Adaptive Capacity of Water Management to Climate Change in Brazil: A Case Study Analysis of the Baixo Jaguaribe and Pirapama River Basins

By

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ABSTRACT

Adaptive capacity to climate change describes the ability of a system to adjust to climate-change impacts, consequences, and opportunities. The capacity to adapt is considered one component of the broader topic of vulnerability to climate change. In vulnerability studies, researchers have focused on understanding the anticipated impacts on a respective region, and the physical conditions that leave systems sensitive and exposed. The unique human component of vulnerability analysis, adaptive capacity, has until recently, been largely under analyzed. This study takes an in-depth look at one of the most influential determinants of adaptive capacity, institutions and governance mechanisms. The recently reformed water management system in Brazil provides the backdrop for a comparison of adaptive capacities between two river basins in the Northeast; the Baixo Jaguaribe and the Pirapama. In an attempt to assess the ability to make the measurement of adaptive capacity operational, I developed an adaptive capacity index from previously collected survey data, and explored its findings using qualitative data obtained through in-depth interviewing of key informants in each basin. The study finds that adaptive capacity has increased in each basin, but for different reasons. Also, the development of institutional and governance adaptive capacity indicators is insufficient at the river basin scale alone. Rather than identifying scale-specific indicators, future assessments of adaptive capacity would greatly benefit from a process that accounts for the institutional and governance dynamics within and between various scales; from the local to the global.

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"We cannot put in the hands of nature, the luck of the people." (Interview, July 2006; Baixo Jaguaribe basin)

"If you want to know how a society is doing, look at the waters that are near them and you are going to have the best indicator of how things are happening." (Interview, August 2006; Pirapama basin)

1. INTRODUCTION

For the past decade, scientists, decision makers, businesses, and nongovernmental organizations (NGOs) throughout the world have been devoting increasing attention to global climate variability and change[1]. Many of these stakeholders are working to stabilize atmospheric concentrations of greenhouse gases through 'mitigation' efforts. However, even if greenhouse gas emissions could be altogether arrested today, experts agree that the world is already committed to a certain level of anthropogenic climate change in the coming century. Changes in climate will affect the world's regions differently, and the impacts associated with these changes will affect communities in these regions differently as well. The range of physical, social, economic and political circumstances make some communities more vulnerable, and others more capable of adapting to changes in climate. Specifically, populations in developing countries are likely to experience a disproportionally large amount of these impacts. Additionally, researchers anticipate mass migrations of developing-country populations away from low lying coastal areas, as well as severe droughts and floods resulting in increased malnourishment and death. The potentially unprecedented magnitude of the impacts and the sensitivities of numerous natural and human systems around the world make adapting to climate change an important, but complex issue. An increasing area of priority in the research community has been to identify those systems that are most vulnerable to climate change, and the factors that contribute to these vulnerabilities. Perhaps the most significant component of such vulnerability is the overall ability of systems to adapt to climate change, or their 'adaptive capacity'; a concept that is examined in this study.

Adaptive capacity, often used interchangeably with the term 'resilience',[2] is defined as "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences'' (IPCC, 2001). In working to categorize adaptive capacity, researchers are moving

[1] I make little distinction between climate change and climate variability in this study. The need for distinction often arises during debates regarding the level of anthropogenic influence behind these changes. As a recent Pew Center on Global Climate Change Report highlights, "In that adaptation is referenced only in the context of climate change, the implication is that support under the Convention (United Nations Framework Convention on Climate Change) must be directed to activities addressing primarily if not exclusively human-induced impacts. Yet….adaptation strategies often are most effective when addressing the full continuum of climate risk" (Burton et al, 2006). Thus, from the adaptation perspective, understanding the response to climate variability may serve as a good proxy to infer potential responses to climate change; a leap that I make in this paper by referring to "climate change", rather than "climate variability and change".

[2] This study avoids the definitional debate between vulnerability, adaptive capacity, and resilience. While establishing distinctions between and common interpretations among concepts is critical, I generally default to the IPCC-definitions of key adaptation-related terms. For further discussion of the definitional debate of adaptation to climate change concepts, see Gallopín, 2006.

toward a framework to analyze components of a given system that might either aid or hinder adaptation to climate change. As the components of adaptive capacity, and thus vulnerability, become better understood, methods and tools of analysis can be developed, refined and positioned to assist communities in adapting to climate change. Researchers are currently focusing on identifying the attributes of a system's adaptive capacity, and developing methods to measure them. Publications in this area have increased dramatically over the past few decades, although there is still the need to integrate paradigms across disciplines and knowledge domains (Janssen et al, 2006). While debate continues to surround common definitions (Schröter et al, 2005), this study aims to further develop and define the terms of adaptive capacity, particularly in the water sector.

In this paper, I assess the adaptive capacity to climate change in the context of water resources management in Brazil; specifically in two Northeast river basins. The research tests the *institutional* and *governance* mechanisms of water management, which are theorized to be among the most influential determinants of adaptive capacity. Three guiding research questions are: a) what mechanisms and attributes of water governance and institutions make water systems more resilient to climate change?; b) to what extent has recent water management reform enhanced or decreased adaptive capacity in these basins?; and c) does an assessment of institutional and governance mechanisms at the river-basin level accurately predict adaptive capacities within each basin? I hypothesize that the more flexible, democratic, participatory, and resourceful the water management system, the greater adaptive capacity of the system. I also predict that the water reform helped to increase adaptive capacities of water resources management in both basins. Finally, I predict that the more in-depth analysis from key-informant interviews will uncover institutional and governance components of adaptive capacity that are not captured by the river-basin-scale analysis alone. I anticipate that this research could ultimately help practitioners and users of adaptive capacity analyses by: a) identifying who will benefit from the creation of adaptive capacity knowledge; b) offering insight into how this knowledge might be integrated into the planning process; and c) beginning to build a framework for placing into operation the assessment of water management institutions' adaptive capacities to climate change.

The water sector, particularly the people and organisms that rely upon freshwater systems, is one area that is anticipated to experience significant stress as a result of climate change. Impacts such as increased droughts and floods, less predictable and more intense storms, and decreased water quality are just some of the direct and indirect consequences of climate change on the water sector (IPCC, 2001). For the past 15 years, the Brazilian government has implemented a comprehensive reform that replaced the country's poorly integrated, centralized

and technocratic approach to water management (Lemos and Oliveira, 2004). As the old system increasingly failed to address or resolve the most serious problems associated with water quality and quantity, a new approach emerged, first at the state level, and later at the federal level, which enacted a new National Policy for Water Resources in 1997. The Brazilian reform is based on the French system of water management and the Dublin Principles, which are categorized by several specific features (Johnsson and Kemper, 2005). First, the reform identified the river basin as the appropriate level for management. Second, a large portion of the decision making concerning water planning and use has been decentralized. Third, officials established the prioritization of human consumption and animal usages during periods of water shortages. Fourth, the creation of river basin committees and consortia greatly encouraged public participation. And fifth (and potentially the most controversial aspect of the legislation), the federal water law required a bulk water permit and charging system; still recognizing water as a public good, but with an economic value (Garrido, 2005; Formiga, Kumler and Lemos 2007).

Currently, the water reform (and its five components) has been implemented to varying degrees throughout river basins in Brazil. Such variation provides diverse cases for analysis of institutional and social processes, and in the case of this study, an excellent opportunity to perform comparative adaptive capacity analyses. I focus on two river basins in Northeast Brazil; the Baixo Jaguaribe basin in Ceará state, and the Pirapama in Pernambuco state. Both basins are expected to experience increased stress from climate change. However, the basins have implemented the reform through different institutional arrangements. The study draws on data collected by the Watermark Project (the Watermark),[3] as well as field interviews with water managers and stakeholders in Brazil. The Watermark survey results in the two basins are used to characterize and compare each basin's adaptive capacity, based on the most salient variables theorized in the adaptive capacity and institutions/governance literature. In-depth interviews with key informants "ground-truth" the Watermark data. The interviews are also used to test and calibrate the predicted adaptive capacity indicators.

Adaptive capacity of the water management system serves as the single dependent variable in this study. The independent variables used to predict adaptive capacity are

[3] The Watermark Project seeks to analyze and describe Brazil's recent institutional changes in water management. Over forty collaborators have participated in this effort, spanning from scholars (from Universities in Brazil and the United States) to policymakers and water advocates in Brazil. In 2005, the Watermark carried out an extensive survey of eighteen river basin committees and consortia, including the basins analyzed in this study. The survey measures attributes, characteristics and factors affecting the work of the river basin committees and water management at the basin level. It is designed around four themes comprising socio-demographic data, participation, representation, and knowledge use in decision making. For a more in depth description of the Watermark, see Engle et al, 2006.
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representation, participation, knowledge and information availability and use, equality, flexibility, commitment, networks, experience, and resources. All of the independent variables describe the various dynamics within the river basin committees, as well as the water managers themselves. In the context of this study, water managers include committee members surveyed during the Watermark, and also the key informants interviewed (some of whom are on the committees, and others who are not).

The ultimate goal of this work is to contribute to the growing theory and research on adaptation to climate change, specifically the adaptive capacity and resiliency literature. Currently, most of the work within this domain has focused on the global and national scales. While aggregate data can serve as a useful guide to understanding adaptive capacity, such large-scale analyses fail to capture the intricacies and influences of adaptive capacity at the smaller, local scales. This is particularly important when the institutions and governance mechanisms, which are theorized to be highly influential in determining adaptive capacity, exist at smaller local and regional scales, such as the river basin. Therefore, the case analysis approach of this study hopes to provide more in-depth insight into adaptive capacity of the water management system in Brazil. Additionally, one cannot ignore the policy relevancy of this work. Since water reform in Brazil was mainly driven by the need to alleviate future water crises, knowledge generated from this work might be used by managers and practitioners to decrease the vulnerability of their water systems to current climate variability and future climate change.

The subsequent section offers a literature review of climate change adaptation and adaptive capacity research and its relevance to governance and institution studies, water management in Brazil, and case study research. The third section describes the background of the two river basins selected for analysis in this study. Section four highlights the framework for analysis and the methodology. The fifth section reports the results and analyzes the Watermark data and key informant interviews. Finally, section six discusses the results and the seventh section concludes by exploring opportunities for future research.

2. LITERATURE REVIEW

2.1.1. Adaptation and Mitigation

Two approaches to addressing climate variability and change are mitigation and adaptation. Mitigation involves working to reduce and stabilize the concentration of greenhouse gases in the atmosphere. Well-coordinated global efforts are required to reduce emissions significantly, because one country's emissions reductions are unlikely to have a considerable influence on total global emissions reductions. Adaptation efforts on the other hand, have traditionally been theorized as localized reactive measures that lessen negative impacts and increase resilience of natural and social systems to climate disruption. Within the past five to ten years, researchers have mounted a concerted push to focus further on adaptation studies. This effort stems from the understanding that the world is already committed to a certain amount of warming from past emissions, and as a result, society will experience significant changes in climate to which it must adapt. With the overarching aim to increase resilience to climate change, decision makers, NGOs, businesses and the research community are placing a growing emphasis on identifying the ability for systems and sectors of society to adapt to climate change—a concept known as *adaptive capacity*.

The study of adaptation (and specifically adaptive capacity) to climate change is in many ways a more complicated subject from which to draw research insights and policy recommendations than that of mitigation. The determinants of adaptive capacity are often thought to be difficult to quantify, because of their latent nature. Also, unlike the global context of mitigation, impacts of climate change will be experienced locally. Each community will have differing abilities to adapt to climate change, and the ability to downcast future impacts accurately at smaller scales remains in itself, a developing field. Still, numerous works discuss the congruencies between these two fields and many researchers are pushing to consider adaptation and mitigation simultaneously within the policy-making context (Klein et al, 2005; Adger, 2001; Dang et al, 2003; Huq et al, 2003). Further, recent efforts have emerged that aim to integrate adaptation and sustainable development initiatives (SEG, 2007; Pielke et al, 2007; Adger et al, 2003). The goals for integrating these subjects are to capture "win-win" situations, and to bypass the "additionality"[4] debate by developing policy action that simultaneously addresses both issues.

[4] "Additionality" discussions attempt to understand how much a system needs to adapt to climate change versus the need to adapt to other stressors.

There exists a serious need for further progress in the fields of adaptation and adaptive capacity (Smit et al, 2000). Issues requiring further development include: a) determining the *appropriate scale* to focus adaptation and adaptive capacity strategies, policies, and funding initiatives; b) understanding the *determinants and indicators* that best describe a system's adaptive capacity; and c) *operationalization* of adaptive capacity to climate change assessments. Building from these research gaps, the primary aim of my study is to explore the theorized components that characterize a system's adaptive capacity, in particular, the adaptive capacity of water systems in Brazil. Secondarily, this study hopes to gain insight into the scale and operationalization of variables to assess adaptive capacity of water management systems. My research does not seek to better quantify the physical impacts from climate change, but rather assumes a given type and extent of climate stress, and focuses on the broader issue of understanding adaptive capacity to climate change.

2.1.2. Vulnerability, Sensitivity, Exposure, and Adaptive Capacity (Technical Need)

Throughout history, humans have reacted and adapted to climate variability and stress with varying degrees of success (Orlove, 2005), but climate change is anticipated to require a certain amount of planned adaptation. Although climate change is arguably being experienced in regions throughout the world today, many of the impacts are anticipated decades from now. Our ability to understand these inevitable impacts grants us the unique opportunity to plan adaptive responses to future changes. Adger et al (2005) define adaptation as "an adjustment in ecological, social or economic systems in response to *observed* or *expected* changes in climatic stimuli and their effects and impacts in order to alleviate adverse impacts of change or take advantage of new opportunities" (emphasis added).

Studies indicate that waiting to adapt to the experienced impacts of climate change may be much more costly than mitigation efforts and efforts that increase the ability of the system to adapt (Stern, 2006). However, even a thorough understanding of future climate change impacts may not be reason enough for societies to take preventative and anticipatory actions. Modern paradigms like future discounting and political short-sightedness make it difficult to convince decision makers to take proactive measures against future climate-change impacts. Additionally, convincing these decision makers to act specifically in the name of future climate change is even more difficult, due to the unavoidable degree of uncertainty in climate models and forecasts. Still, societies are beginning to consider actions that will lessen the impacts of climate change, and some of the most vulnerable countries are beginning to implement adaptation efforts; as

referenced by initiatives such as the United Nation Framework Convention on Climate Change's National Adaptation Programs of Action (NAPA), among others.[5] It is unclear to what extent policy actions will be carried out solely due to anticipated climate change. Drivers other than climate change are often cited for these preventative actions, such as climate variability and sustainable development initiatives (as discussed above). The underlying motivations for preventative actions are mostly insignificant. Rather, their real and tangible effects on the overall robustness of a system to climate change are much more important. At the center of this issue of increasing robustness and decreasing vulnerability is the concept of adaptive capacity, or the ability of "an affected system, region or community to cope with the impacts and risks of climate change" (IPCC, 2001). Conceptually, the ability to adapt (i.e., adaptive capacity) can be thought of as the overall health of a system or actor (Frankhauser et al, 1999). As with the importance of a person's good health in contributing to sickness prevention, having good health, or high adaptive capacity, is important to preventing the negative impacts of climate change.

Understanding the issue of adaptive capacity to climate change requires a basic understanding of the vulnerability equation.

$V = f\{E(AC); S(AC)\}$ (as adapted from (Yohe and Tol, 2002), where V is vulnerability, E is exposure, S is sensitivity, and AC is adaptive capacity).

Here, vulnerability of a system is a function of its exposure and sensitivity, which in turn are a function of the system's adaptive capacity and resilience. Although the above model has non-linear, multivariate, and case-specific factors, it is evident that a general increase in adaptive capacity is an integral component to decreasing vulnerability. While some portion of vulnerability is inherently natural and unsolvable, or uncorrectable, it is the responsive nature of humans that makes adaptive capacity such an important research subject to study (Füssel and Klein, 2006). Unfortunately, actually measuring adaptive capacity has not proven to be an easy task, because of its latent nature (adaptive capacity will not be fully realized until systems experience climate change stresses) and the large number of theorized determinants of adaptive capacity.

$AC = D_1 \ldots D_n$ (as adapted from (Yohe and Tol, 2002), where AC is adaptive capacity and $D_1 \ldots D_n$ are the determinants of adaptive capacity).

[5] For a more in depth description of NAPAs, visit the UNFCCC's website; http://unfccc.int/national_reports/napa/items/2719.php.

The adaptation epistemic community lists the general categories of adaptive capacity determinants as economic resources, technology, information and skills, infrastructure, institutions, and equity (IPCC, 2001). Yohe and Tol (2002) offer a slightly expanded description of the determinants of adaptive capacity; take institutions as an example, where "the structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed" describe the institutional determinant of adaptive capacity. Others highlight networks, collective action, and social capital as expanded definitions of determining factors (Pelling and High, 2005; Adger, 2003). Yet these descriptions remain relatively vague, and are difficult to assess, because they lack indicators at various scales. Moreover, the respective weights to assign to these determinants are uncertain. Researchers continue to work toward a way to operationalize the measurement of adaptive capacity and vulnerability (Adger et al, 2004; O'Brian K. et al, 2004), but the prioritization of determinants, and the development of indicators within each determinant category remain in their infancy. See *Appendix* 1 for an illustration of the range of determinants as described in the adaptive capacity literature.

Several recent works in the adaptive capacity field have given priority to governance and institutional determinants. Brooks et al (2005) found that of the three determinants tested (i.e., education, health, and governance) at the nation-state level, governance was the most important determinant of adaptive capacity. This finding is consistent with others (Haddad, 2005; Eakin and Lemos, 2006; Ivey et al, 2004), and is depicted in *Figure 1* as one of the salient determinants in the adaptive capacity literature. The underlying idea for institutions and governance as significant determinants of adaptive capacity is that the governance structure associated with a particular sector or resource has the ability to both facilitate and to encourage adaptation, or to serve as a barrier to adaptation. Institutions either allow or impede access to resources, and perhaps even more relevant, they are a uniquely human component of adaptive capacity across various scales (local to global).

The issue of scale is also at the forefront of adaptive capacity studies. Researchers find that the national scale is relevant for investigating adaptive capacities, because the state is the focus of most of the available adaptation funding (Adger et al., 2005; Dixon et al., 2003). However, scholars also recognize critical limitations to national-level adaptive capacity analyses. Indicators at the national level continue to use aggregate data that are oftentimes not indicative of real, on-the-ground conditions that determine adaptive capacity. This is problematic within the context of institutional and governance indicators for two reasons. First, resources are usually managed on lower-level scales, and vary considerably within a given country. Second, impacts of

and actual adaptations to climate change are anticipated to be realized at regional and local scales. Because of these reasons, studies of the institutional and governance determinants of adaptive capacity should be performed at the *appropriate level* to promote equity and efficiency (Adger, 2001 emphasis added); the relevant governance schemes affecting adaptive capacity are highly context-specific. Therefore, researchers propose the consideration of the local and community levels for such assessments (NAST, 2000; Stephen and Downing, 2001). Others offer similar insight regarding global change studies in general, making the case for "a greater emphasis on a more local scale of data gathering and analysis and on bottom-up perspectives on global change issues, as well as more attention to interactions among domains and processes operating at different scales" (Wilbanks and Kates, 1999). Integrating the macro and meso scales "allows studies to be topical, but at the same time holistic" (Turner et al, 1990). Along the lines of this reasoning, the most appropriate level for assessing the institutional and governance components of adaptive capacity of water management is the river basin level.

As argued above, contextualization is inherently necessary for adaptive capacity studies. Still, there is a need for generalization across similar cases and similar *appropriate scales* in order to aid policy formation/implementation and theory development. A review of literature concerning adaptive capacity to climate change reveals crucial gaps between theory and research. While insights, such as the importance of governance and institutional analyses have emerged, specific indicators of these determinants, the operationalization of adaptive capacity, and understanding the appropriate scales to assess adaptive capacity remain high research priorities. For these reasons, sectoral case studies of institutional and governance structures are critical for better understanding adaptive capacity to climate change. To date, empirical evidence of such studies has been limited partly because such variables are not easily measured, and data collection requires substantial fieldwork.

