are positive and continue to grow until the time of disastrous change. For example, consider a catastrophic hurricane in the Gulf of Mexico that destroys offshore oil facilities and coastal communities. With reactive adaptation, disaster costs are severe and recovery time is long. It is also possible that redevelopment occurs without any change for future defenses. In contrast, proactive adaptation might anticipate the disastrous event and take prudent and appropriate steps to mitigate damages, such as strengthening defenses around facilities and communities prior to disaster. Under proactive adaptation, investments cause an initial drop in economic welfare, after which growth proceeds until the disaster. With successful adaptation, damages still occur but they are much smaller and are recovered from more quickly. Long-run economic welfare can be enhanced by proactive adaptation (Hurd 2008).

Mexico's Intersecretarial Commission on Climate Change published mitigation and adaptation strategies in 2007 (Comisión Intersecretarial de Cambio Climático 2007). This report is Mexico's "National Strategy on Climate Change" in which it a) identifies mitigation measures and estimates of potential for emissions reduction; and b) recognizes the vulnerability of various economic sectors and geographic regions to climate change, and broadly outlines national- and local-level opportunities for building adaptive capacity. Key areas identified in this strategy for building adaptation capacity are:

- Hydro-meteorological risk and water resource management,
- Biodiversity and environmental services,
- Agriculture and farming,
- Coastal developments,
- Human settlements, and
- Energy generation and use.

General principles of Mexico's Climate Adaptation Strategy (Comisión Intersecretarial de Cambio Climático 2007) are shown in



**Figure 2.** Understanding Reactive and Proactive Adaptation.

Appendix 1, and identify policy and program initiatives that could be undertaken to strengthen adaptive capacity. Many of the themes refer to improved data and information gathering and other management-related activities.

### **Confronting Obstacles to Binational Cooperation and Co-Adaptation**

Where vulnerabilities and challenges are shared across a common national border, there may arise opportunities for cooperative adaptation or co-adaptation. Although significant challenges to binational cooperation exist along the U.S./Mexico border (including issues of governance, data-sharing, institutional and legal barriers), it may be possible to explore mutually-beneficial strategies that will enhance adaptive capacity for both sides (Granados et al. 2006). Wilder et al. (2010) have identified some promising pathways for adaptation that explore opportunities under models of cooperation, mutualism, and binational integration. Their research explores transboundary approaches “to improve the adaptive capacity to climate change, especially for water resources management.” In spite of the difficulties of cross-border collaboration, their research supports the hypothesis that:

Regional adaptive responses across borders could increase resilience and decrease vulnerability to climatic changes. Such cross-border approaches can emerge through shared social learning and knowledge, by creating binational communities of practice, such as among water managers or disaster-relief planners, and by addressing inequities resulting from uneven development (Wilder et al. 2010).

Upon assessing three distinct efforts at binational cooperation along the Arizona-Sonora border, Wilder et al. (2010) conclude that adaptive potential across the border is promising and likely to show positive impacts. Continued efforts following Wilder et al. in these directions show distinct ways for co-adaptation that not only contributes to building regional adaptive capacity in response to climate change but offers a glimpse toward cooperative strategies that may benefit efforts to manage other binational resources and offer a template to other regions.

## **Conclusions**

With limited opportunities for new water sources along the U.S./Mexico border, continued population growth must necessarily compete with existing water users for available supplies. This competition will intensify as runoff and aquifer recharge rates fall under a projected warmer and drier climate, and likely result in reducing agricultural water uses in favor of domestic and urban. All water users will likely experience the adverse economic consequences that accompany rising water scarcity and costs. The regional vulnerability to climate change and the additional stresses from population growth will increase the struggle and hardship of those communities with limited means. It appears, therefore, all the more prudent to identify and promote strategies that recognize the challenges of changing conditions and contribute to and building adaptive capacity. The potential benefits of proactive adaptation have been highlighted along with the potential synergies of pursuing regional and binational efforts and activities to strengthen adaptive capacity.

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**Appendix 1: Key Provisions of Mexico's Climate Adaptation Strategy.**

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1. Design a program promoting the natural recharging of aquifers.
  2. Increase knowledge and deployment of information exchange and early warning systems.
  3. Adjust water treatment technology in line with changing climatic conditions.
  4. Review and strengthen the implementation of natural resource management instruments such as seasonal bans, marine and coastal Protected Areas, and payment for environmental (hydrological) services, so as to adapt them to changing climatic conditions.
  5. Establish biological corridors between Protected Areas, and evaluate the need to adjust the current boundaries of these and of Priority Regions for Conservation, to improve the adaptive capacities of ecosystems and species.
  6. Evaluate design adaptation policies based on these evaluations. The experience acquired by vulnerable groups in the face of climate variability and
  7. Preserve Mexican agrobiodiversity in situ through programmes jointly implemented by the Ministry of Environment and Natural Resources (SEMARNAT) and the Ministry of Agriculture, Rural Development, Fisheries and Food.
  8. Develop and implement a climate information and monitoring system specifically designed for the farming community.
  9. Strengthen epidemiological monitoring systems.
  10. Plan for an increase in mean sea level of 40 cm between now and the end of the century as a baseline for infrastructure development in coastal zones.
  11. Articulate the national policy for marine and coastal sustainable development with the strengthening of national capacities for adapting to climate change.
  12. Promote synergies between the tourism, fishing, and water sectors, and with the National System for Civil Protection.
  13. Include appropriate environmental design criteria in all aspects of urban planning and development.
  14. Include the watershed management approach in schemes for environmental services protection and disaster prevention in peri-urban and rural areas.
  15. Design and build decentralised, small-scale, local energy supply systems.
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**Source:** Comisión Intersecretarial de Cambio Climático (2007).