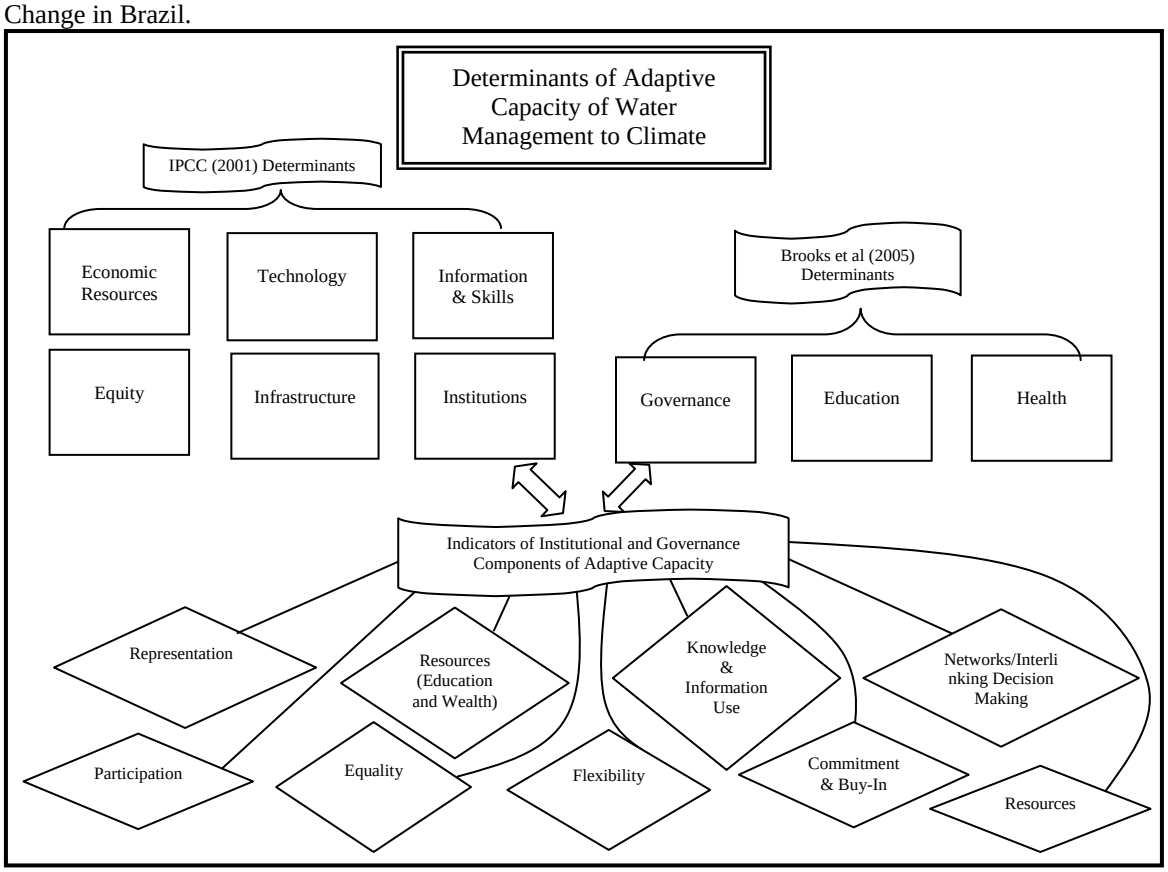
2.2. The Role of Governance and Institutions in Determining Adaptive Capacity

While efforts are underway to increase adaptive capacity of systems to extreme events, adaptive capacity is generally theorized to be a medium (year) to longer-term (decade) concept, and thought to be evident at various spatial scales (Brooks et al, 2005). The multi-scalar, multi-temporal nature of climate change and adaptive capacity add complexity to policy making designed to address them. Focusing on the most *appropriate scale* allows researchers to explore the social components associated with decision making that can positively or negatively influence human-environment outcomes. In other words, governance and institutions serve as important

influences of human-environment interactions. In the case of adaptive capacity, such social constructs serve either to facilitate responses to climate change, and thus lessen negative impacts, or to act as barriers to climate change adaptation. Various indicators of governance and institutional arrangements that would enhance adaptive capacity are assessed within this section.

Guided by the prioritization of institutions and governance determinants of adaptive capacity, *Figure 1* maps the key indicators that will be explored in this study. These indicators represent only one category, albeit extremely influential, of the IPCC and Brooks et al (2005) adaptive capacity determinants. It is also important to note that other determinants of adaptive capacity might be captured by focusing on institutions and governance (e.g., knowledge, income, equity, etc.). Thus, a hybrid model of the IPCC and the Brooks et al adaptive capacity determinants is proposed that focuses on institutions and governance mechanisms. An in-depth analysis of the relevant indicators will reveal valuable insights into the important influences of adaptive capacity.

Figure 1: Institutional and Governance Indicators of Adaptive Capacity of Water Management to Climate Change in Brazil.



Each indicator is an independent variable affecting adaptive capacity to climate change—the dependent variable—through the governance and institutional determinants. It is important to examine how each of these components influences effective governance and institutional arrangements. All of the variables are described in the context of the river basin committee as the appropriate level of institutional and governance adaptive capacity analysis. However, the role of other levels of institutional and governance arrangements (e.g., state, federal, and international levels) cannot be completely ruled out from influencing adaptive capacity of the water management system in Brazil. These other scales are assessed through the interviews with key informants.

1. *Representation*: The extent to which various stakeholder interests are represented has important implications for the level of downward accountability[6] (Ribot, 2003). The level of representation and the established credibility and legitimacy of such representative arrangements serve to measure representation within each river basin. Therefore, the more 'representative' the river basin committee is of its 'constituents', the greater the adaptive capacity.
2. *Participation*: The type and extent of participation from civil society has important implications for downward accountability (Brannstrom et al, 2004). The process (including restrictive barriers) and types of participation vary between river basin basins, and thus serve to measure different levels of participation. The more participatory the committee members, the greater the adaptive capacity.
3. *Knowledge and Information Availability and Use*: The access to, and incorporation of both local knowledge and scientific information is indicative of the efficiency and effectiveness of river basin's decision-making process. The basins receive knowledge and information in different manners, and to varying extents. Therefore, the more knowledge and information availability and use within the basin committee, the greater the adaptive capacity (Lemos, 2007; IPCC, 2001).
4. *Equality*: Similar to representation, the extent to which a diverse set of stakeholders are provided with equal 'say' in the decision-making process, determines the management agenda and priorities. The power dynamics between stakeholders are very different within river basins. Therefore, the greater the

[6] Downward accountability is considered the accountability of the state and higher institutional levels to the lower level actors, such as the river basin scale.

equality within the river basin committees, the greater the adaptive capacity (IPCC, 2001).

5. *Flexibility*: In the face of adversity, such as climate change, the ability of the institution to bend, but not break, and to learn through experience, speaks to its ability to effectively and efficiently manage crises. These attributes are captured by adaptive management theory, and have recently been applied to the climate change field (Arvai et al, 2006). Several factors influence this variable within the river basin committees, such as conflict (and the committees ability to resolve it), stakeholder resistance to progress, and the ability for committee members to change their views. Therefore, the greater the flexibility of the river basin committee, the greater the adaptive capacity.
6. *Commitment/Buy-In*: Believing that the institution and governance structure can be successful in managing resources, speaks to the level of commitment that the stakeholders have to the management model. If an institutional/governance model has been tested and shown to be more efficient and effective, the extent to which stakeholders buy into this model is crucial to its ultimate success. Assuming that the new Brazilian model has the potential to be more effective and efficient than the previous model, the different levels of river basin committee-buy-in will influence adaptive capacity. Therefore, the greater the commitment/buy-in of the river basin committee, the greater the adaptive capacity.
7. *Networks/Connectivity*: Informal networks within and between individuals involved in the institution and governance structure serve to make management more efficient and effective, especially in times of crisis (Adger, 2003; Pelling and High, 2005). Often deemed as "social capital", this concept attempts to capture the various institutional levels and relationships involved with river basin management. Therefore, the greater the network and connectivity between groups and stakeholders involved in management processes, the greater the adaptive capacity.
8. *Experience*: More experience suggests a greater ability to deal with everyday happenings, as well as crisis situations, effectively and efficiently. Experience in water issues, and policy related processes varies greatly within river basins. Therefore, the greater the experience, the greater the adaptive capacity.

9. *Resources*: The levels of financial and human capital are critical for determining the overall success of an institution or governance mechanism. Specifically, education and wealth vary greatly between river basin committee members.[7] Therefore, the greater the resources, the greater the adaptive capacity. (Brooks et al, 2005; IPCC, 2001)

These selected governance and institutions indicators are backed by recent scholarship within the adaptation to climate change field. Eakin and Lemos (2006) have explored the various impacts of governance and institutions on adaptive capacity to climate change, within the context of globalization and the nation state (i.e. regarding state, policy, and administrative capacities). The authors conclude that adaptive capacity is enhanced by increased flows of information and knowledge, elements of democratic decentralization (increased participation and representation), social capital and networks, interactions and negotiations between institutions and stakeholders at various levels, resource availability, and equality. All of these components are either a result of, or facilitated by the relevant institutional and governance mechanisms. Although Eakin and Lemos (2006) describe these indicators at the state level, they are equally relevant at the river basin level in Brazil. As we shall see, the river basin management model is local-regional in physical nature, but it is influenced by local, state, regional, and federal governance and institutional forces.

The nine indicators developed in this study do not come without caveats, however. First, the respective weight to assign to each indicator is challenging to discern, without field-testing their applicability. To address this issue, each indicator is initially assigned an equal weight. Insight gained from interviews serves to verify and/or recalibrate the index, making future adaptive capacity predictions ultimately more accurate and reflective of the on-the-ground situation. Also, the assumption of "if X, than Y" is susceptible to overgeneralization. For example, this study assumes that more knowledge and information availability and use leads to greater adaptive capacity. However, Lemos (2007) finds that climate technology and information can be either a facilitating or hindering factor of more efficient and effective water management in Brazil. To address this issue, the indicators generated by the Watermark data are complemented by qualitative interview data, which will help explain some of the complex interactions of the governance and institutional mechanisms, as Lemos (2007) did with

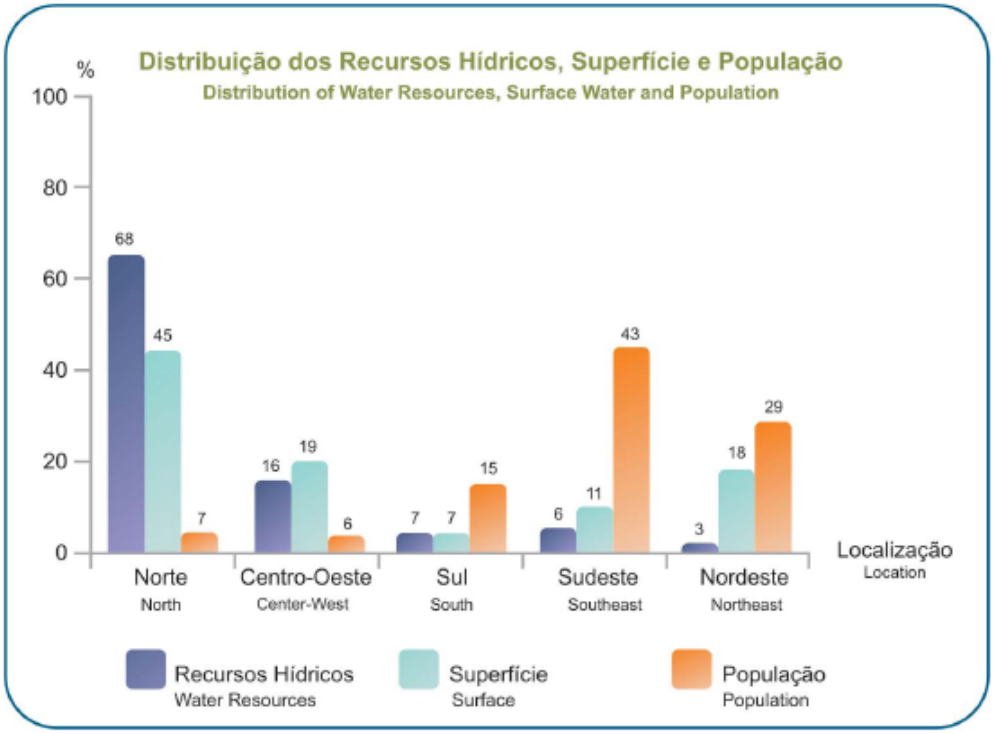
[7] Unfortunately, funding for the committees in the form of bulk water charging (cobrança) is not measured in the Watermark. The inability for the index to depict this type of resource is discussed in Sections 5 and 6.

technology and information. Analysis of these interviews will either verify the predicted adaptive capacities, or expose areas where further emphasis and study are needed. Thus, it is crucial to note that these indicators are used to guide the research, and not be taken as rigid or inflexible. A more in depth discussion of how the indicators are measured within each basin is offered in Section 4.

2.3.1. Water Management in Brazil

It is estimated that Brazil holds roughly 13 percent of the world's surface water (ANA, 2002). However, water availability throughout Brazil is unevenly distributed geographically and demographically. For example, the Amazon region contains nearly 75 percent of Brazil's freshwater, with only 4 percent of the nation's population. The Northeast, which houses over 28 percent of the population, holds less than 5 percent of the nation's fresh water (Formiga-Johnsson and Kemper, 2005). *Figure 2* illustrates the disparities between water availability, geography, and demography in the Northeast and other regions of Brazil.

Figure 2: Brazil's Freshwater Resource Disparity



Source: Agência Nacional de Águas (National Water Agency), 2002

Such geographic and demographic disparities have resulted in water stress in certain regions; especially the Northeast and the Southeast. Climate variability has exacerbated the water shortage problem, particularly in the Northeast. The constant struggle to inhabit this region is well documented, and the number of lives lost over the past two centuries is in the millions (Villa, 2000). The majority of the deaths are related to climate variability and water stress. This long history of drought has made the successful management of water one of the highest priorities of the region. In order to understand the most recent water policy reform in Brazil, one must first take a brief glimpse at the past water management situation.

Historically, water management in Brazil was centralized, inefficient, insulated, and tended to favor certain sectors of the economy and population such as hydroelectricity and elites. The dominant paradigm throughout the 1900s emphasized technological and infrastructural solutions to water stress (Lemos, 2003). Addressing the water and climate problem with technical solutions like cloud seeding (Interview, July 2006; Fortaleza) and massive reservoir projects may have actually made the Northeast more vulnerable to climate variability and change. Such policies essentially ignored many of the root social, economic, and political causes of the problem, such as poverty and unequal representation, while also favoring elite land holders. Most of all, previous water management practices have become culturally entrenched over the past century, and the recent water reform has not easily overcome technological and infrastructure-centered solutions to water management (Lemos and Oliveira, 2004).

Not surprisingly, in the early 1990s the two most stressed regions, the Southeast and the Northeast, were the first to legislate water management reform.[8] The archaic technological and infrastructure-centered policies of the past began to be challenged with new concepts such as sustainability, decentralization, and water pricing (Formiga-Johnsson et al, 2007). Subsequently, Brazil passed a national water reform policy in 1997, echoing much of the spirit of the Southeast and Northeast reforms. This national policy paved the foundation for the institutional and governance mechanisms that are assessed in this study.

2.3.2. National Water Policy Reform

Prior to 1997, the last water policy reform occurred under the Brazilian Water Act of 1934, which placed priority in hydroelectric power uses for a transforming industrial society. Roughly fifty years later, inspired by reforms in the Southeast and Northeast, as well as regional

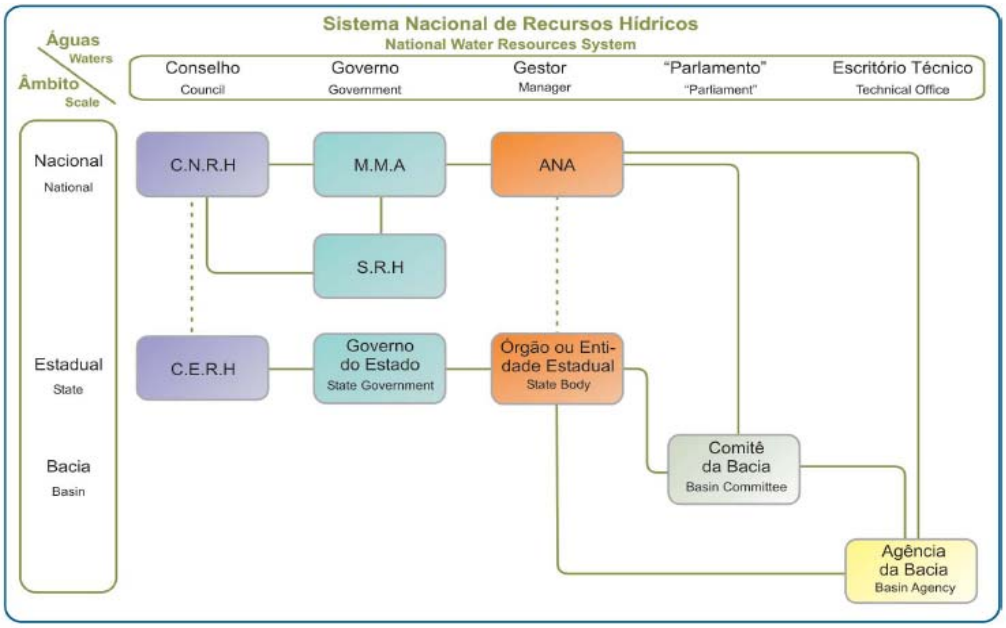
[8] The first state to embark on comprehensive water reform prior to the federal mandate was São Paulo state in the Southeast in 1991. The Northeast state of Ceará followed shortly after São Paulo, in 1993.

differences throughout Brazil and the desire to increase efficiency and economic development, a push for water reform occurred in management circles throughout the country (Porto and Kelman, 2000). In 1988, Brazil's newly reformed democracy provided the medium for such change, and in 1997, Brazil passed Federal Law n° 9.433/97, which established the National Water Resources Policy and National Water Resources Management System (Garrido, 2000).

The National Water Resources Policy brings forward the Dublin Principles of 1992, which strive to achieve sectoral integration, decentralization of management and decision making to the river basin level,[9] increased participation of stakeholders, valuation of water as an economic good, and priority given to humans and animals in shortage situations (Formiga-Johnsson and Kemper, 2005). These five principles drive the national policy, and aim to ensure future access, achieve sustainable development, and protect society from future water crises (Garrido, 2000). Several tools are outlined for the successful implementation of these principles including; water resource plans, classification of water bodies, water-use permits (as designated by the water resource plans for users withdrawing significant amounts of water), water tariff/pricing (also known as cobrança), and a resources information system (Porto and Kelman, 2000).

[9] Decentralization is defined as "any act in which a central government formally cedes power to actors and institutions at lower levels in a political-administrative and territorial hierarchy" (Gibson and Lehoucq, 2003). The process is often touted as more efficient, more equitable, exuding greater stakeholder participation, increasing flexibility of policies, and also maximizing governmental accountability. Decentralization begins with the nation state. As the centralized governing body over a conglomeration of localized communities, decentralization would not occur if the centralized governing body were not in some way benefiting from the process (Ribot, 1999). In many cases, the altruistic goals of decentralization to empower local communities are overshadowed by the underlying motives to decrease rule breaking and increase efficiency of scarce resources. In most cases, the nation state does not desire to lose power and control. In the case of water management in Brazil, the nation state aims to maintain order over water conflicts and perhaps decrease inefficiencies of centralized water management regimes.

Figure 3: Institutional Framework of Brazil's Recent Water Reform



Source: Agência Nacional de Águas (National Water Agency), 2002

The institutional framework, the National Water Resources Management System established by Law n° 9.433/97, includes national and state water councils, national and state water agencies, river basin committees, and river basin agencies (Porto and Kelman, 2000). Although decentralized, the federal level maintains majority power over conflicting situations at lower levels, as well as the policies administered at lower levels (Garrido, 2000). This federal management occurs through an autonomous National Water Agency, Agência Nacional de Águas (ANA) (ANA, 2002). States also play a major role in administering water management, and determining the policy arena in which the river basins will operate (see *Figure 3* and *Table1* for a better understanding of institutional hierarchy and entities' roles).

One of the most innovative aspects of the reform has been to encourage the creation of river basin committees and consortia, which make allocation, project development, and conflict-resolution decisions among interests of federal and state government, stakeholders and users, and civil society. The committees are theorized to be the most representative and influential management mechanism of the water governance system.

The river basin agencies provide the managerial and technical support to the committees, and are supposed be funded through bulk water charges (Porto and Kelman, 2000). Law 9.433 has given states a significant voice in the specificities of the reform and the design of the basin committees (e.g., percentage of stakeholder representation within the committees, implementation of bulk water charging, level of agency and technical support). Thus, each state's institutional

structure and degree of implementation of the national water reform law may vary considerably. The diversity of river basin committee influence and authority make case studies between basins both possible and important for evaluating different adaptive capacities to climate change.

Table 1: Entities Involved in Brazil's Recent Water Reform

Water Resources Management Instruments		
Institutional	Technical	Economic
National Water Resources Council State Water Resources Councils Basin Committees Water Agencies	Water Resources Plans Classification of Water Bodies Grants Water Resources Information Systems	Water Charges and Effluent Dilution Charges

Source: Adapted from Agência Nacional de Águas (National Water Agency), 2002

2.4. Case Study Analysis

This study of adaptive capacity builds on a growing trend in the global change research community towards case studies. The primary purpose of this research is not for generalizability, but rather, to assess two unique case studies. Still, as previously indicated, there is a call for a broader, systematic approach for analyzing adaptive capacities. Therefore, a secondary element of this research works to further operationalize the concept of adaptive capacity; starting first with water management within the two water basin case studies, moving to water management in Brazil, then to water management in general, and finally on to broader theoretical adaptive capacity considerations.

I pursue a case study approach here for both practical and theoretical reasons. From a practical perspective, many policy decisions are based on comparing costs and benefits of similar cases; either historical or currently occurring cases. Therefore, establishing cases from which policy decisions can be made helps to guide questions such as resource allocation, welfare, and equity. Cases are also useful in refining theory by examining complexities for future analysis (Denzin and Lincoln, 2000). A further argument can be made that if performed at the *appropriate scales*, case studies can offer some generalizability to the broader research agenda.

A word of caution is necessary here. It might be argued that the merits of case-study-based analyses are too specific, and generalization oversteps the parameters of the cases' boundaries. While cases should not be assessed for the sole purpose of generalizability (each case is unique and interesting in its own right) (Denzin and Lincoln, 2000), the objective of the researcher should be to design research that allows for the most comparability between cases.

Specific to adaptation to climate change literature, scholars argue that "case studies provide a means of 'ground truthing' the macro-level vulnerability profiles. In addition, they can be used to identify local circumstances and institutional factors that are important in terms of vulnerability, yet do not come across in the macro-indicators" (O'Brien et al, 2004). Adger et al, (2004) also stress the importance of smaller-scale case studies as verifying adaptive capacities predicted at nation-state levels. Thus, not only are case studies validated within the global change research community, there is a specific need for case analyses of adaptive capacity, vulnerability, and resilience to climate change. The qualitative data assessed in this study, in combination with the quantitative data of the Watermark, begins to build a foundation for future comparisons between the other sixteen basins for which Watermark data are available.

3. BACKGROUND

3.1. Northeast Brazil

The Northeast is composed of nine states, and is generally considered the poorest region in Brazil. In the 2000 census,[10] the population of the Northeast was almost 48 million, which represented over 25 percent of the nation's population at that time. Of these inhabitants, approximately 33 million were classified as 'urban' dwellers, and nearly 15 million as 'rural' dwellers. The Northeast has one of the most rural populations throughout all of Brazil; many of whom are poor farmers. Illiteracy has decreased throughout Brazil from 32.9 percent in 1970 to 13.6 percent in 2000. While similar improvements have been made in the Northeast (from 53.8 percent to 26.2 percent), the region continues to have the highest illiteracy rate in the country. Many of the rural parts of the Northeast still lack proper basic sanitation infrastructure. For example, in 2000, the percentage of the rural Brazilian population without access to sanitation was 35.3 percent, while the same figure in the Northeast was almost double that number, 60.5 percent. Education rates are also indicative of the level of poverty that persists in the Northeast. The rate of people over 15-years-old with less than four years of schooling in the Northeast was 42.5 percent in 2000, while the national rate was 27.8 percent. Also striking is the proportion of the inhabitants in the Northeast that have children under 14-years-old, make half of the minimum salary, and have less than four years of schooling. This figure was 43.1 for the Northeast and 22.1 for Brazil; again these regional figures represent the highest of any region in the country.

The Northeast's well-documented history of hardship associated with extreme climate variability and stress exacerbates its impoverished conditions. Throughout the past several centuries, inhabitants in the Northeast have experienced numerous famines, migrations, and massive deaths associated with water stress (Villa, 2000). Although regional forecast models are only beginning to be sharpened for Brazil, preliminary data indicate that the Northeast will experience annual average temperature increases, decreases in precipitation, and increases in frequencies and magnitudes of extreme events (Nobre et al, 2006; Krol and Bronstert, 2007, IPCC, 2001). The specific climate-related concerns vary slightly between the two river basins in this case analysis, but both are expected to experience increased climate stresses, making them vulnerable to future climate change.

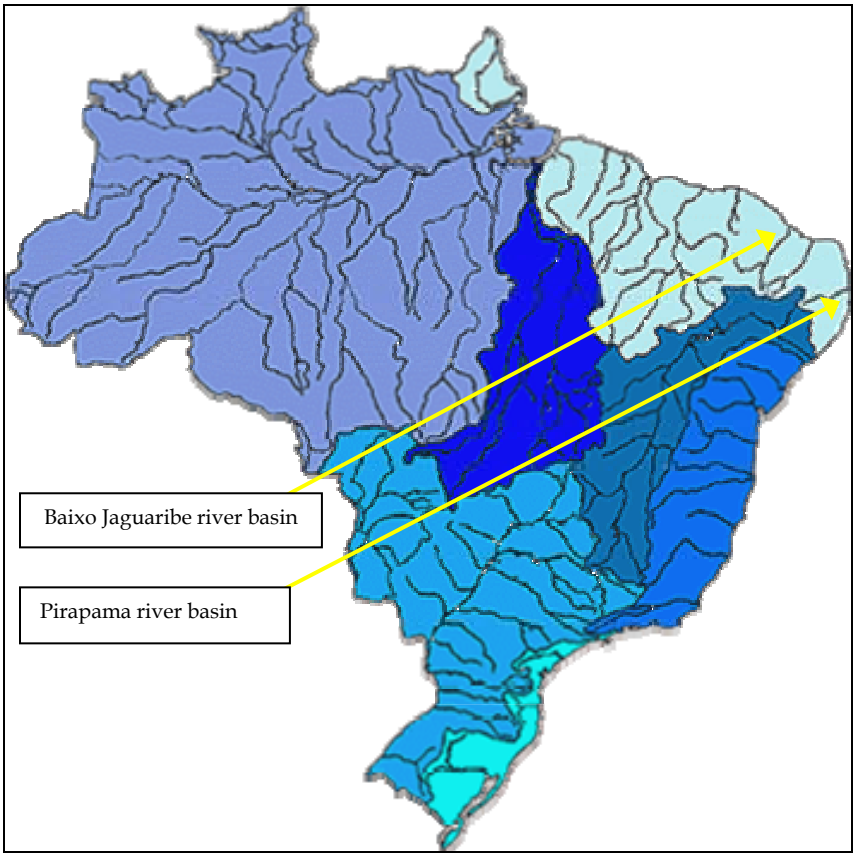
[10] The demographic information contained in this section was acquired from the Brazilian federal government, and can be accessed via the Instituto Brasileiro de Geografia e Estatística (IBGE) website at; http://www.ibge.gov.br/home/, or in English at; http://www.ibge.gov.br/english/.

3.2.1. Ceará and the Baixo Jaguaribe River Basin

Ceará is one of the poorest states in the poorest region of Brazil. Of its 7, 431,597 inhabitants, 2,117,200 are considered rural dwellers.[11] The Jaguaribe river basin (of which the Baixo is a part), is located in the state of Ceará. The basin falls within the larger Atlantic hydrographic region (see *Figure 4*), and its total 72,560 km^2 comprises almost 50 percent of the state (Formiga-Johnsson and Kemper, 2005). The dry, drought-ridden climate associated with the river basin is referred to as the "sertão", or "hinterland", with most of the rainfall occurring between December and March (what is referred to as the "winter" regionally, but actually corresponds with Brazil's summer months) (Lemos and Oliveira, 2004). The basin is also situated in the region called the "drought polygon", and the climate is considered "semi-arid"; receiving between 500 and 900 mm/year with evapotranspiration rates sometimes exceeding 2000 mm/yr (Krol and Bronstert, 2007). The high evapotranspiration rates from low surface permeability and high temperatures make water a scarce resource in the Baixo Jaguaribe; as indicated by its intermittent nature and lack of groundwater resources (Lemos and Oliveira, 2004). Historically, inhabitants of the river basin have relied upon infrastructure (i.e. reservoirs, canals, etc.) for storage and transfer of water during periods of climate stress. *Figure 5* depicts one of the three reservoirs, Castanhão, which is the largest and most recently completed of the three. In addition to meeting the needs of the Jaguaribe river basin, these large reservoirs also provide the main source of water for Fortaleza, the largest city in the state, located outside of the water basin. A series of canals has been built to provide Fortaleza with water, and a new canal is currently under construction. These water transfers have proven to be controversial water management issues in Ceará (Interview, July 2006; Baixo Jaguaribe basin).

[11] See Note 10, IBGE.

Figure 4: Brazilian Hydrographic Regions (highlighting the Baixo Jaguaribe and Pirapama river basins within the Northeast Atlantic hydrographic region)



Source: Adapted from the Brazilian Cacti Project, 2007(www.brcactaceae.org/hydrography.html)

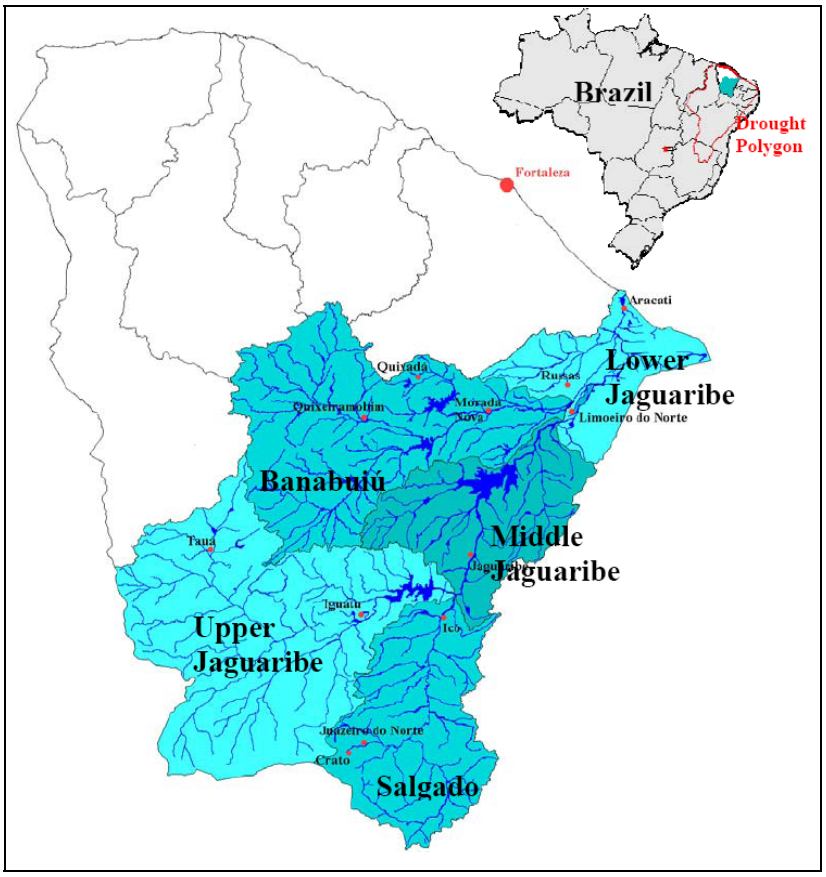
Due to its size, the Jaguaribe has been divided into five hydrographic regions. The Baixo Jaguaribe, or Lower Jaguaribe, is one of these sub-basins. *Figure 6* depicts the orientation of the river basin, with the Baixo Jaguaribe as the northeastern-most portion that feeds into the Atlantic Ocean. The Baixo Jaguaribe has an area of 8893 km^2, and contains 9 municipalities and 207 reservoirs (of various sizes) (Formiga-Johnsson and Kemper, 2005).

Figure 5: Recently Completed Castanhão Reservoir: a) view of the dam, from atop of the dam; b) view of the Jaguaribe river valley below the dam and the reservoir, facing northeast towards the Baixo Jaguaribe river basin; c) view of the reservoir, facing southwest towards the Alto Jaguaribe river basin

a) b) c)

Source: Author

Figure 6: The Hydrographic Sub-basins of the Jaguaribe River Basin



Source: Formiga-Johnsson and Kemper, 2005

The main uses of water in the Baixo Jaguaribe river basin are human consumption (by the municípios, or municipal water suppliers), irrigation by farmers, and larger scale agri-business (Lemos and Oliveira, 2004). Irrigation is particularly water intensive, as evidenced by the inefficient growing of rice. Conflict between various interests is primarily due to water quantity

during periods of climate stress, but new agribusiness practices are creating concerns about water quality. Particularly, shrimp farming in the Baixo Jaguaribe is an increasingly contentious issue among water stakeholders (Interview, July 2006; Baixo Jaguaribe basin).

Water management, and the recent water reform, plays an integral role in addressing the key issues of water conflict within the basin (i.e., inter-basin transfers to Fortaleza, intra-basin allocation, water quality concerns, and extreme flooding, among others). As with most basins, there are numerous entities involved with water management in the Baixo Jaguaribe river basin. At the federal level is ANA, along with the drought relief and prevention agency, the Departamento Nacional de Obras contra as Secas (DNOCS), which focuses mainly on infrastructure (i.e. reservoirs). Prior to the reform, DNOCS was the main body responsible for water management of river basins in Ceará (Formiga-Johnsson and Kemper, 2005). The most unique component in Ceará is the state water management company, Companhia de Gestão dos Recursos Hídricos (COGERH). No other state in Brazil has such a similar water agency. Along with the guidance and funding from the World Bank, COGERH was created to provide technical support for the river basin committees, administer and collect bulk water charges (which is a basin-committee responsibility in other states), and take over some of the responsibility of infrastructure maintenance previously performed by DNOCS. The formation and eventual self-financing quality of COGERH has created a more centralized nature of water management in Ceará than in other states in Brazil (Formiga-Johnsson and Kemper, 2005). However, it has also allowed for the implementation of a uniquely participatory decisionmaking system in the state (Lemos and Oliveira 2004). Also important at the state level are the state water secretariat, Secretaria dos Recursos Hídricos (SRH), which assists COGERH in planning and implementation, and the state meteorological agency, Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME), which supports and advises COGERH and the river basin committee.

Another unique component of Ceará's water management, and the Jaguaribe river basin in particular, are "user commissions". Emerging from the need for better-coordinated management after the drought period of 1992-4, these 37 commissions (one large user commission ruling over three major reservoirs, and 36 commissions ruling over smaller strategic reservoirs) are responsible for integrated management of the reservoirs in the Jaguaribe river basin (Formiga-Johnsson and Kemper, 2005). This institutional reordering resulted in a greater focus on the infrastructure as the unit of management, and less of an emphasis on the physical basin, or hydrographic unit. Only after these commissions began to operate did the Jaguaribe river basin committees emerge.

The river basin committees are by function, slightly less influential than in other states. Somewhat weakened by COGERH and the user commissions, the committees serve to resolve conflict, facilitate river basin master plans, and set broader management guidelines (Formiga-Johnsson and Kemper, 2005). State leaders have recently attempted to increase the power of the committees vis-à-vis the commissions, but the influence of the committees remains marginal (Interviews, July 2006; Baixo Jaguaribe basin). The Baixo Jaguaribe basin committee was created in 1998, and like the other four committees in the greater Jaguaribe region, it distributes membership in a 30/30/40 model among users (agriculture, irrigation, water sanitation, water companies, and other industries), civil society (NGOs and academics), and public entities (municipal officials and state and federal government officials), respectively. Specifically, there are 14 user representatives, 14 civil society representatives, and 18 public representatives (nine from each the municipal level and state and federal levels), for a total of 46 committee members (Marca d'Água, 2003).

3.2.2. Pernambuco and the Pirapama River Basin

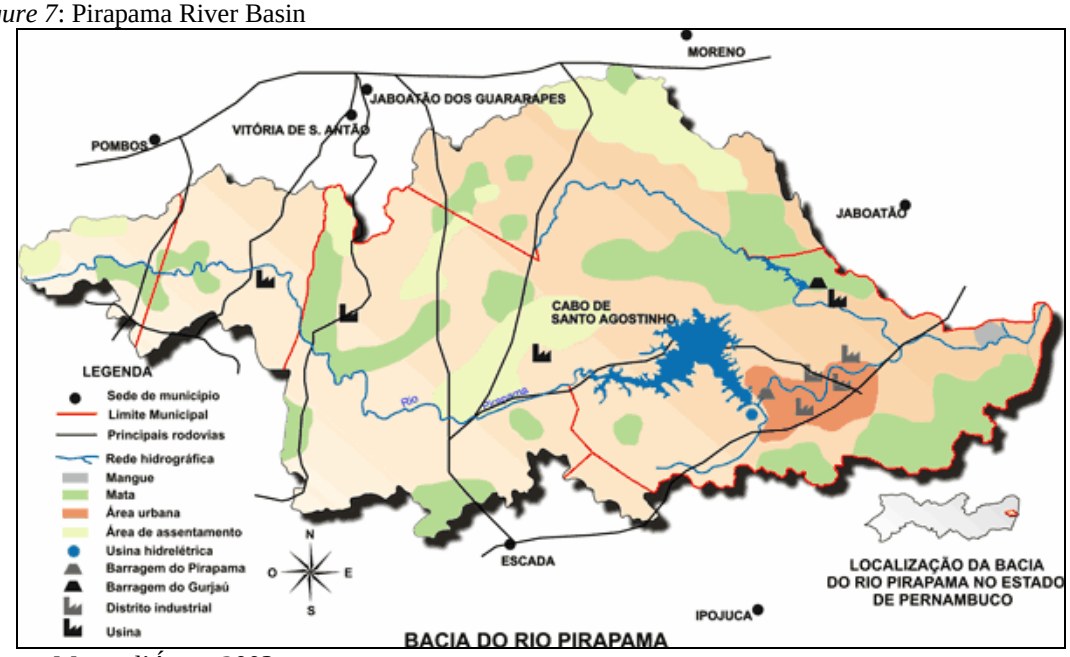
Located southeast of Ceará, the state of Pernambuco has 7,929,154 residents. The population is slightly more urban than Ceará, with 6,054,901 urban dwellers, and 1,874,253 rural dwellers.[12] The Pirapama river basin is located in the eastern-most section of Pernambuco (see *Figure 7*). Like the Jaguaribe River, the Pirapama flows into the Atlantic Ocean, and is included within the Northeast Atlantic hydrographic region (see *Figure 4*). The Pirapama falls within the "Zona da Mata", or the narrow strip of Atlantic forest that runs north-south along much of the Northeast's coast line. This area historically receives more rain than the Baixo Jaguaribe river basin, and it is not considered part of the "drought polygon". However, situated adjacent to this thin strip of land is the "sertão"; the semi-arid region of the Northeast that falls within the "drought polygon". *Figure* 8 offers several images of the Pirapama basin and surrounding areas, which represent starkly different landscapes than those of the Baixo Jaguaribe basin.

Unfortunately, the "Zona da Mata" has not received as much attention from the climate modeling community, because the region is not associated with the same historic climate variability and drought as the semi-arid regions of Ceará. Still, the basin experiences occasional drought periods (Interview, August 2006; Pirapama basin), and climate change is expected to negatively affect the region. The main climate stress on the basin has historically been extreme flooding, which in combination with population stresses and erosion, raise significant water-

[12] See Note 10, IBGE.

quality issues within the basin (Interviews, August 2006; Pirapama basin). Additionally, like the Northeast in general, the climate is expected to warm, become drier, and experience more intense precipitation events (IPCC, 2001; Nobre et al, 2006; Krol and Bronstert, 2007). The basin's lack of experience in dealing with extreme drought periods could make it particularly vulnerable to such future climate changes.

Figure 7: Pirapama River Basin



Source: Marca d'Água, 2003

At 600 km^2, the Pirapama river basin is significantly smaller than the Baixo Jaguaribe basin. The main water use within the basin is human consumption. Four out of the seven municipalities included in the basin are considered part of Metropolitan Recife Region (MRR), the largest city in Pernambuco and also the state capital. This makes the Pirapama basin very important, for it is the primary source of freshwater for the MRR. Other major water users are agri-industry, mostly alcohol distilleries, and agriculture, mainly sugar cane irrigation. (Marca d'Água, 2003). Two dams have been constructed over the past century (the most recent completed in 2002), and serve to store water for Recife and the surrounding municipalities, as well as provide hydroelectric power for the region (Marca d'Água, 2003).

Figure 8: Images of the "Zona da Mata" and Sugarcane Agriculture within the Pirapama River Basin and Surrounding Areas

Source: Author

Again, the main water-related issues are centered upon water quality. Flooding and heavy industrial use within the river basin has created significant environmental concerns (Interview, August 2006; Pirapama basin). Such concerns make sustainable development a priority for the basin and the respective management institutions. The desire to promote sustainable development within the basin led to the formation of the Pirapama Project, in 1997, which pushed for multi-disciplinary, cross-institutional, and participatory management of water within the basin.[13] Federal water reform occurred during the same year, and as a result, many of the same principles and goals of the Pirapama Project were incorporated into the formation of the river basin committee in June 1998. Pernambuco's environmental agency, the Secretaria de Ciência, Technologia e Meio Ambiente (SECTMA), and the water resources agency, the Companhia Pernambucana de Recursos Hídricos (CPRH), helped establish the river basin committee. Two other important state actors are the science and technology agency, Instituto Tecnológico do Estado de Pernambuco (ITEP), and the state water supply and sanitation company, Companhia Pernambucana de Saneamento (COMPESA).

The committee is structured differently than the Baixo Jaguaribe river basin, with civil society representing 50 percent, federal and state 28 percent, and municipalities 22 percent, totaling 32 members (Marca d'Água, 2003). Unlike the Baixo Jaguaribe, the "users" are considered part of civil society. The evolution of river basin management and water reform within Pirapama is clearly not as comprehensive and well-documented as that of the Baixo Jaguaribe river basin. Also, the institutional and governance arrangements are not as intricate. In comparison with the Baixo Jaguaribe basin, this situation, combined with the more decentralized

[13] An English description on the history and functioning of the Pirapama Project can be found at; http://www.cprh.pe.gov.br/pirapama/index-english.html#5.

water management structure have resulted in a more well-defined and potentially more influential role for the river basin committee with in the water management system.

4. METHODS AND FRAMEWORK

4.1. Research Methods

Data for this study were obtained through two means. First, the 2005 Watermark survey was analyzed to establish proxy questions for each of the nine indicator categories (see Section 4.2 for an in depth explanation of the proxy question selection process, and how rankings were generated for the adaptive capacity index). The Watermark questioned all of the committee members in eighteen river basins, including the Baixo Jaguaribe and Pirapama basins, from 2004 to 2005. The survey was conducted by Watermark project coordinators and field assistants in a structured format.

I conducted semi-structured interviews in each basin during a six-week period in July and August 2006. The interviews targeted key informants involved with the water management system, but not strictly river basin committee members. The interviewees were identified through colleagues involved with the Watermark, and through "snowballing" techniques. Interviewees included federal and state agency representatives, municipality officials, technical personnel/scientists, farmers, NGO representatives, and bulk water users. In total, I performed 18 interviews; 10 in the Baixo Jaguaribe river basin, and eight in the Pirapama river basin. All of the interviews, but one, were conducted in Portuguese. Prior to the interviews, I obtained written consent to record all of the conversations. During the interviews, I wrote notes in English and Portuguese. Subsequent to my return to the United States, I hired assistants to transcribe most of the interviews and used Nvivo software to code the interviews for analysis.

The majority of the meetings took place at the interviewees' offices, but several of the interviews occurred in peoples' homes, hotel lobbies, or while traveling in a car. I was accompanied by a field assistant during the first seven interviews in the Baixo Jaguaribe. The assistant was also a key informant involved with water management. On several occasions, I allowed him to help clarify my questions when the interviewees needed further explanation. I utilized "snowballing" techniques to obtain interviews with several individuals in the Baixo Jaguaribe. I did not hire a field assistant in the Pirapama basin because the basin was small enough to coordinate my own logistics. Finally, I established the interviews in Pirapama solely from "snowballing".

My interviews served both to calibrate the predicted indicators derived from the Watermark, and also to add specific information about climate change, vulnerability and adaptive capacity (which were minimally represented in the Watermark survey). Additionally, the

interviews verified and complemented committee members' responses from the Watermark with perspectives from key informants both inside and outside of the river basin committees. Every interviewee was asked questions specific to how the basins managed climate stress before and after the water reform, in order to verify predicted adaptive capacities. While some of the same questions were asked to all of the individuals, the questions were tailored specifically to the particular interview, in order to obtain the most pertinent information. As much as possible, I attempted to "triangulate" answers to assess the validity of responses between participants. *Appendix 2* provides a list of the general interview questionnaire template.

I was fortunate to observe and participate in a water management meeting in each of the river basins. The Baixo Jaguaribe meeting served as a two-day educational workshop for new basin committee members, and was organized by the state water management company, COGERH. In Pirapama, I participated in a seminar reporting on river basin committee activities throughout the state of Pernambuco. The seminar was administered by the state water supply and sanitary company, COMPESA. Both of these water management meetings helped to educate me about the current status of the committees, and strengthened the Watermark data verification process. The meetings also served as opportunities to interview various participants, and to "snowball" with new contacts.

One must recognize several potential sources of error this methodology. First, there is a reasonable chance for bias in the interviewees' responses. They may wish to make their river basin appear better managed than it really is. Interviewees may also perceive the possibility of personally gaining, or of having their profession gain by providing a less accurate response. However, because of the limited risk and low sensitivity of the questions, the interviewees most likely did not perceive there to be a lot at stake; thus the incentive to falsify their responses was probably minimal. Requiring participants to provide written consent may have also made them respond less candidly to my questions. This same logic applies to having my field assistant present during some of the Baixo Jaguaribe interviews. However, the field assistant was not a "gate-keeper", and may have actually helped the interviewees perceive me as more trustworthy; leading them to have answered more truthfully than if the assistant had not been present.

It is important to note that my interviews involved current and past committee members, as well as non-committee members who have an interest or stake in water management. The Watermark data that predicts adaptive capacities, however, only applies to the committee members who served during the 2004-2005 period. Such a discrepancy in "research universe" is acceptable in this situation for several reasons. First, the most appropriate level for water systems' adaptive capacity analysis in Brazil is anticipated to be the river basin committee; thus the

indicators can be justifiably derived from basin committee insights. Still, the committee members' views may not be congruent with other stakeholders who are not on the committee. For this reason, it is appropriate to expand the "research universe" beyond the basin committee itself, to the larger community affected by water management decisions within the river basins. Second, the static temporal nature, and the quantitative responses of the Watermark data are complemented by the more recent, and more in depth qualitative interview data.

4.2. Framework for Assessing Adaptive Capacities

The initial predictions of the river basins' adaptive capacities are based on questions from the Watermark survey. I selected questions from the survey to serve as proxies for each of the nine indicator categories described in Section 2.2. Maximum and minimum scores in each indicator category for the initial adaptive capacity predictions were 10 and 0, respectively (totaling a maximum score on the index of 90). The number of questions for each category ranges from 1 –19. Therefore, questions within an indicator category may weigh into the overall indicator score more heavily than questions in another indicator category. For example, the "resources" indicator contains only two data points (survey questions), while the "representation" indicator contains 16. Thus, each question within the "resources" indicator counts for 1/2 of the 10 possible points, equaling five points for each question, and each question within the "representation" indicator counts for 1/16 of the 10 possible points, equaling 0.62 points for each question. It is difficult to know the optimal number of questions needed to represent the indicators. Arguments for both greater and fewer indicators are logical. More indicators could help to cancel-out erroneous or non-representative results, and thus lead to a more accurate understanding of the indicator. On the other hand, having more indicators could also dampen more critical proxy questions, thus leading to an inaccurate indicator prediction. My solution to this methodological dilemma is to include as many questions for each indicator as possible, with the caveat that the questions do not double count results. Using the interview data, the index will also be analyzed to obtain a better understanding of priorities to assign to indicators and proxy questions.

Proxy questions derived from the Watermark for the adaptive capacity index generally pertain to questions for which a higher percentage response is designated a higher score. For example, within the 'participation' indicator, one of the questions is: "Have you ever taken part in a community activity about water, outside of the committee's activities?" The percentage of the committee members answering 'yes' is used to calculate the total percentage of possible points

'earned' from that question. Thus, if 63 percent answered 'yes', then the basin earned 63 percent of the points possible for the question. Each question's score is then added to the total of the other questions within that indicator category, for a total possible score of 10 for the respective indicator. It is important to remember that each indicator category does not have the same number of questions; resulting in questions being weighed more heavily than others in the index predictions.

A detailed summary of how every proxy question was scored in this study is provided in *Appendix 3*. The following broad assumptions guided the scoring process for predicting the adaptive capacity index, as indicated in Section 2.2. Each indicator relates to the river basin committees' perceptions of their collective assessments of their respective committees.

1. *Representation*: The more representative, the higher the adaptive capacity.
2. *Participation*: The more participatory, the higher the adaptive capacity.
3. *Knowledge and Information Availability and Use*: The more knowledge and information available and used, the higher the adaptive capacity.
4. *Equality*: The more equal distribution of power and agenda setting ability, or the less inequality, the higher the adaptive capacity.
5. *Flexibility*: The more flexible, the higher the adaptive capacity.
6. *Commitment/Buy-In*: The more commitment/buy-in, the higher the adaptive capacity.
7. *Networks/Connectivity*: The more networked and connected with other institutions and stakeholders, the higher the adaptive capacity.
8. *Experience*: The more water management and public policy experience, the higher the adaptive capacity.
9. *Resources*: The more resources (wealth and education), the higher the adaptive capacity.

5. RESULTS & ANALYSIS

5.1. Watermark Survey

This study uses Watermark survey data to predict adaptive capacities of river basins to climate change. The nine river-basin level indicators are discussed above, and the results of the index analysis of the indicators are displayed below in *Table 2*.

Table 2: Adaptive Capacity Indicators of Brazilian Water Management

																	Score
Representation (R)																	
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	
Baixo Jaguaribe	7.22	7.58	5.88	6.68	5.59	5	6.29	73.2	53.7	85.4	20.7	82.8	27.6	17.2	41.4	58.6	5.644
Pirapama	7.18	7.5	5.14	6.96	6.36	6.48	5.44	71.4	17.9	50	41.2	82.4	70.6	23.5	29.4	70.6	5.673
Participation (P)																	
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	
Baixo Jaguaribe	41.4	24.1	44.8	51.7	6.9	17.2	10.3	36.6	76.1	82.9	56.4	43.2	82.8	78	68.3	7.73	4.988
Pirapama	35.3	17.6	41.2	52.9	5.9	23.5	11.8	42.9	60.7	85.7	60.7	50	88.2	85.7	53.6	7.11	4.918
Knowledge and Information Use and Availability (K)																	
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	
Baixo Jaguaribe	8.32	7.75	7.46	8.35	8.45	80.5	51.2	7.3	22	92.7	93.1	51.7	79.3	75.9	79.3	62.1	62.1	82.8	62.1	7.487
Pirapama	7.83	7.19	8.25	8.22	8.54	78.6	50	3.6	28.6	7.1	94.1	88.2	47.1	47.1	70.6	100	70.6	82.4	35.3	6.985
Equality (E)																	
	E1	E2	E3	E4	E5	E6	E7	E8									
Baixo Jaguaribe	13.8	20.7	72.4	37.9	51.4	75.9	31	86.2									4.866
Pirapama	41.2	11.8	47.1	52.9	30.4	82.4	52.9	70.6									4.866
Flexibility (F)																	
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12					
Baixo Jaguaribe	42.1	73.7	100	89.5	73.7	52.6	73.7	52.5	69	56.1	5.59	7.67					6.796
Pirapama	53.8	61.5	76.9	7.7	92.3	38.5	76.9	53.6	94.1	50	6.06	7.33					6.160
Commitment/Buy-In (C)																	
	C1																
Baixo Jaguaribe	6.83																6.830
Pirapama	7.43																7.430
Networking/Connectivity (N)																	
	N1	N2	N3	N4	N5	N6	N7	N8									
Baixo Jaguaribe	96.6	31.7	2.4	7.3	14.6	9.8	48.8	46.3									3.219
Pirapama	76.5	25	0	21.4	25	3.6	50	67.9									3.368
Experience (X)																	
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14			
Baixo Jaguaribe	22	19.5	22.4	4.9	34.1	12.2	65.9	4.9	22	17.1	22	40	3.28	9.61			2.68607
Pirapama	17.9	28.6	25	17.9	57.1	28.6	60.7	28.6	32.1	50	39.3	50	4.4	11.6			3.92036
Resources (S)																	
	S1	S2															
Baixo Jaguaribe	44	29.3															3.665
Pirapama	78.6	60.6															6.960
TOTAL (out of 90)																	
Baixo Jaguaribe																	**46.181**
Pirapama																	**50.279**

The indicators illustrate that the Pirapama basin (46.18) has a combined score of roughly four points greater than the Baixo Jaguaribe basin (50.28). While both basins' scores are strikingly similar for the representation, participation, equality, and networking/connectivity indicators, there exist differences in the remaining five measures that are worth noting.[14] The greatest difference can be found in the resource indicator, within which the Pirapama basin (6.96) ranks over three points higher than the Baixo Jaguaribe basin (3.66). This difference is almost as large as the differences in total scores between the two basins. The Pirapama basin also ranks higher than the Baixo Jaguaribe in both commitment/buy-in and experience. In commitment/buy-in and experience, the Pirapama basin scores 7.43 and 3.92, respectively, and the Baixo Jaguaribe scores 6.83 and 2.69, respectively. The Baixo Jaguaribe (7.49) has a greater ranking in knowledge and information use and availability than the Pirapama (6.98). Similarly, the Baixo Jaguaribe (6.80) is greater in flexibility than the Pirapama (6.16).

5.2. Key Informant Interviews

The adaptive capacity index suggests moderate levels of adaptive capacity for both basins, with the Pirapama basin's adaptive capacity predicted slightly higher than the Baixo Jaguaribe's. Key informant interviews were conducted to assess whether these adaptive capacities have increased or decreased since the water reform, and also to test the on-the-ground validity of the predicted adaptive capacities from the Watermark with respect to the level of importance of the institutional indicators within each basin.

5.2.1. Response to Climate Stresses before and after the Reform

Has adaptive capacity increased in both of these basins since the recent water reform? To answer this question, I asked each of the key informants about their perception of how successfully the water management system responded to periods of climate stress (i.e., droughts and/or floods) before the reform and after the reform. In each interview, the individuals noted improvements in water management since the reform. While the general message from the interview data illustrates increases in adaptive capacity to climate change, the extent to which capacity has increased, and the reasons provided for these increases, differs in each basin.

[14] These differences should not be interpreted as "statistically significant". The adaptive capacity index in this study serves only as a descriptive gauge, and not as a tool for statistical comparison. Such a statistical tool for comparison is an important concept for researchers to consider in future studies of adaptive capacity.

Baixo Jaguaribe

The water reform occurred in Ceará and the Baixo Jaguaribe basin in 1993, before the federal water reform law in 1997. In the 1980s, individuals, especially poor farmers, were severely displaced by droughts. Situations like this have not gone away completely, but have drastically decreased (Interview, July 2006; Baixo Jaguaribe basin). Most informants for this study were confident that the basin is more prepared for climate change today than before the reform. When probed, they reasoned that even though they are not often discussing it directly, the forum for discussion and the information available today makes the Baixo Jaguaribe more sensitive to the consideration of climate change in the future. One interviewee was slightly more critical, suggesting that while management has improved since the 1990s, small farmers remain as vulnerable as they were before the reform, because the farmers still do not have money or access to bank loans. Another interviewee provided an example of the mixed success of the new management system. He recounted that in 2001, the committee mistakenly thought that there was more water available than really existed, and as a result, there were significant water shortages. In the opinion of another interviewee; "The law on paper is different than the law in practice…but still it is a beautiful law and advances things more than they were previously." All interviewees shared similar accounts of improved water management during climate stress periods since the water reform, but cautioned that there remains significant room for further progress regarding water management within the basin. The question remains, is the improvement due to institutional mechanisms, specifically those created by the reform, or is the increased success better attributed to other, non-institutional factors?

Most of the interviewees pointed to some aspect of the institutional reform as a source of improved management during climate-stress periods. Prior to the reform, DNOCS relied solely on technical expertise to decide when to release water from the reservoirs; a process that is now performed more effectively with social input by the commissions and committees, with priority allocation devoted to human consumption (as opposed to the previous priority given to irrigation) (Interview, July 2006; Baixo Jaguaribe basin). Many of the informants emphasized that the change in the federal law, which placed a priority on human consumption, has made people in the basin less vulnerable. As one interviewee stated when referring to the priority on human consumption; "Now in terms of a collapse, people suffer less."

Moving from the federal to the state level, many of those interviewed stressed the critical role that COGERH has played in improving water management. I found it common for the interviewees to associate the term "water reform" directly with the formation of COGERH, when

a relationship with civil society and the local basins began to evolve. In 1994, the year COGERH was instituted, there was a large drought, and water was allocated relatively successfully by the new water management company. One interviewee went as far to say that the creation of COGERH resulted in "an organic bond with society." Interestingly, the committee that is meant to connect civil society with water management was not formed until four years later in 1998.

Also at the state level, the meteorological agency, FUNCEME, has been given credit by several of the interviewees for the success of water management during droughts and floods. Citing data that was recently gathered from his agency, a FUNCEME meteorologist pointed to decreased vulnerability in the region during El Nino years in 1998 compared to 1983. The new institutional management structure has given FUNCEME more channels through which to disseminate their climate information.

The committee's role in improving water management seems to be less clear. Only two interviewees specifically described improved management due to the committee's actions. One person recalled the drought of 1998, and the committee's ability to successfully negotiate conflict between stakeholders during this period. Another key informant claimed that merely the idea of the discussion and participation within the committee has improved water management, noting that before the reform, it was closed, and only a few people had the power. After the reform, societal actors have gained an important forum, which the interviewee claims has made them more capable of dealing with future climate stress. Most of the interviewees, however, were cautious to attribute gains directly to the existence of the committee. In most cases, people were critical of the small degree of power that the committee has been given by the state. Interestingly, some described this as a fault of the committee, rather than the state, for not proactively demanding a stronger role in water management within the basin.

Finally, over half of the interviewees specifically described infrastructure as improving water management. Particularly, as one person described, problems with drought over the past 15 years have significantly decreased due to the construction of Castanhão and other reservoirs and canals. Water storing capacity has more than doubled since the early 1990s. The canal currently under construction from Castanhão to Fortaleza is generally viewed as an improvement in water management. Many interviewees envision this as one of several projects that will eventually take water to the water-deficient regions of North and Northwest Ceará. However, several of the interviewees described serious equity issues raised by taking water from the poor farmers within the basin and transferring it to the wealthier city dwellers living outside of the basin. It is important to note the difficulty in attributing these interpretations of improvements during droughts and floods to the physical infrastructure itself, versus improvements in the management

of this infrastructure (which would point again to institutional and governance factors contributing to the improvements). In the end, the increased capacity of the Baixo Jaguaribe basin to respond to climate stress is mainly attributed to institutional and governance mechanisms.

Pirapama

As with the Baixo Jaguaribe river basin, those interviewed in Pirapama claimed improvements in water management after the reform were due mostly to institutional and governance changes. There are two clear differences between the basins, however. First, water management improvements were less associated with responses during climate stress periods. Rather, improvements were associated with the ability of the committee to instill a sustainable development paradigm within the basin. Second, interviewees in Pirapama were much more likely to attribute successes directly to the existence and activities of the river basin committee, while downplaying the role of the state.

Unlike the Baixo Jaguaribe, the Pirapama basin developed and adopted a basin plan at its inception. During the Pirapama Project, local leaders within the basin pushed for the water management plan to be incorporated into a larger plan for sustainable development. The committee accomplished this by immediately linking the basin plan to the Agenda 21 plans promoted by the United Nations Department of Economic and Social Affairs. This effort, according to interviewees, has allowed the basin to focus more broadly on water quantity and quality issues, while also allowing for the inclusion of climate stress concerns, social issues, and economic development within the basin.

In the Pirapama basin, the committee is given much more credit for the improved management since the reform. However, according to the interviews, the recent changes to water management are improvements that one experiences rather than measures, because the reform is still new to the basin. Despite the expressed need for further improvements, interviewees characterized these changes in optimistic terms, as opposed to the more critical, negative characterizations expressed in the Baixo Jaguaribe basin. For example, rather than criticizing the committee for making mistakes, it was common to hear encouraging language, such as “people are still learning what to do.” The positive sentiment associated with the Pirapama committee is also captured through another interviewee’s description; “The committee empowers people to know that environmental quality is a right, not a privilege. The country of Brazil has many faults, but environmental quality is the right of the people and they collect this through the committees, through which people are more prepared to act.”

Before the water reform in 1997, the water management was implemented by CPRH, who did not consider "right of use". In fact, the technical nature of this management privileged large users, like electricity generation, who were very organized, but did not care for the quality of the water and did not represent all of the people within the basin. Similar to the introduction of COGERH in the Baixo Jaguaribe, the Pirapama basin committee was formed in a period of conflict to negotiate the construction of the "Barragem Principal", or the Principal Dam. As one interviewee stated; "….discussions would not have happened, such as the one to build or not build the dam before the reform," and civil society's interests would not have been represented. The dam construction was eventually approved, but not without significant consideration of stakeholder input and interests. Another interviewee's account of the recent success of management within the basin occurred during that same inaugural year for the committee, 1998. The basin experienced a drought, during which several conflicts were successfully resolved in the committee. The committee is considered a powerful force in water management within the basin, which is not necessarily the case in the Baixo Jaguaribe. I learned from several of the interviews that the reform has provided small users an opportunity to organize politically, which they did not have before the reform. As a result, participation has increased, and inequalities have diminished significantly. In the first several years of the committee's existence, individuals who were not even members of the committee were attending meetings. To most interviewees this represented a practical and important improvement in the management of water resources.

The committee is also praised by some for preparing the basin to deal with future conflicts (e.g., those caused by climate change), because of its potential role as a forum for a constant, legitimate exchange of information. Unfortunately, the extent to which the information is actually helping management is questionable. The ability for committee members to understand the scientific and technical discussions is currently limited; a similar sentiment was expressed in the Baixo Jaguaribe basin. Additionally, some suggested that the forecasts in Brazil do not have substantial credibility because the unique climate and vegetation of the Northeast is not captured or depicted in the climate models, and thus is not considered as valuable information to water managers. As one interviewee stated, "sadly the government allows us to go through drought and flood periods without government action....even when the meteorologists warn, they do not act upon them." However, as it will be discussed in the next section, many of the interviewees were optimistic of the channels for disseminating information to the committees in the future.

The majority of the interviewees had expectations that the committee and water management could do better. For several of the individuals, the recent decrease in participation (which was cited to be less than 50 percent participation in recent months) is an encroaching

problem. They attribute this to the lack of significant water conflicts in recent months to drive discussion. Also, there have been several extreme climate events in Pirapama and the surrounding basin for which the committee has not been prepared. One person described floods that struck the major municipality of Cabo de Santo Agostinho in 2005, which devastated the municipality. She was quick to point however, that the committee is now discussing the causes and consequences of similar future events on the basin.

As with the Baixo Jaguaribe, the interviewees in the Pirapama referred to one potential non-institutional factor that has improved water management. Few references were made to infrastructure as improving management. In fact, some pointed to COMPESA's leaky pipes as dampening the gains made from the reform. Rather, the informants viewed the small physical size of the basin as an advantage to managing water effectively and efficiently. Being able to see the problems more quickly has allowed for more immediate discussion of these problems within the basin. Institutional rhetoric was not missing from this subject though, as some of the interviewees viewed the small nature of the basin as allowing more people to participate in the committee meetings. Similar to the emphasis on infrastructure in the Baixo Jaguaribe basin, it is difficult to discern whether the influence of the Pirapama basin's size can be separated from institutional and governance influences. Nonetheless, infrastructure installation and physical size of the basins represent factors that will most likely have significant implications on future adaptive capacity.

5.2.2. Institutional and Governance Indicators

A second use of the key informant interview data is to explore the relevance of each of the theorized adaptive capacity index indicators. Are the rankings and the degrees of importance of each indicator expressed accurately in the adaptive capacity index, and which institutional and governance indicators are the most important for building adaptive capacity? To analyze the data in these contexts, I explore each institutional and governance indicator separately below, with the adaptive capacity index score for each indicator in parentheses.

Representation (Baixo Jaguaribe 5.64; Pirapama 5.67)

Similar depictions of representation might be expected in both basins, because the spirit of the water management reform, by law, makes the process more democratic, and thus more representative. This equal ranking of "moderate representation" within each of the committees was accurately depicted in the interviews. In the broader institutional context however, one might

expect the score for the Baixo Jaguaribe basin to be lower because of the less influential role of its committee within the management scheme. That is, the ability to be represented in the committee is only as good as the power that the committee has to represent those interests. One Baixo Jaguaribe interviewee described that within the committee, “Representation is equal, and it is incredibly important to have civil society in the discussion. It makes them more exempt of stronger politics. The committee needs to get better at having a more defined role in the management process.” Also, there was a general agreement that the poorer small farmers have not been well represented. From this, we can see that the index may inflate the level of democratic representation, because of its focus on the committee. Thus, without a greater understanding of the other scales, representation appears higher in the index than the interviews.

The index’s depiction of representation in the Pirapama basin is also “moderate”. It appears to capture the sentiment expressed in the interviews that most stakeholders are well represented. There are however, those who are disproportionably represented, which could explain the “moderate” score as opposed to a “high” ranking that one might expect. The accounts of several interviewees indicate that civil society is represented more than any other group in the basin, through NGOs and labor unions. Municipal government interests are strongly represented as well. The small/less resourceful water users (i.e. the fisherman) are often not represented because they cannot make it to the meetings, and the large users that do not hold seats in the committee are represented politically through the government. This serves as a good reminder that the indicator variables, such as representation, equity, participation and resources are not independent of one another.

The coding analysis of the interviews shows 43 direct or indirect references to representation in both basins. Only two interviewees in the Baixo Jaguaribe and three in the Pirapama basin referred directly to the importance of representation for improving water management. As we will see later, it was much more common for people to refer to other institutional variables, such as participation, as influencing successful management within the basins. This does not suggest that representation is not necessarily a priority variable in the context of water management in Brazil, but rather, differentiating it from other variables may be difficult.

Participation (Baixo Jaguaribe 4.99; Pirapama 4.92)

The relatively equal, “moderate” rankings of participation in both basins were supported by the interviews. While advancements in participation have occurred in each, the basins could

still benefit from increased participation. In the Baixo Jaguaribe, interviewees reported low levels of participation from the municipalities, because of their perception that their stake in the management process is not as significant as other stakeholders. Most interviewees indicated vast improvements in participatory management of the basin since the reform, but one person stressed the importance of the state in facilitating, or determining the level of non-state actor participation. He cited a change in the state leadership in 2003, during which there was pushback to limit stakeholder participation, because the state perceived societal participation to be too influential. Similar sentiment was attributed directly to COGERH by another interviewee, when he stressed that COGERH needs to serve as more than a consultant for the committee, by working to build participation and dividing power among stakeholders. He went further to say that COGERH is far from accomplishing this, and the committee is far from asking for it, because they fear that too much power may lead them to make decisions that might negatively affect their livelihoods (e.g., jobs, resources, etc.).

The role of higher-level institutional influence is also evident by the international push for participatory management. According to one interviewee, the World Bank has had a significant influence on participation in the Baixo Jaguaribe. The World Bank initially proposed building the recent dam, Castanhão, but in order to legitimize itself, The Bank formed the user commissions and eventually the committees. Interestingly, the interviewee asserted that the World Bank views water markets, which are inherently non-participatory, as the best method for water-resources management. In the case of the Baixo Jaguaribe, the participatory model is the next best thing according to the World Bank, and thus it promotes participation within the basin. This mixed message creates a superficial level of participation in this particular interviewee's mind.

Key informants in the Pirapama basin also expressed the need for more active participation. In their view, participation was high during the beginning of the reform, but has since diminished (to levels at roughly 50 percent, as noted above). While civil society and the municipality of Cabo de Santo Agostinho remain highly participatory, there is a clear lack of participation by the state and federal government, as well as by other municipalities. The lackluster participation by the state government in particular often leads to discouragement in those who do participate. Also, when the most vulnerable stakeholders in the Pirapama participate, according to some of the informants, this participation is deemed less meaningful by an overall lack of understanding of what is occurring in the basin. Several interviewees did stress however, the significant amount of empowerment that participation brings to the most vulnerable populations. One individual stated; "They (the poor) all have the possibility of participating in

some way or another in the committees. It brings the discussion closer to the people, as opposed to it being in the state capital. If they come to the meeting, they can speak at the microphone. He does not even need to be a member of the committee."

Like the Baixo Jaguaribe, the Pirapama basin's level of participatory management has been substantially influenced by international forces. According to the interviews, the United Kingdom initially financed the formation and implementation of the committee during its first few years.[15] Since the basin's original success, England has distanced itself from the management process. Because of this, the committee no longer possesses funds to pay the poorer stakeholders a day's wage to participate in the committee meetings. The committee is awaiting the installment of cobrança to once again implement these payments that will hopefully revive poorer stakeholder participation. The interaction between participation and financial resources is important to note in this case, as it is difficult to differentiate between these two variables.

Participation was the second most referred to institutional variable for its importance in improving water management within the basins. The coding analysis shows 73 direct or indirect references to participation in both basins. Seven participants in the Baixo Jaguaribe and six in the Pirapama referred to this variable when discussing successful management within the basin, suggesting that participation is a crucial indicator of institutional adaptive capacity to climate change in Brazil. Also, the influence from international actors makes assessing participation, and the institutions driving it or hindering it, important on all institutional and governance scales.

Knowledge and Information Availability and Use (Baixo Jaguaribe 7.49; Pirapama 6.98)

The relatively "high" level of knowledge and information availability and use predicted by the Watermark in both basins was confirmed by the interviews. The basins have interesting stories regarding this variable and its effects on adaptive capacity of water management to climate change. The Baixo Jaguaribe's high score in this variable category is mostly supported by its history and experience working with climate models and information. Pirapama, interestingly, could be considered as high as the Baixo Jaguaribe in this category, particularly because of the knowledge and information system that it is developing to make the information accessible to its users. The creation of this system, as it is discussed below, is new however. Therefore, the

[15] After further research, it appears that this funding came from the United Kingdom's Department of International Development in the amount of £ 1.4 million. More information is provided in the report at; http://www.dfid.gov.uk/aboutdfid/performance/files/ev653.pdf.

Watermark would not have been able to capture its use, or potential use in the water management process, because it did not exist when the survey was executed.

Most of the interviewees in the Baixo Jaguaribe confirmed that FUNCEME provides the committees, and more commonly, the commissions with the season's climate probability forecasts each December before the rainy season. This information presumably helps them decide how much water to free from the reservoirs to allow for refill during the rainy season. A similar meeting takes place to help plan for the dry season. One interviewee alluded to the potential power of this information; "In greater periods of stress there is greater social pressure, so there is more demand for information, and it has to be good." Most agreed that the models are improving, and the individual from FUNCEME was confident that their experience and skill in meteorological studies would soon result in models that could be applied to each individual basin within the state. Also, this same individual has been pushing for his department to better incorporate climate change into the institution's agenda. Other important sources of information and knowledge that were cited by the interviewees were COGERH and DNOCS, for making the condition of drought, and how to innovatively manage it, more familiar in the basin.

While "good" information is evidently available to decision makers in the Baixo Jaguaribe basin, most of the interviewees hesitated to say that the forecasts are really informing decision making. When reasoning these claims, most cited either difficulty understanding the highly technical nature, the superficial predictions of the models projections, or the legitimacy of the information's source. These same individuals could not stress enough however, the importance of making this information "useable" for all aspects of water management in the future. It was common to hear them specifically cite the importance of technology innovation and dissemination, both in the form of improved forecasts and monitoring abilities and also technology changes in irrigation for improved demand management (particularly regarding the poorer farmers). While not necessarily climate information technology, improvements in irrigation would theoretically be made available through similar institutional arrangements.

The history of FUNCEME's involvement in water management is important in this analysis. At one point in time, the entity had formal institutional ties to water management. Recently, it has been removed from its direct role with water management; an action with which most of the interviewees expressed concern and frustration. On numerous accounts, I was informed that FUNCEME needs to be more directly tied to water management for more efficient and equitable management of water. According to these individuals, the committee needs this information in an accessible form, and FUNCEME must work better with COGERH and DNOCS to transfer it to them. Because of this lack of coordination among the organs, they are still not

prepared to adequately discuss allocation in the face of extreme events. One interviewee suggested that committees do not absorb the information, because it is coming from the technicians that have historically had a lot of power. To him, in the future the committees need a more active role in defining priorities, particularly in periods of climate stress. Yet another interviewee identified the need for better collaboration between FUNCEME, COGERH, and DNOCS to study the climate, water, and vegetation in the basin; "There are many studies that could be done jointly with institutions, but are not. Thus, you do not have this information arriving for the users." Not surprisingly, the individual that I interviewed from FUNCEME was the only person to defend the fragmentation of institutions for producing usable information for water management. In his opinion, the delineation of focus between these organizations allows for greater efficiency in accomplishing their individual goals.

Institutions at the international level have also influenced the availability and use of knowledge and information within the Baixo Jaguaribe. Strong ties with universities and institutes in Europe and the United States, like the International Research Institute for Climate and Society (IRI), exist in the basin. It is common for FUNCEME scientists to be trained in the U.S., and many of the agency's models are from IRI. Several of the interviewees expressed reservations about these ties to the U.S., in that the information may be perceived as less credible to its potential users.

Efforts in the Pirapama basin to make knowledge and information available do not have as long of a history as in the Baixo Jaguaribe. However, they have progressed quickly at making information available to the committee and other water managers within the basin. According to several interviewees, the information is either directly available to the committees if they request it, or the information is provided to SECTMA, who then works to get the information to the committees and to COMPESA. The greatest concerns with this process are the ability for the users on the committee to make the connection between climate variability and change and water management, and like the Baixo Jaguaribe, the accessibility of the information for the common stakeholder. To this first concern, one interviewee stated; "What I see very much here is that people speak about the environment, but they don't always understand the environment….people say water is there because of the basin, and not there because it fell from the clouds." Another concern was the lack of monitoring capabilities of climate in the basin, which was mostly attributed to absence of cobrança and the financial resources it would produce. Yet another concern was how the indicators for water quality are developed and assessed. One person stated; "….indicators have to be crafted specifically for regions though, like the semi-arid region. We need indicators that are not only produced by the technician, but are also produced by the local

population." Finally, like the Baixo Jaguaribe, the Pirapama basin often relies on IRI's models. However, the same sense of distrust was not as apparent, which could be indicative of ITEP's efforts to produce their own models and decision support tools. One final critique of the knowledge and information system in Pirapama's water management was the susceptibility of initiatives to changes in the state political order. As one interviewee put it; "When the politicians change, the information produced goes into drawers, and they have to start over again."

While the interviewees from COMPESA seemed to think that climate knowledge and information is only exchanged between the agencies, several other agency and committee interviewees thought otherwise. For example, in Pirapama, climate scientists have recently created a tool that can couple climate models with the hydrologic models of the basin to forecast climate scenarios three to four months in advance. This would help the basin better manage the water resources, particularly in the reservoir. The tool, or "portal", is a decision support mechanism that is being developed in Pirapama by ITEP, with financial support of the Federal government through the Financiadora de Estudos e Projetos (FINEP). It allows the committees to use information and knowledge "without needing a team of meteorologists at their disposal." The researchers at ITEP are beginning to train committee members to use the tool though various workshops. It is not yet in its final phase, and ITEP is currently working to "get all of the kinks and bugs out before making it available to the committees." The effort, as explained by the same interviewee, is quite ambitious. Not only does it involve collaboration across a team of engineers, computer scientists, meteorologists, hydrologists, and powerful computers, it is more innovative than any initiative that FUNCEME has attempted in the past. And according to her, "FUNCEME usually sets the bar." Federal agencies like ANA, and other state organs such as COMPESA and CPRH are interested in using the tool, or building one like it to fit other various basins and regions. It is important to note however, that this interviewee, along with one other who was aware of the project, did express their concerns that the information might still be too technical for the members of the committee to comprehend. They were hopeful though that the models could be simplified even further in the future, and that the committee members could learn how to use the decision support tool over time. One person stated; "When the people know, then they have already begun to prepare for the situation…. (We) need an alert system to see the floods, the droughts....when you have this information it should be used in the preparation of the master plans of the basins. This master plan should incorporate all these actions to prepare the basin to the familiarity with climatic changes." This illustrates the potential for knowledge and information to increase future adaptive capacity within the Pirapama basin.

Knowledge and information availability and use was clearly the most referred to institutional variable for its role in improving water management within the basins. The coding analysis shows 105 direct or indirect references to this variable in both basins. Seven participants in the Baixo Jaguaribe and five in the Pirapama referred to this variable when discussing successful management within the basin. This suggests that knowledge and information availability and use is a tremendously important priority variable for assessing adaptive capacities of water management to climate change in Brazil.

Equality (Baixo Jaguaribe 4.87; Pirapama 4.87)

The "moderate" levels of equality depicted by the watermark are relatively supported by the interviews. Each basin appears to be lacking equality with respect to different stakeholders, however. In the Baixo Jaguaribe, the public and private entities appear to hold considerable power within the basin and the committee. In addition to holding power in the committee, the large agri-businesses have built particularly strong ties with state politicians. According to many interviewees, these stakeholders stifle the voice of civil society, especially the small irrigators, and thus, water and benefits are not distributed to the greatest number of people.

This level of inequality is best represented by the example of the governmental program, "Aguas do Vales", which was implemented after the reform during a severe drought period in 2001. The purpose of the program was for the Federal government (through ANA) and the state government of Ceará to provide incentives to farmers to switch from rice production to fruit production, or to reduce the amount of land they were cultivating. Essentially, the water-intensive rice production was "using too much water", as one interviewee stated. On the surface, the program appeared to be fair, but numerous interviewees described its failure to achieve fairness. First, it was the state government that had initially provided incentives for the production of rice but later became critical of it, especially during drought events. Most farmers resisted changing, because they had grown accustomed to it and they also did not have access to bank credit to buy new seeds, or modify their irrigation system in order to support fruit production—the alternative supported by the government. Along with small grants, "Aguas do Vales" promised small farmers information and assistance in making the transition out of rice to export-led fruit products. For example, farmers were supposed to have wells drilled and be provided with irrigation kits, but most of them did not receive either. The second major critique of this program by the interviewees was the level of reimbursement that the parties received. The distribution of compensation was not transparent, as some farmers received $R 128,000, and others received $R

600. One interviewee in particular viewed this program as unfair because the small rice farmers had to stop farming, but the "fat farmers" could keep producing. He essentially attributed this to the state government not wanting to discourage the economic development associated with the agri-businesses. This equity problem might have been solved in a basin committee with more power, but the Baixo Jaguaribe committee could not convince the government of the inequality, and the situation was not resolved fairly.

In the Pirapama basin, the situation with respect to equality is essentially the opposite of that in the Baixo Jaguaribe. As explained in the representation section, civil society and the municipalities are well represented in the committee. However, the state's role seems to be significantly lacking. While devoted employees of state agencies do exist, such as those committee members from SECTMA and CPRH, the formal involvement with water management by the state has been little. Almost every interviewee expressed concern with this, for the state helps to provide legitimacy, technical resources, and financial assistance to water management. Without their equal involvement, many view the management system as possibly failing in the future. Again, it is difficult to distinguish between equity in this situation, and other variables, such as networks/connectivity, commitment/buy-in, representation, participation, and resources.

Equality fell in the middle of the set of variables for its role in improving water management within the basins. The coding analysis shows 45 direct or indirect references to this variable in both basins. Seven participants in the Baixo Jaguaribe and four in the Pirapama referred to this variable when discussing successful management within the basin. While equality was not mentioned as frequently as others (i.e., knowledge and information use and availability and participation), the large number of people that discussed its importance is worth noting. All of the interviewees placed considerable emphasis on the importance of the diversity of opinions and equality of representation in the water management process. As one interviewee in the Baixo Jaguaribe described; "Distribution of water and the democratization of water and the land are the two basic elements that provide you with a better quality of life for the people." Thus, equality is a significant variable for assessing adaptive capacities of water management to climate change in Brazil.

Flexibility (Baixo Jaguaribe 6.80; Pirapama 6.16)

I found it difficult to measure the interviewees' descriptions of flexibility in relation to water management. As it is described in the adaptive capacity index, I looked for interview data that suggested the ability for individuals to change their opinions and for conflict to be

successfully managed within the basin. “Moderate to high” levels of flexibility would be expected, as interviewees in both basins cited examples of how the committee and/or the management system as a whole resolved conflict in an efficient and equitable manner. However, unlike what the index shows, interviews did not provide significant evidence of greater flexibility in the Baixo Jaguaribe basin versus the Pirapama.

Like the representation variable, flexibility is difficult to tease apart from other indicators, such as participation and equality. Also, one key element that might be considered flexibility, but is not depicted in the index, is the ability for the institutional organs and actors to change their individual roles and relationships with one another over time in order to maintain institutional continuity. This characteristic is difficult to measure without qualitative data, and it is also difficult to distinguish from experience. However, it has played an important role in the basins; particularly in the Baixo Jaguaribe basin. One interviewee cited DNOCS’s long history of involvement within Ceará, highlighting its various changes; from its role of characterizing flora and fauna to one of drought management and finally onto its most recent role of providing historical information and documentation within the region. The flexibility in this sense for DNOCS to change its mission and overcome difficult turf battles (as was the case with the institutionalization of COGERH) shows the dynamic qualities of this institution. A similar experience has occurred with FUNCEME, as it transitioned from a role of cloud-seeding to meteorological studies. In both the DNOCS and FUNCEME cases, leadership played a significant role in enhancing organizational flexibility.

Flexibility was the least referred to variable of the nine for its role in improving water management within the basins. The coding analysis shows eight direct or indirect references to this variable in both basins. Only one participant in the Baixo Jaguaribe basin referred to this variable when discussing successful management within the basin. This result most likely stems from the difficulty to distinguish the variable from other indicators, and also because it is not inherently part of the implementation of water reform, as are the other variables. However, in the end, flexibility in the larger institutional context is not captured by the index, as shown by the DNOCS and FUNCEME examples, but it is important for the assessment of adaptive capacity.

Commitment/Buy-In (Baixo Jaguaribe 6.83; Pirapama 7.43)

The relative rankings of commitment/buy-in from the adaptive capacity index were accurately reflected in the interviews. Those in the Pirapama basin were more optimistic of the water reform model than in the Baixo Jaguaribe, and they expressed greater faith in the reformed

system to address the critical problems of the basin. In the Baixo Jaguaribe, many conveyed frustration with the limited role that the committee has assumed in the management process. One Pirapama interviewee expressed their situation quite differently and bluntly; “The committee is not a thing to be harnessed by the government, but the government is the thing to be harnessed by the committee.” This attitude indicates that people are convinced that the system as a whole is more capable of effectively managing water, and that those involved with water management have faith that their model will help them adapt to future climate-change impacts. The highly involved role of the largest user within the Pirapama basin, COMPESA, also illustrates the commitment within the basin. Not only has the water company been involved with educating and facilitating the eventual implementation of cobrança in the basin, their recent attention to reforestation projects in the basin is an example of how the committee and the reformed management system are being embraced by most actors within the system. The less-engaged role of the state government in the system might be the only factor that lowers Pirapama’s score with respect to commitment/buy-in. Commitment to the decentralized model has, according to many interviewees, isolated the state from assuming a highly active role in water management. This is quite the opposite of the Baixo Jaguaribe, where less buy-in to the decentralized model has entrenched the state’s influence in water management (or reversely, the state’s entrenched influence has created less buy-in of the water reform’s decentralized attributes).

Commitment and buy-in to the water management system fell in the middle of the set of variables for its role in improving water management within the basins. The coding analysis shows 40 direct or indirect references to this variable in both basins. Five participants in the Baixo Jaguaribe and six in the Pirapama referred to this variable when discussing successful management within the basin. Like equality, the large number of people that discussed its importance is worth noting. One interviewee directly stated that “Commitment is the first thing for the reform to work.” The interviews confirm that commitment/buy-in is an important variable for assessing adaptive capacities of water management to climate change in Brazil.

Networks/Connectivity (Baixo Jaguaribe 3.22; Pirapama 3.37)

Determining if the adaptive capacity index accurately depicted the levels of networks/connectivity that exist in each basin was complex because from the interviews, the association of a number ranking to this category was extraneous. However, this category might be the most important to assessing adaptive capacity, suggesting a need for comprehensive qualitative assessments of what is occurring in and between all of the institutions and entities

involved with water management. Solely relying on a number that depicts how well networked a committee might be within the broader institutional complex severely overlooks critical relationships and interactions at other scales.

Evidence from the interviews supports this assertion about the importance of networks/connectivity. In the Baixo Jaguaribe basin, one interviewee describes the on-again-off-again relationship between the state institutions. He states; "The greatest challenge to water management is to strengthen the organizations and to institutionalize greater partnerships….The last COGERH administration was terrible. It isolated itself from the others." On a more positive note, the interviewee from FUNCEME envisioned his agency's role as helping to pull together a conversation with the other institutions. Contrary to this, a DNOCS interviewee criticized FUNCEME for not having a relationship with the community, and complained about the lack of an "….organic bond with the community and institutions that they need to be able to survive." Echoes of this same sentiment are expressed in the Pirapama basin. The changing institutional priorities and responsibilities of SECTMA and CPRH (like with DNOCS and FUNCEME) have left water management as a secondary priority. Now, SECTMA's role with other institutions is not very formal. It is more of a relationship of people than of institutions. At one point in time, SECTMA dealt specifically with water resources, but a governor's decree has since changed this. The Governor extinguished SECTMA's water resources work, and transferred these efforts to the Secretary of the Environment. Now water management "….does not have much of an identity, their relationships are not formal....unlike CPRH, which has been around for 25 years." While water management might very well be influenced by informal relationships, the interviewees seemed to believe that formal institutional arrangements, with defined roles in water management and good relationships between one another, are critical to water management in Brazil.

Networks/Connectivity fell in the middle-to-upper end of the group of indicator variables in the interviews. The coding analysis shows 47 direct or indirect references to this variable in both basins. Four participants in the Baixo Jaguaribe basin and six in the Pirapama basin referred to this variable when discussing successful management within the basins. While the index may have depicted the relationship of the committee with other institutions, it missed important associations of networks and relationships between other institutions involved with water management. Thus, networks/connectivity is important to adaptive capacity assessments in Brazilian water management, but in the widened context of the entire institutional landscape.

Experience (Baixo Jaguaribe 2.69; Pirapama 3.92)

The index did not succeed in predicting the levels of experience in water management that were described in the interviews. Perhaps the low rankings were a result of the methodological choices in ranking. More importantly, however, is the discrepancy in relative experience between the two basins. From the interviews, I gathered that the Baixo Jaguaribe actually has much greater experience in water management than the Pirapama basin. While the committees were formed at essentially the same time, Ceará was one of the first states to reform their general water management system. The water model has been more institutionalized in Ceará than in most other states because of its history of water stress. Also, according to one interviewee, the decision of the World Bank to invest in infrastructure and projects within the basin is indicative of the experience that the state has in managing water during climate stress periods. Also an indicator of the experience in the Baixo Jaguaribe, is the historical presence of DNOCS, and the consistent involvement of COGERH, which started in the Jaguaribe, and slowly branched out to the rest of the state. Regarding climate change specifically however, one person stressed that the committee is still young, and dealing with climate change will require even more time and experience.

The experience in water management appeared distinctly lower in the Pirapama basin. This was indicated by the low levels of state involvement and commitment to water management, as well as by the frequent description by interviewees that water management has only recently been thought of as a priority since the reform and the initiation of the Agenda 21/basin plan in the late 1990s. With respect to climate change, most interviewees seemed to think that the reform is still young, and they need to continue building experience in order to better prepare for its effects.

With respect to relative importance in the interviews, experience fell towards the bottom of the nine variables. The coding analysis shows just 19 direct or indirect references to the importance of experience in both basins. Five participants in the Baixo Jaguaribe basin and three in the Pirapama basin referred to this variable when discussing successful management. According to insight gained from the interviews, a narrow focus on experience does not necessarily capture the broader institutional context in which experience is placed. Also, it is difficult to distinguish between experience and other indicators, such as flexibility. Thus, on its own, experience may not be good indicator of adaptive capacity, but when considered in the broader institutional context of flexibility and networks/connectivity it may prove more relevant to the adaptive capacity assessment process.

Resources (Baixo Jaguaribe 3.67; Pirapama 6.96)

After ground-truthing the interviews, it is evident that the resources variable is accurately depicted in the adaptive capacity index. One note of caution however, is that education and wealth of the committee members were measured in the Watermark. While I received feedback that confirmed the level of each of these factors in the interviews, the majority of the input from the interviews regarding resources revolved around cobrança, or bulk water charging. Cobrança, and any other funding sources for the basin were not measured by the Watermark, and thus not depicted in the index. With this in mind, it is difficult to determine whether the gap between the two basins would narrow in this category, if the index were to more specifically measure institutional funding resources.

The importance of cobrança to both basins could not be underscored enough by the interviewees. The Baixo Jaguaribe basin views it both as an economic resource, and a tool for promoting equity and social development. One interviewee in the Baixo Jaguaribe described that once it is institutionalized, the resources could be used to educate farmers on how to better economize water. Others saw it as an opportunity to improve infrastructure. Almost all of the interviewees noted though, that the method chosen for eventually implementing and regulating cobrança will have significant implications for the livelihoods of stakeholders in the basin. For example, cobrança is already being collected in the Baixo Jaguaribe through the water supply and sanitation company, CAGECE (the water that is transported to metropolitan Fortaleza). When other users begin to pay for water however, there are social concerns that the smaller farmers will refuse to pay, because they cannot afford to do so. Their expected failure to pay may create an impasse as agri-businesses may use it as an excuse for not wanting to pay for the water as well. Thus, the institutions will play a significant role in determining how the resources are generated, and how they will eventually be used in the basin. A few of the interviewees have been working with the committee to make them a more active participant in this decision making process, although it has not been promising to date.

The Pirapama basin is also eagerly awaiting the implementation of cobrança within its borders. The interviewees see water charging as a sustainable source for funding the committee's activities. As one interviewee stated; "The law was introduced, the policy was introduced. Now to have sustainability, principally financial, it is necessary to implement cobrança….the system is consolidated in the basins, but what is lacking is financial sustainability." Since the funding from England has disappeared, the committee no longer has the resources it needs to manage water in the basin, such as tools for monitoring water quality and quantity, for which they are still

depending on the state. Many within the Pirapama also view the prospect of using the finances for further social development, as in the Baixo Jaguaribe basin. One person envisioned the money to train the poorer farmers and fisherman to perform their jobs in a more sustainable manner. Also, as mentioned before, the funds are planned to be used to offset the costs to poorer stakeholders for participating in the committee meetings.

Resources fall in the middle of the range for number of times the variable is associated with successful management in the basins. This number may be skewed downward, because in many of the interviews, the emphasis on the importance of cobrança was substantial, but may have methodologically only counted for a few of the references. Thus, in future studies a separate variable for institutional funding may be helpful. The coding analysis shows 40 direct or indirect references to the importance of resources in both basins. Five participants in the Baixo Jaguaribe basin and eight in the Pirapama basin referred to this variable when discussing successful management within the basins. Resources, both educational and financial are coveted within both basins and associated by most of the interviewees as critical institutional tools for successful water management. Thus, resources are one of the most important indicators of adaptive capacity of water management in Brazil to climate change.

Table 3 summarizes the analysis of the institutional variables predicted by the adaptive capacity index, as well as their assessed importance within each basin.

Table 3: Summary of the Adaptive Capacity Index's Accuracy and Assessed Level of Indicators' Importance (as assessed by interviews with key informants)

Indicator	Accurately Depicted in the Index?	Good Indicator of Adaptive Capacity to Water Management in Brazil?
Representation (R)	+	?
Participation (P)	+	+ +
Flexibility (F)	—	+
Equality (E)	+	+ +
Knowledge and Information Availability and Use (K)	+	+ +
Commitment/Buy-In (C)	+	+
Networks/Connectivity (N)	—	+ +
Experience (X)	—	?
Resources (S)	+	+ +

6. DISCUSSION

As the interview data indicate, the index created from the Watermark survey did not completely capture the adaptive capacities in each basin. The data, particularly the interviews, show that the networks/connectivity and resources of the various water management actors tend to moderate the other important variables of institutions and governance mechanisms, which were, knowledge and information availability and use, participation, equality, flexibility, and commitment/buy-in. The importance of representation and experience seemed less obvious within the basin. Representation was often undifferentiated from participation and equality, and it is difficult to claim that more experience, as we will see below, increases adaptive capacity.

While some of the indicators were successful in predicting relative values, and occasionally the magnitude of an adaptive capacity indicator, the index failed to describe what is really occurring within these basins. The main reason for this is not necessarily due to a flaw in capturing the basin committees' actions and attributes, but rather, the index fails to look beyond the imagined appropriate scale to a more thorough description of the institutions and governance mechanisms at all scales (local to international). In other words, focusing on the basin committees proved necessary but insufficient. The interviews helped to uncover important prioritization of institutional indicators, and also served to describe relationships between these variables. Each of the two cases appears to have attributes that both increase and decrease adaptive capacity to climate change, but the attributes are strikingly different between the basins. These cases offer insight into what might increase or decrease adaptive capacity to climate change, and I argue that both basins can learn from one another, and that the broader adaptive capacity field might also benefit from these findings.

6.1. Adaptive Capacity at the Appropriate Scale?

Adaptive capacity researchers have been arguing for the development of institutional and governance indicators across appropriate scales (Adger and Vincent, 2005; Brooks et al, 2005; Yohe and Tol, 2002; Adger, 2001; Smit et al, 2000). In this study, I attempted to develop and test indicators at one "appropriate scale" and in one particular setting; the river basin level in Brazilian water management. Brazil's recent water reform, which created governing bodies at the river basin level, would appear to offer adequate institutions on which to focus adaptive capacity indicator development in this particular context. However, even with a well-developed database of governance and institutional information (i.e., the Watermark), a prediction of adaptive

capacities at the river basin level did not prove accurate. Primarily, a focus at the relevant "appropriate scales" for indicator development, in this case at least, ignored the complex interactions that go beyond the committees that officially govern water management at the basin scale. Thus, accurate indicators of adaptive capacity of water management in Brazil cannot be developed without focusing on the other various institutional and governance arrangements that affect river basin management.

The inability of this study to develop robust indicators at the river basin scale does not devalue the importance for creating a process for assessing adaptive capacity. Rather, it suggests that a more comprehensive assessment of how a resource is managed across scales and between institutions operating at the same scale remains critical. The in-depth view into both basins offers a better description of what is influencing adaptive capacity in each basin, and it also gives important methodological insight for what might be included in future assessments of adaptive capacity.

6.2.1. Adaptive Capacity of the Baixo Jaguaribe Basin

In addition to the adaptive capacity indicators discussed above, there are several institutional levers within the Baixo Jaguaribe that might significantly increase and/or decrease adaptive capacity to climate change. The institutional mechanisms contributing to its adaptive capacity include; experience in water management during climate stress periods; a more centralized water management model; a prioritization of economic development; the use of cobrança; and the international influence within the basin. *Table 4* summarizes these major institutional and governance levers that influence adaptive capacity within the Baixo Jaguaribe basin.

Water management during drought and flood periods in the Baixo Jaguaribe river basin has a long institutional history. The necessity to respond during such situations has created a breadth of experience in dealing with climate stress. Particularly, the ability of DNOCS and FUNCEME to adapt their institutional missions bodes positively for the basin's adaptive capacity. Similarly, the ability of COGERH and DNOCS to resolve their initial "turf battle" indicates the flexibility of the institutions to adapt over time to meet the changing needs of the basin. It also highlights the importance of maintaining the institutional knowledge that has evolved over the past 95 years (Interviews, July 2006; Baixo Jaguaribe basin). However, as Lemos and Oliveira (2004) point out, the institutional knowledge produced over these years may in fact insulate decisions within the technical bodies. Analysis of the knowledge and information

availability and use variable indicates that FUNCEME and COGERH are working to bring this knowledge to the committees, but the preliminary indications are that the use of this information within the committees remains minimal at best. Thus, in this context future adaptive capacity of the Baixo Jaguaribe will be dependent upon the ability of the institutions in the basin to draw upon their collective experiences to make decisions in a changing climate. In the case of FUNCEME, this could mean realigning itself directly with water management. In the case of COGERH, this may imply enhancing the power of the committees to make decisions within the basin, and also working with FUNCEME to transfer tangible information into the committees to better inform decision making.

A second critical influence on adaptive capacity within the Baixo Jaguaribe relates to its more centralized water management model. The basin agencies that are outlined in the law to offer support to the committees have been replaced by a state agency, COGERH. The greater power of the state, particularly through COGERH, represents a tradeoff with a more empowered civil society. Also, the basin plan that was supposed to be developed by the committee was strong-armed by powerful state actors at higher scales of government. Interestingly, as reported in the analysis above, many of the key informants viewed the need for a stronger committee in the basin. To them, the committees are more capable of acting in the interests of the regional character of the basin. The state entrenchment in water management has also led to leadership changes and politics having a significant influence in the basin; with some heads of COGERH being open to increased committee autonomy, and others enjoying a quiet committee. As one interviewee described; “The government of the state remains, but the persons of the government change.” One positive component of COGERH’s power within the basin is that it serves as a technical resource for the committees. The technical support however, as noted above, is subject to insulation by its centralization within one institution. Therefore, the state maintains significant control of what it interprets as “important” from a water management perspective. It is difficult to discern if this model will be better or worse for adapting to future climate change than the more decentralized model, which is promoted by the federal government and embraced by the Pirapama basin. The answer to this requires a discussion of values and which type of development, social or economic, is prioritized within the Baixo Jaguaribe.

The issue of development within the basin is crucial. State institutions involved with water management (directly and indirectly) have clearly promoted economic development initiatives within the Baixo Jaguaribe; as evidenced by the influx of agri-business and shrimp farming. Often, the economic goals of the state are in conflict with social development. The “Aguas do Vales” program that prioritized agri-business over small farmers is a good example of

the emphasis on economic development over social development. Another example is the lax water quality regulations of shrimp farmers. The sulphites that are used to kill the shrimp are dumped in the river and result in the deaths of other fish. Increased clearing of the mangroves around the edges of the rivers also decreases water quality in the basin (Interview, July 2006; Baixo Jaguaribe basin). Historically, the basin has worried about water quantity problems. However, if activities such as agri-business and shrimp farming continue to grow and remain unregulated, the issue of water quality will also be exacerbated by climate change. One of the goals of the water reform is to better represent all interests within the basin. Without autonomous, empowered committees however, the disproportionate focus on economic development severely decreases the collective adaptive capacity of the river basin and water management.

The use of cobrança within the basin can be viewed as either increasing or decreasing adaptive capacity, depending on how it is administered and used. Again, I turn to the discussion of social versus economic development. Currently allowing multi-national fruit companies to not pay for water represents a lost opportunity for the state to raise money. Along with a more empowered river basin committee, cobrança presents an opportunity to further prioritize social development. The major issue discussed in the interviews regarding cobrança was the inability for poor small farmers to pay for the water. Opinions were significantly mixed as to how to collect the water charges. Some felt that the small farmers should be exempt from these payments. Others felt the solution was a regulatory one, advocating for water metering and monitoring of all users, including the small farmers. Still others envisioned the eventual implementation of water charges on a tiered social scale, or ability to pay. The manner in which this is resolved will have great implications on the livelihoods of those within the basin. One aspect of the management structure that does not make equity and social development appear to be optimistic in this case is that the committees have not had a consistent voice in the cobrança process. Rather, the Governor was responsible for establishing cobrança by decree, without a consultation process with the committees; relying on technicians and researchers to decide how to administer it. These parties reportedly accepted advice from the committees, but when it came to a vote, the committees were excluded from voting. The inability for the committees to have power to represent all interests within the basin reduces its potential role in future adaptation planning. While a few may gain from this arrangement, large numbers are likely made more vulnerable to climate change because of this missed opportunity. As one person stated; “If cobrança is implemented fully without the discussion of the committees, it will intensify social inequality.” Finally, what money is being collected through the canal transfers to the metropolitan region of Fortaleza is not being

transformed into the tangible benefits, such as social programs, which could improve the quality of life within the basin.

International influence within the Baixo Jaguaribe exists mostly in two contexts. First, the World Bank has played a considerable role in infrastructure projects, as well as in promoting participation within the basin. While many researchers predict that continuing to focus on supply-side management to alleviate climate stresses may decrease adaptive capacity, most of the water managers in the basin felt that the infrastructure has made the region less vulnerable. Not surprisingly, the World Bank's projects have opened the basin to increased agri-business. The implications on social development have already been discussed, but one interviewee explained; "The World Bank loans are not helping the people, but instead are for building infrastructure to feed the rich." Also, while civil society participation has been a focus of the World Bank, the superficial nature of the participation in these contexts may delegitimize this seemingly progressive initiative.

Second, the reliance on developed countries climate information, particularly IRI's, creates a potentially tumultuous reception of this information by its users. It can either be viewed as helpful and credible, or useless and not legitimate. In both cases, it is possible that adaptive capacity could be decreased. If viewed as valuable, the information may be used to gain power and exclude those that are already marginalized (Miller, 2004). This could be particularly true of the centralized structure of the Baixo Jaguaribe. If the information is viewed as worthless on the other hand, the water managers might miss crucial opportunities to decrease their vulnerabilities. Thus, it is important for international influences within the basin to be closely monitored in iterative adaptive capacity assessments.

Table 4: Major Institutional Leverage Points for Increasing/Decreasing Adaptive Capacity in the Baixo Jaguaribe Basin

Institutional Leverage Point	Current Status; Increasing (+), Decreasing (—), or Uncertain (+/—) Effect on Adaptive Capacity
History of Extreme Climate Stress	+/—
Centralized Model	+/—
Economic Development Prioritization	—
Cobrança	—
International Relationships	+/—

6.2.2. Adaptive Capacity of the Pirapama Basin

Like the Baixo Jaguaribe basin, there are several broader institutional elements of water management within the Pirapama that increase and/or decrease adaptive capacity to climate change. The institutional mechanisms contributing to its adaptive capacity include; its inexperience with climate stress; a more decentralized water management model; a prioritization on sustainable development; the use of cobrança; and the international influence within the basin. *Table 5* summarizes these major institutional and governance levers that influence adaptive capacity within the Pirapama basin.

At first glance, it may seem that the relatively inexperienced water management system in Pirapama would decrease adaptive capacity to climate change. However, I suggest that the basin's lack of experience may actually increase adaptive capacity. The main argument supporting this claim is that while the basin may not possess historic knowledge of managing droughts and floods, fully embracing the participatory model of water management (i.e. the reform) makes the basin less susceptible to insulated decision making. The apparent advancements made in knowledge and information availability and use speak to this point. It appears that there are less institutional barriers to overcome in providing climate information into the committees. While the system is still "working the bugs out", it has begun to facilitate a process for creating and disseminating usable information that can inform committee decision making. A key element that will determine if adaptive capacity is augmented in this category over longer temporal scales will be the ability of the various institutions to avoid insulated decision making and also maintain the autonomous and empowered nature of the basin committee.

"The committee walks with its own legs", declared one interviewee. The autonomy of the committee generally increases adaptive capacity, and such an empowered civil society can mostly be attributed to the commitment and implementation of the decentralized water management model, which captures the full spirit of the federal reform law. The heightened participation of civil society and municipalities is the main driver for the ability of the committee to effectively and equitably manage water conflict. There are several important issues that the basin needs to address however, if adaptive capacity to climate change is to further increase in this decentralized model. Mainly, buy-in from the state will be critical to its success. As researchers suggest, a decentralized model without downward accountability and support is likely to be unsuccessful in managing resources (Ribot, 1999). Numerous interviewees cited decreased participation in recent months because of the distancing of the state entities' roles. Beyond the demoralizing effects of these actions, the state's lack of formal ties to water management also closes off important

channels for resource support, both technical and financial. Specifically, the Pirapama basin does not have a basin agency, as mandated in the federal law, and the state does not have a formalized entity to offer technical support, like COGERH does in the Baixo Jaguaribe. To resolve this, some individuals suggest an expanded role of CPRH in water management and climate change issues, or a refocusing of SECTMA back to water management, or even the creation of a state water agency like those in Ceará (SRH or COGERH). Regardless of the solution offered by the interviewees, it is clear that there is a pleading sentiment within the basin for a more formalized state role within water management; beyond the current 'we're here if you need it' approach of the state agencies.

One characteristic of the basin that most certainly increases its adaptive capacity is its emphasis on sustainable development, which uniformly promotes environmental, social and economic sustainability. Its proponents praise sustainable development as a more comprehensive and long term vision of resource management and development. Recently, a movement has evolved in the climate change field to link adaptation to climate change with sustainable development efforts (SEG, 2007; Pielke et al, 2007). The Pirapama basin's ability to link its water management initiatives to sustainable development stem mostly from the basin plan's ties to the Agenda 21 initiative. The plan focuses on water quality, reforestation, social development and equity, and general quality of life improvement. All of this is balanced with significant economic development in the basin (i.e., sugar refineries, agri-business, etc.). One telling indication that the sustainable development model is alive and working in Pirapama is that the state water supply and sanitation agency, COMPESA, has implemented water quality and reforestation projects around the main dam in the basin. Of the several hundred dams and reservoirs that COMPESA manages, this is the only one within which such progressive projects exist; evidence of the basin's ability to implement sustainable development initiatives through the power of the committee. It would greatly benefit the basin even further, if it integrated climate change into this basin plan. It is important to consider a contrary interpretation of the basin's embracing of the sustainable development model. One could argue that the relatively milder conflicts, due to less historical climate stress in the basin, allow for a greater focus on sustainable development and other 'luxury issues'. If this is the case, the basin may have to be extra cognizant of the possibility for increased pressure to focus on economic issues as climate change ensues. While it is clear that the basin is presently devoted to the sustainable development model, the level of commitment could feasibly shift in the future, making the basin more vulnerable to climate change.

Another important aspect of the water management system that deserves attention is the way in which the basin implements and uses cobrança. The decentralized model with an

empowered civil society and the focus on sustainable development indicate that the basin may use cobrança as an instrument to improve social issues, as opposed to amplifying social exclusion of the already vulnerable populations. Many of the interviewees expressed optimism in the future with cobrança, for not only are social issues an anticipated target of the funds, the basin contains users that for the most part have the potential to pay for the water (unlike in the Baixo Jaguaribe where small farmers refusal to pay has stunted cobrança's implementation). In Pernambuco, administering of water charging is subject to the passage of a state law, but most informants were confident that the legislation would be passed sometime in 2007. Still, it is important that the water managers within the basin express caution regarding the exact method for implementing cobrança. The committee would need to be careful about instilling transparency and accountability in the collection process, or risk similar criticisms that state agencies oftentimes face in Brazil. Details of how much each user pays within the basin, and the state of Pernambuco for that matter, are still being debated. Most of the concerns are that the social priority currently promoted in the basin will be eroded by state and economic interests once cobrança is administered. The ability for the committee to uphold this social standard could prove an important test for the legitimacy, effectiveness, and ability to adapt to future climate change. Paraphrasing one individual; "The greatest challenge in dealing with climate change is political will for distributing financial resources….to prepare the basin for climate changes, we need communication and environmental education through cobrança." Interestingly, this comes from a representative of the largest eventual payer of water, COMPESA.

International influence within the basin is also important to evaluating its adaptive capacity. The initial trainings, administered by France, and the first financial resources, provided by England, created a strong water management scheme from the outset. The World Bank was not involved in the basin, which may have helped lessen criticism attributed to outsider influence. Interestingly however, the Agenda 21 plans are initiatives of another international governmental organization, the UN. Perhaps its acceptance stems from the focus on sustainable development (i.e., it was promoted by the UN Commission on Sustainable Development), as opposed to economic development and infrastructure projects, which are typical of the World Bank. While the original support from the European countries seems to have helped with the basin's overall success, the water management model might fail in the future without the reliable flow of funding from cobrança. Additionally, like the Baixo Jaguaribe basin, the Pirapama must be careful with how the climate knowledge and information from other nations and international organizations is utilized within the basin. Depending on how this is used, the information could either help or hurt the basin's adaptive capacity.

Table 5: Major Institutional Leverage Points for Increasing/Decreasing Adaptive Capacity in the Pirapama Basin

Institutional Leverage Point	Current Status; Increasing (+), Decreasing (—), or Uncertain (+/—) Effect on Adaptive Capacity
History of Moderate Climate Stress	+
Decentralized Model	+/—
Sustainable Development Prioritization	+
Cobrança	+/—
International Relationships	+

6.3. Lessons from the Basins

The data suggest several important lessons from these cases in terms of water management and adaptive capacity to climate change. In addition to the need for decision makers to focus iteratively on the five above-described institutional leverage points, I wish to discuss a handful of themes that stand out in this research. First, both of the basins' reformed water management systems derived from a relatively organic source. In the Baixo Jaguaribe's case, this came from historical experience with climate stress and conflict, and in the Pirapama, this was due to a specific conflict event; the planning of the Barragem Principal. Interestingly, the federal government was instrumental in the ultimate success of the Pirapama basin, because of the passing of the water reform law. However, the Baixo Jaguaribe's reformed model was not dependent on federal momentum. Still, the federal government plays a role in the Baixo Jaguaribe, but it is more of a technical support role through DNOCS.

What appears to significantly influence the level of civil participation, equality, and commitment to the reformed water management model is how each of the basins pairs water management with development. In the Pirapama, water managers have been successful in integrating their model into sustainable development goals, with a significant focus on the environment and social issues. In the Baixo Jaguaribe however, economic goals are clearly prioritized. The state serves as an important influence in the prioritization of development. In the Baixo Jaguaribe, the more centralized paradigm allows for greater influence of the state in water management matters, and it is not surprising that water management is linked to broader macroeconomic goals. On the other hand, the Pirapama basin has a much less active and formal relationship with the state, and thus, a focus on sustainable development becomes possible. It is difficult to determine which model is "better". The Baixo Jaguaribe seems to have more of an adaptive management approach, while the Pirapama's resembles integrated environmental management. The adaptive management theory suggests that people and institutions learn through

iterative processes and make changes in management decisions from past experiences, and to reduce uncertainty throughout this process (Holling, 1978). This is essentially what the various institutions have done within the Baixo Jaguaribe as their experience with climate stress has grown, and as the institutions have learned and successfully evolved to maintain themselves. The integrated environmental management structure links together institutions, sectors, and actors for the collective management of resources (Born and Sonzogni, 1995). The Pirapama basin has embraced this integrated management model through its emphasis on sustainable development. Rather than relying on experience with water stress, the basin envisions its sustainable development focus as eventually increasing adaptive capacity.

Elements of both of these models, adaptive management and integrated environmental management, are most certainly applicable to aiding adaptation to future climate change. In fact, adaptation scholars have already written on both of these topics (Arvai et al, 2006; Thomson et al, 2006; Tompkins and Adger, 2004).What is unique about this research study however, is that the case analysis has unveiled several tangible levers on which each basin can focus to improve their adaptive capacities to climate change. In the end, the analysis suggests that water management in these basins, especially but not exclusively in the face of climate change, could benefit greatly from combining positive elements from both the adaptive management and integrated environmental management theories. A greater number of individuals and sectors could be made less vulnerable in the Baixo Jaguaribe basin if water mangers further empowered the committee, and worked to integrate water management and climate change into broader sustainable development goals. The Pirapama basin could learn from the Baixo Jaguaribe's success in adapting its water management model under periods of significant climate stress; a situation that will become much more common in the basin as its climate changes. Each basin does not need to look far from its borders to begin this learning process. I would also urge caution to both of these basins as they continue to develop and implement their water management models to avoid overlooking the positive aspects that have developed within their own basins. Particularly, to address the common sentiment in the Baixo Jaguaribe that greater participation and a focus on social development is desired, and in the Pirapama that a more involved state is desired, I offer the follow the axiom; "Be careful what you wish for, because it might come true." It might prove difficult for each basin to identify the right level of state participation that can best facilitate adaptation to climate change initiatives (i.e., adaptive capacity). The true test will be for each basin to encourage buy-in of the state to garner resource and technical support, while also promoting equity and participation in the water management sector.

6.4. Implications for the Adaptive Capacity Field: Areas for Future Research

Identifying indicators of adaptive capacity at a single "appropriate scale" for a given system may be a futile task. This study suggests that the uniqueness of each case creates difficulties for operationalizing the concept of adaptive capacity by focusing only on one level. That said, this study supports the need for the standardization and operationalization of adaptive capacity, but across the various scales involved. It also reaffirms that institutions and governance mechanisms are important for determining adaptive capacity to climate change. Two other factors were identified as affecting adaptive capacity within the basins. In the Baixo Jaguaribe, it was infrastructure, and in the Pirapama, it was the physical size of the basin. These factors are not disassociated from institutional and governance mechanisms however, and a thorough assessment focused on the institutions should still capture elements of other determinants of adaptive capacity.

I have identified three specific areas for future research in the adaptive capacity field. First, qualitative data must complement quantitative data analysis in adaptive capacity assessments. The interviews conducted in this study have provided invaluable information for describing the adaptive capacities of water management in both river basins. This implies that any future operationalization of adaptive capacity would greatly benefit from the creation of a process that can capture the level of specificity in each basin through a qualitative component. This qualitative component would complement and confirm whatever quantitative indicators are eventually developed. Most importantly, the qualitative data is extremely helpful for identifying tangible leverage points within the institutional arena that can increase or decrease adaptive capacity.

Second, scales matter. While the adaptive capacity index that I developed predicted (more or less) the relative institutional and governance indicators of the basin committees, it failed to adequately capture the institutional actors at various scales within which adaptive capacity is either enhanced or hindered. A crucial next step for the research community would be to develop a method for assessing these institutional mechanisms on all scales, and their influences on adaptive capacity. The field might also benefit from the development of a spatial mapping tool that could identify and track institutional and governance relationships at all of the relevant scales. In this sense, a process for assessing adaptive capacity could be standardized, but the exact indicators would be flexible to accommodate for specificity of each relevant system. Such a tool could couple the qualitative institutional data with physical and climatic data. This would help bolster the robustness of the adaptive capacity component in the vulnerability

equation. Ultimately, this tool could be developed as a decision-support instrument that might be tangible to policy makers (from various levels) as they assess adaptive capacity to climate change.

Third, testing adaptive capacity assessments against proxies for climate change is important. The research community and decision makers would benefit from evaluating the tools and methods against events that are expected to be similar to climate change impacts, such as climate variability. For example, a regression discontinuity analysis of a system before and after an institutional change could measure the impacts of that institutional change as increasing or decreasing adaptive capacity. This would be similar to the study that I performed, but it would be complemented with quantitative data from before and after the institutional change.

7. CONCLUSION

Developing and testing indicators of adaptive capacity to climate change has proven to be a difficult task for the adaptation to climate research community. Among many methodological and definitional debates, the often perceived latent nature of adaptive capacity to climate change makes assessing adaptive capacities a difficult task. Northeast Brazil's history of climate variability and predicted exacerbation of climate stress from climate change provide a unique opportunity to assess future adaptive capacities to climate change based on past actions and responses to droughts and floods.

This study of adaptive capacity assessment in the Baixo Jaguaribe and Pirapama basins sought to answer the following research questions: a) what mechanisms and attributes of water governance and institutions make water systems more resilient to climate change?; b) to what extent has recent water management reform enhanced or decreased adaptive capacity in these basins?; and c) does an assessment of institutional and governance mechanisms at the river-basin level accurately predict adaptive capacities within each basin? I hypothesized that the more flexible, democratic, participatory, and resourceful the water management system, the greater adaptive capacity of the system. I also predicted that the water reform helped to increase adaptive capacities water resources management in both basins. Finally, I predicted that qualitative data from key-informant interviews would describe institutional and governance components of adaptive capacity to a degree that has yet to be explored in the adaptive capacity field.

To evaluate these questions, I developed an adaptive capacity index, based on institutional indicators at the river basin scale. I ground-truthed the data with key informant interviews, and discovered that the index was necessary, but insufficient for identifying adaptive capacities within the basins. The index did help to accurately depict dynamics in the basin committees, and also confirm the importance of most of the institutional variables (i.e., participation, flexibility, equality, knowledge and information availability and use, commitment/buy-in, networks/connectivity, and resources), but a full understanding of adaptive capacities required the data from the interviews, which highlighted the various institutional factors beyond the river basin committee level that have been influencing the adaptive capacities. The interviews suggested that adaptive capacities have been increasing in both basins, and the interviews also helped to identify leverage points on which decision makers in the basin should focus and learn from one another to increase their respective adaptive capacities.

Finally, this study identifies the need to develop a methodology for assessing adaptive capacities that is both standardized as a process, but context-specific in its evaluation. In other

words, future research is needed for creating a method for assessing adaptive capacity that puts into operation a process that allows for both some level of standardization and flexibility to focus on case specificity through both quantitative and qualitative methods. One important lesson from this research is that institutions and governance mechanisms really do matter, but they matter at all scales. It is important to remember that adaptive capacity composes only one component, albeit an important component of the vulnerability equation. Therefore, vulnerability assessment might be improved by developing methods to assess adaptive capacity that focus scarce resources on institutional and governance assessments or mappings that consider all scales. As the global change literature indicates, the vulnerability assessment process is also benefited by the inclusion of various stakeholders; a provision that would be most certainly applicable to the adaptive capacity portion as well.

APPENDICES

Appendix 1: Range of Adaptive Capacity Determinants

Determinants of adaptive capacity	
Determinant	Encompasses
Human capital	Knowledge (scientific, "local", technical, political), education levels, health, individual risk perception, labor
Information & Technology	Communication networks, freedom of expression, technology transfer and data exchange, innovation capacity, early warning systems, technological relevance
Material resources and infrastructure	Transport, water infrastructure, buildings, sanitation, energy supply and management, environmental quality
Organization and social capital	State-civil society relations, local coping networks, social mobilization, density of institutional relationships
Political capital	Modes of governance, leadership legitimacy, participation, decentralization, decision and management capacity, sovereignty
Wealth & financial capital	Income and wealth distribution, economic marginalization, accessibility and availability of financial instruments (insurance, credit), fiscal incentives for risk management
Institutions and entitlements	Informal and formal rules for resource conservation, risk management, regional planning, participation, information dissemination, technological innovation, property rights and risk sharing mechanisms

Source: Eakin and Lemos (2006); as adapted from Smit and Pilifosova (2001) and Yohe and Tol (2001).

Appendix 2: Interview Questionnaire

1 BP	*Qual é sua profissão?*
1 BE	*What is your profession?*
2 BP	*Qual é o seu papel na gestão das águas na bacia?*
2 BE	*What is your role in water management within the basin?*
3 BP	*Como a reforma afetou o seu trabalho? Ficou mais fácil ou mais difícil?*
3 BE	*How has the water reform affected your ability to do your job? Is it easier, harder?*
4 EP	*Na sua opinião, quanto da reforma já foi implementada na bacia? O que falta?*
4 EE	*In your view, to what extent has water reform been implemented by the river basin?*
5 EP	*O que significa uma gestão bem sucedida da bacia? Tem algums exemplos?*
5 EE	*What does it mean to have successful management for this basin? Do you have some examples?*
6a EP	*Especificamente, em comparação com outras secas nos últimos quinze anos, quão efetivo tem sido o comitê ou a bacia em geral na gestão do fornecimento de água?*
6a EE	*Specifically, in comparison to periods of drought in the past 15 years, how effective has the committee or the river basin been at successfully managing water supply?*
6b EP	*No que você baseia esta comparação? Numero de emergencies referents a segurança alimentar? Outros indicadores? Como eu posso ter acesso a estes dados?*
6b EE	*What do you base this comparison on? Number of Food emergencies? Internal migration? Other indicators? Can I get access to this data?*
7a EP	*O que faz a gestão de água mais ou menos eficiente nesta bacia e nas outras bacias do estado?*
7a EE	*What makes water management more or less effective in this basin than other basins in the state?*
7b EP	*Do que outras bacias no Nordeste?*
7b EE	*Than other basins in the Northeast?*
8 CP	*O que mudou na gestão da seca depois da reforma? Como era a resposta do governo e recuperação antes da reforma? E melhor ou pior? O que é melhor e o que é pior?*
8 CE	*What changed in the management during drought periods after the reform? What was the response of the government before the reform? Is it better or worse? What is better and what is worse?*
9a CP	*Aumento de eventos extremos como seca e enchente são os impactos mais antecipados de mudanças climáticas globais no Nordeste. As pessoas discutem mudanças climáticas na bacia? No comitê?*
9a CE	*Increased extreme events, and more severe floods and droughts are the most anticipated impacts of global climate change in Northeast Brazil. Is climate change discussed in the water management system/ committee meetings?*
9b1 CP	*Se sim, vocês estão considerando a posível mudança de clima no planejamento de gestão de águas?*
9b1 CE	*If so, to what extent is it being considered in the planning and decision making process?*
9b2 CP	*Se não, hipoteticamente, você acha que estas discussões são mais faceis agora que antes da reforma?*
9b2 CE	*If no, do you anticipate future discussion of climate change, or would such discussions have been more likely to occur before the reform?*
10 CP	*Do ponto de vista institucional, a bacia está preparado para as mudanças climáticas que podem afetar a bacia?*
10 CE	*From an institutional perspective, is the basin prepared to handle changes in climate within your basin?*

11 CP *Você acha que a bacia está mais preparada agora do que antes da reforma e a criação do comitê? Por que sim; por que não?*
11 CE *Is it the basin more prepared than before the reform and the formation of the committee? Why, or why not?*

12 CP *Qual a coisa mais importante para preparar a bacia para mudanças climáticas?*
12 CE *What is the most important characteristic of the basin for being prepared for changes in climate?*

13 CP *Qual é o maior desafio para a gestão das águas em relacão as mudanças climáticas?*
13 CE *What is the greatest challenge facing the water management system in dealing with climate change?*

14 CP *Qual grupo você acha que é mais vulnerável as mudanças climáticas na bacia?*
14 CE *Which group do you think is the most vulnerable to climate change in the basin?*

15 CP *Você acha que a maneira através da qual a gestão é implementada ajuda a diminuir a vulnerabilidade aos impactos das mudanças climáticas? Por que sim; por que não?*
15 CE *Does the current water management scheme help to decrease this vulnerability, as compared to climate stressors before water reform? Why or why not?*

16 CP *Voce acha que dadas as atribuicões do comitê (resolução de conflito, disseminação de informação, etc), este seria o lugar mais indicado para discutir questões sobre mudanças climáticas? Quais as limitações que você vê no comitê para tomar decisões sobre mudanças climáticas?*
16 CE *Do you think the attributions of the committee (conflict resolution, information dissemination, etc.) make it the best place to discuss questions about climate change? What are the limitations that you see in the committee for making decisions about climate change?*

17 CP *Você acha que a COGERH poderia ser um gestor mais eficiente do que o comitê em face de mudanças de clima?*
17 CE *Would COGERH be a better place to more effectively manage water in the face of climate change?*

18 IP *Qual é a importancia da COGERH? Por que você acha que este modelo não foi adotado em outros estados?*
18 IE *Why is COGERH so important? Why haven't other states followed this specific model?*

19 IP *Qual é a origem da COGERH? Quão importante foi o Banco Mundial no processo de criação da Cogerh??*
19 IE *What is the main reason that COGERH exists? How important was the World Bank?*
20 IP *Qual e o papel do DNOCs? Como se compara com outros estados do Nordeste?*
20 IE *What is the role of DNOCS? Compared to other Northeastern states?*

21a IP *Por favor descreva o relacionamento entre o comitê de bacia e órgãos do governo como a COGERH e o DNOCS. Qual do dois órgãos tem mais poder? Como você definiria este poder?*
21a IE *Please describe the relationship between the basin committee and important governmental agencies like COGERH and DNOCS. Does one exercise significantly more power than others?*
21b IP *Por favor, compare com anos passados?*
21b IE *Compared to past years?*

22 IP *Quão importante é o papel da FUNCEME, ANA, SRH e CAGECE na bacia?*
22 IE *How important is the role of FUNCEME, ANA, SRH, CAGECE na bacia?*

23a IP *Qual é o papel dos governos federal, estadual e municipal na gestão da água? Eles cooperam entre si ou tem algum nível que é menos cooperativo do que os outros?*

23a IE *What is the role of federal, state, and municipal governments in the management of water? Is there cooperation, or has one level been less cooperative than the others?*

23b IP *Comparar com anos passados?*
23b IE *Compared to past years?*

24 IP *Is there conflict between state agencies and Municipal governemnets?*
24 IE *Existe conflito entre organizações estaduais e municipais?*

25 IP *Quão estavel é a reforma na bacia? No estado? Já foi institutionalizada o suficiente para ser sustentável em vista de mudanças políticas nos níveis federal e estadual?*
25 IE *How politically stable is the water management reform process in the basin? The State? Has it been institutionalized enough to stand up to political changes at the federal and state levels?*

26a IP *Existe cobrança na bacia doBaixo Jaguaribe? Se sim, como ela afetou a bacia? A bacia está mais sustentável financeiramente?*
26a IE *Does bulk water pricing exist in the Baixo Jaguaribe? If yes, how has it affected the basin? Is the basin more financially sustainable?*

26b IP *Como são usados os fundos arrecadados?*
26b IE *How are the funds being used?*

27a IP *O Baixo recebe fundos da cobrança coletada no estado?Se sim, qual e o processo?*
27a IE *Does Baixo Jaguaribe receive bulk funding from the bulk water charges collected from the state?*
27b IP *Como são usados os fundos arrecadados?*
27b IE *How are the funds being used?*

28 IP *Uma grande parte dos fundos que financiam a reforma vem da cobrança da Metropolitana (e dos usuarios de Fortaleza). Você acha que estes fundos compensam a aumenta da demanda por água de Fortaleza?*
28 IE *A large portion of the funding for the water management system comes from users in Fortaleza. Does this financial benefit outweigh the burden of increasing demand from Fortaleza users on the water supply?*

29 CP *O que você acha do fato dos irrigantes não pagarem pela água? Você acha que a falta de conbrança pode prejudicar a integridade do sistema se houver mudança climática e mais seca*
29 CE *How do you feel about the main user group, irrigation, not being accountable for water payments? Do you see this jeopardizing the integrity of the system under future climate change and more droughts?*

30 IP *Você acha que os irrigantes poderiam ser convencidos a plantarem culturas que usam menos água se houverem mudanças climáticas? O que aconteceu com o Águas do Vale? Você acha que uma política como esta a longo prazo funcionaria?*
30 IE *Could irrigators be convinced by water managers to switch to less water-intensive crops under future climate changes? What happened to the Águas do Vale? Do you think a policy like this is functional in the long term?*

31 IP *Voce acha que a Comissão de Usuarios esvazia o Comite do Baixo Jaguaribe? Qual você acha deveria ser o futuro da Comissão? Você acha que seria fácil mudar o atual desenho institucional da gestão das águas?*
31 IE *Does the Jaguaribe-Banabuiú Commission take power away from the Baixo Jaguaribe committee? What do you see as the future of the Commission? Do you think it would be easy to change the actual institutional design of water management?*

32 PP *O poder da sociedade civil parece informal mas significativo no comitê; isto é correto? O que motiva este envolvimento?*

32 PE *Local stakeholder power appears informal in the basin committee, but quite significant is this correct? What drives this involvement?*

33 PP *Qual e a sua opiniao sobre o desmantelamento do Departamento de organizacao dos usuarios para a gestao? Afetou o nível de participação?*
33 PE *How detrimental has the dismantling of the DOU been to the overall participatory nature of the current management system?*

34a RP *Você acha que algum grupo é representado desproporcionalmente na bacia (para mais e para menos)? Quais?*
34a RE *Do you think any groups are over represented or under represented in the basin? Who?*
34b RP *Comparar com anos passados?*
34b RE *Compared to past years?*

35a PP *Descreva o nível de participação democrática na bacia. E no comitê?*
35a PE *Describe the level of democratic participation in the basin. In the committee?*

35b PP *Probe: Você acha que existe um balanço entre tensão e competição?*
35b PE *Probe: Is there a healthy balance in terms of tension and competition*
36 TP *O comitê usa tecnologia e informaões tecnicas para tomar decisões na bacia? Qual tipo de informação? Informação climática? Cenários de disponibilidade de água? Cenários de mudanças climaticas?*
36 TE *To what extent is technology and information used a decision making aid in the basin? What type of information? Weather forecasting and monitoring equipment? Water availability models? Climate change models?*

37 TP *Você acha que é melhor ter apoio tecnico do estado ou a gestão poderia ser mais efetiva se tivesse sua propria agencia como a AGEVAP?*
37 TE *Is it better to have technical support from the State, or would Baixo Jaguaribe be more effective by having its own water agency like the federal model?*

38 TP *Na sua opinião, qual o papel deste tipo de informação na tomada de decisão na sua bacia? Pode comparar com o sistema antes da reforma? Havia informações e conhecimento disponível?*
38 TE *In your view, how does information make its way into the decision making process within your basin?*

39 EP *Comparado com o periodo antes da reforma, quais as mudanças em termos de prioridades e objetivos na gestão das águas?*
39 EE *Compared to before the reform, has there been a change in priorities for water management goals?*

Appendix 3: Proxy Questions for Developing the Adaptive Capacity Index

Question #	Corresponding Watermark Question #	Question		Baixo Jaguaribe	Pirapama
R1	q16r1a-i	What grade would you give to the following aspects of the committee? On the scale of 0 to 10, where 0 means terrible and 10 means great:	The representation of society's interests on the committee.	7.22 (41)	7.18 (28)
R2	q16r1a-i		And regarding how democratically decisions are made, what grade would you give it?	7.58 (40)	7.50 (28)
R3	q16r1a-i		And regarding communication with the population at large?	5.88 (41)	5.14 (28)
R4	q16r1a-i		And with regard to dealing with the most important problems in the basin, what grade would you give it?	6.68 (40)	6.96 (28)
R5	q16r1a-i		And as to its success in influencing the decisions of governmental organs?	5.59 (41)	6.36 (27)
R6	q16r1a-i		And as to its success in influencing decisions of private firms, what grade would you give it?	5.00 (39)	6.48 (27)
R7	q16r1a-i		And as for its success in influencing the behavior of the basin's inhabitants?	6.29 (41)	5.44 (26)
R8	q18sd18	How often do you have contact, either personally or by phone or e-mail, with the organization you represent on the committee? 1) Daily 2) Weekly 3) Monthly 4)Less than monthly		73.2 (41)	71.4 (28)
R9	q1r9	Can you tell me how your organization, agency, or firm won a seat on this committee? Did this happen because of 1) Election among organizations in the sector 2) Designation 3) The organization is designated a member by the by-laws, by law, or by committee decision 4) Other		53.7 (41)	17.9 (28)
R10	q1bsd1b	Is this municipality (where they live) in the same water basin as your committee?		85.4 (41)	50.0 (28)
R11	q18r6	How do you inform your organization about the committee's activities? Do you do it via	Written reports	20.7 (29)	41.2 (17)
R12	q18r6		Oral reports in meetings	82.8 (29)	82.4 (17)
R13	q18r6		Informally	27.6 (29)	70.6 (17)
R14	q19r7	How do you contact other organizations in the segment you represent? Do you do it via	Written reports	17.2 (29)	23.5 (17)
R15	q19r7		Oral reports in meetings	41.4 (29)	29.4 (17)
R16	q19r7		Informally	58.6 (29)	70.6 (17)

P1	q15o7a-g	What do you do in relation to the committee's activities in addition to the plenary meetings….how often do you	Take part in Working Groups or technical subcommittees?	41.4 (29)	35.3 (17)
P2	q15o7a-g		Organize events and seminars?	24.1 (29)	17.6 (17)
P3	q15o7a-g		Collaborate with other members on specific projects?	44.8 (29)	41.2 (17)
P4	q15o7a-g		Facilitate negotiation among members?	51.7 (29)	52.9 (17)
P5	q15o7a-g		Write documents or technical reports?	6.9 (29)	5.9 (17)
P6	q15o7a-g		Represent the committee in other forums	17.2 (29)	23.5 (17)
P7	q15o7a-g		Raise money and materials for committee activities?	10.3 (29)	11.8 (17)
P8	q26or6	In some cases committee members find it difficult to come to meetings. If this is true for you, which of the following is the main difficulty you encounter? Or do you not have any difficulty getting to meetings? 1) Distance and travel time 2) Transportation cost 3) Difficulty in getting there (bad or dangerous roads, etc.) 4) Lack of time 5) Difficulty in getting employer to grant time off 6) No difficulty 7) Other		36.6 (41)	42.9 (28)
P9	q28o2	How many days per month, on average, do you spend on this committee's activities, outside of the plenary meetings? 1) Not any time 2) Up to 1 day a month 3) Between 1 and 5 days a month 4) Between 6 and 10 days a month 5) More than 10 days a month		(100-23.9) = 76.1 (41)	(100-39.3) = 60.7 (28)
P10	q27o1a-c	Now I would like you to assess your involvement in this committee, telling us how often you participate in different activities: 1) a majority of plenary meetings 2) a few meetings 3) or none?	Attend	82.9 (41)	85.7 (28)
P11	q27o1a-c		Speak in	56.4 (39)	60.7 (28)
P12	q27o1a-c		Present proposals in	43.2 (37)	50.0 (26)
P13	q11o5	Do you take part in negotiations (decisions)		82.8 (29)	88.2 (17)
P14	q10o20	Have you ever taken part in a community activity about water, outside of the committee's activities?		78.0 (41)	85.7 (28)
P15	q11o21	This year, there were a lot of activities organized around water because of the Catholic Church's Fraternity Campaign theme "Water, source of life." Did you participate in any of these?		68.3 (41)	53.6 (28)
P16	q16r1a-i	What grade would you give to the following aspect of the committee? On the scale of 0 to 10, where 0 means terrible and 10 means great: As to efforts to get all the members actively involved?		7.73 (40)	7.11 (28)

K1	q22inf1	On a scale where 0 means irrelevant and 10 means highly relevant, how much importance would you attribute to the use of technical information for water resource management in the basin?		8.32 (34)	7.83 (23)
K2	q23inf2a-d	For climate information (medium and long term predictions, for example predictions of drought, or of El Niño), how relevant is this kind of information for solving the basin's problems		7.75 (40)	7.19 (27)
K3	q23inf2a-d	And information about water quality? How relevant is this kind of information for solving the basin's problems?		7.46 (41)	8.25 (28)
K4	q23inf2a-d	And hydrological models (for example, studies of water availability)? How relevant are these for solving the basin's problems?		8.35 (40)	8.22 (27)
K5	q23inf2a-d	And management and planning studies? How relevant are these for solving the basin's problems?		8.45 (40)	8.54 (28)
K6	q24inf3a-f	I would like to know how you get hold of information on climate projections (for example, prediction of drought or El Nino). For information on climate forecasts, do you rely on	Radio, TV	80.5 (41)	78.6 (28)
K7	q24inf3a-f		Internet	51.2 (41)	50.0 (28)
K8	q24inf3a-f		Consulting firms	7.3 (41)	3.6 (28)
K9	q24inf3a-f		Special newsletters	22.0 (41)	28.6 (28)
K10	q24inf3a-f		Other	92.7 (41)	7.1 (28)
K11	q6inf7	Generally speaking, in your experience on the committee, does technical information 1) Facilitate decision-making, since it helps us understand the problems 2) Or, make decision-making more difficult, because complicated or because of conflicting assessments		93.1 (29)	94.1 (17)
K12	q4inf5a-h	Which of the following kinds of information have already been used by your committee, or do you not have enough information to answer the question about some of these kinds of information?	Environmental impact studies?	51.7 (29)	88.2 (17)
K13	q4inf5a-h		Weather forecasts (short term forecasting for ex. of rain or temperature)?	79.3 (29)	47.1 (17)
K14	q4inf5a-h		Climate forecasts (medium or long term forecasts for example, predicting drought or El Niño)?	75.9 (29)	47.1 (17)
K15	q4inf5a-h		Reservoir operation models?	79.3 (29)	70.6 (17)
K16	q4inf5a-h		Water quality information?	62.1 (29)	100.0 (17)
K17	q4inf5a-h		Hydrological models (for ex., water availability studies)?	62.1 (29)	70.6 (17)
K18	q4inf5a-h		Management and planning studies?	82.8 (29)	82.4 (17)
K19	q4inf5a-h		Studies on systems of disaster alert and prevention (for ex., floods and environmental pollution)?	62.1 (29)	35.3 (17)

E1	q20r8	How often do other people in your segment watch the meetings or participate in the activities of the committee?		13.8 (29)	41.2 (17)
E2	q3r3a-c	In some committees, there are distinctions among members which can make a democratic decision-making process difficult. In your views, which of these distinctions have gotten in the way of democracy in your committee?	Unequal technical knowledge among members?	(100-79.3) = 20.7 (29)	(100-88.2) = 11.8 (17)
E3	q3r3a-c		Unequal economic power among members?	(100-27.6) = 72.4 (29)	(100-52.9) = 47.1 (17)
E4	q3r3a-c		Unequal political power among members?	(100-62.1) = 37.9 (29)	(100-47.1) = 52.9 (17)
E5	q20or4	With regard to how the committee members participate in defining the organ's activities, which of the following are closest to your opinion? The activities of this organization are defined 1) By all the members who want to be involved in these decisions 2) By a small group, but one that values the contributions of all the members 3) By a small group, which does not always discuss these decisions with other members		51.4 (34)	30.4 (23)
E6	q8or8	In your opinion, do people feel comfortable about expressing themselves freely when they discuss their concerns and proposals in the committee?		75.9 (29)	82.4 (17)
E7	q5inf6a-b	Speaking now of the dissemination of technical information among the (members/associates) of the committee, would you say that they:	Are available and accessible for all members/associates?	31.0 (29)	52.9 (17)
E8	q5inf6a-b		Are presented in a way that facilitates understanding on the part of all members?	86.2 (29)	70.6 (17)

F1	q19or3	Who are the people or groups who make it hard for the committee to move forward?	Businesspeople	(100-57.9) = 42.1 (19)	(100-46.2) = 53.8 (13)
F2	q19or3		Medium or large scale farmers	(100-26.3) = 73.7 (19)	(100-38.5) = 61.5 (13)
F3	q19or3		Small/ family farmers	(100-0) = 100.0 (19)	(100-23.1) = 76.9 (13)
F4	q19or3		NGOs (Nongovernmental Organizations)	(100-10.5) = 89.5 (19)	(100-92.3) = 7.7 (13)
F5	q19or3		Political Parties	(100-26.3) = 73.7 (19)	(100-7.7) = 92.3 (13)
F6	q19or3		Federal or state government	(100-47.4) = 52.6 (19)	(100-61.5) = 38.5 (13)
F7	q19or3		Municipal government	(100-26.3) = 73.7 (19)	(100-23.1) = 76.9 (13)
F8	q18or2	In your committee, are there people or groups who make it hard for the committee to move forward?		52.5 (40)	53.6 (28)
F9	q25o10	In relation to issues discussed in the committee, did you ever change your mind about something as a result of discussions that took place in the committee?		69.0 (29)	94.1 (17)
F10	q5o15	The committees deal with an exceptionally diverse range of issues, situations, and problems. Do you consider yourself well prepared to perform your functions as a committee member? 1) In most situations 2) In some situations 3) Rarely		56.1 (41)	50.0 (28)
F11	q13or9	Thinking now about relations among committee members, how would you assess the level of conflict among committee members in this organization?		(10-4.41) = 5.59 (29)	(10-3.94) = 6.06 (29)
F12	q16r1a-i	What grade would you give to the following aspect of the committee? On the scale of 0 to 10, where 0 means terrible and 10 means great: As to attempting to negotiate conflicts among members in a democratic fashion, what grade would you give it, or are there no conflicts among members in this committee?		7.67 (33)	7.33 (27)

C1	q8vm8	The water laws propose a management model which, among other things, includes decentralization of the decision-making process, participation of society, and charging for the use of water. In your opinion, is this model suited to resolving the problems in your basin? Place it this scale where 0 means not suited and 10 means well suited, or have you not made up your mind on the subject?		6.83 (41)	7.43 (28)
N1	q21o8	Do you have regular contact with public organs in the context of your committee activities?		96.6 (29)	76.5 (17)
N2	q7ao17a1-6	Have you been to any meetings of the organizations on this list?	11. National Forum of Committees	31.7 (41)	25.0 (28)
N3	q7ao17a1-6		12. Brazilian Network of Water Basin Organizations –REBOB	2.4 (41)	0 (28)
N4	q7ao17a1-6		13. Brazilian Association for Water Resources – ABRH	7.3 (41)	21.4 (28)
N5	q7ao17a1-6		14. Brazilian Association of Sanitary Engineers - ABES	14.6 (41)	25.0 (28)
N6	q7ao17a1-6		15. National Civil Society Forum (FONASC)	9.8 (41)	3.6 (28)
N7	q7ao17a1-6		16. State Forum of Basin Committees	48.8 (41)	50.0 (28)
N8	q1o11	Do you talk to (keep in contact with) members of other committees or consortia?		46.3 (41)	67.9 (28)

X1	q11sd11a-l	Do you have experience in some of these areas? From this list, please tell me the areas in which you have worked	Related to meterology, hydrology, and hydraulics: hydro-geology, meteorology, drains, dams and reservoirs, flood forecasting and control	22.0 (41)	17.9 (28)
X2	q11sd11a-l		Related to water quality: Water Quality analysis	19.5 (41)	28.6 (28)
X3	q11sd11a-l		Land use planning: soil management, soil conservation, and forest management	22.4 (41)	25.0 (28)
X4	q11sd11a-l		Information technology: Geoprocessing, Remote sensing, Information system for water resources	4.9 (41)	17.9 (28)
X5	q11sd11a-l		Communication and environmental education	34.1 (41)	57.1 (28)
X6	q11sd11a-l		Law, political institutional issues, economics	12.2 (41)	28.6 (28)
X7	q11sd11a-l		Social mobilization and community organization	65.9 (41)	60.7 (28)
X8	q11sd11a-l		Environmental management in organizations (waste management, ISO 14001, noise pollution, etc)	4.9 (41)	28.6 (28)
X9	q11sd11a-l		Sanitation (water, sewage, solid waste)	22.0 (41)	32.1 (28)
X10	q11sd11a-l		Public environmental management (monitoring, licencing, etc)	17.1 (41)	50.0 (28)
X11	q11sd11a-l		Public management of water resources (Concession, plan, etc.)	22.0 (41)	39.3 (28)
X12	q5p5	Are you or have you been a member of any council, commission, or consortium dealing with public policy issues?		40.0 (40)	50.0 (28)
X13	q2r10	How many years have you been a member of this committee? (Average)		3.28 (36)	4.4 (25)
X14	q12sd12a-c	How long have you worked on water issues, including the time you were studying, professional or volunteer activities, and / or as a member of the committee? 1) Less than a year (number of people with less than 1 year) 2) _____year(s) (cumulative) 3) Since_____ (cumulative)		9.61 (41)	11.61 (28)

S1	q5sd5	How far did you go in school? 1) Never went to school 2) First level, 1st to 4th grade incomplete 3) First level, 1st to 4th grade complete 4) First level, 5th to 8th grade incomplete 5) First level, 5th to 8th grade complete 6) 2º level incomplete 7) 2º level complete 8) College / university incomplete 9) College / university graduate 10) Specialization [Pós-graduação lato senso (Especialização)] 11) Masters degree 12) Doctorate	44 (41)	78.6 (28)
S2	q10sd10	Could you indicate for us please your total monthly household income, adding up all your income, wages, rents, etc., over the last month? 1) Up to 5 Minimum Wages (up to R$ 1.300,00) 2) Above 5 up to 10 Minimum Wages (From R$ 1.300,00 to R$ 2.600,00) 3) Above 10 up to 20 Minimum Wages (From R$2.600,00 to R$ 5.200,00) 4) Above 20 up to 40 Minimum Wages (From R$ 5.200,00 to R$ 10.400,00) 5) Over 40 Minimum Wages (Over R$ 10.400,00)	29.3 (41)	60.6 (28)

ANA	Agência Nacional de Águas (National Water Agency)
Aguas do Vales	Waters of Valleys
Barragem Principal	Principal Dam
CAGECE	Companhia de Água e Esgoto do Ceará (Company of Water and Drainage of Ceará)
COGERH	Companhia de Gestão dos Recursos Hídricos (Water Resources Management Company)
COMPESA	Companhia Pernambucana de Saneamento (Pernambuco Company of Sanitation)
CPRH	Companhia Pernambucana de Recursos Hídricos (Pernambuco Company of Water Resources)
Cobrança	Bulk water charging/collecting
DNOCS	Departamento Nacional de Obras contra as Secas (National Department of Works against Droughts)
FINEP	Financiadora de Estudos e Projetos (Financer of Studies and Projects)
FUNCEME	Fundação Cearense de Meteorologia e Recursos Hídricos (Ceará Foundation of Meteorology and Water Resources)
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
ITEP	Instituto Tecnológico do Estado de Pernambuco (Technological Institute of the State of Pernambuco)
MRR	Metropolitan Recife Region
Marca d'Água	Watermark
NAPA	National Adaptation Programs of Action
SECTMA	Secretaria de Ciência, Technologia e Meio Ambiente (Secretary of Science, Technology and the Environment)
SRH	Secretaria dos Recursos Hídricos (Secretary of Water Resources)
Sertão	The semi-arid region of the Northeast Brazil
Zona da Mata	Narrow strip of Atlantic forest that runs north-south along much of the Northeast Brazil's coast line

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