. . . Until the Well is Dry:
International Conflict *and* Cooperation over Scarce Water Resources

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Abstract

This dissertation examines the relationship between water scarcity and international conflict and cooperation. In it, I find that drought affects international relations, but not always as current scholarship expects. Countries sharing a water resource and enduring a drought are less likely to go to war with each other, or even to experience any militarized conflict. Some tests show that cooperation between countries also dwindles during droughts. However, despite the evidence for a general trend toward less cooperation, countries experiencing a drought have a greater likelihood of water-specific cooperation as expressed in a treaty that explicitly addresses water supply amounts or benefits.

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Pigmei Gigantum humeris impositi plusquam ipsi Gigantes vident.
– Didacus Stella, later quoted by Newton

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Chapter 1

Introduction: How Do States Address Shared, Scarce Water Resources?

> 'There will be water wars in the future' is no more a testable statement than the proverbial 'The End of the World is at Hand!', unless terms such as 'the future' and 'at hand' are clearly specified.
>
> *Nils Petter Gleditsch, 1998*

This dissertation examines the impact of scarce water resources on international conflict and cooperation. The conventional wisdom of natural resources and international conflict usually points to water as a source of violent and political conflict between nations. Most modern literature on the subject of "environmental security" neither draws a distinction between conflicts of *scarcity* and conflicts of *abundance*, nor among the various natural resources: diamonds and gold are often lumped together with water or fisheries. Many authors agree with the Cassandrists[1] of the world, that scarce resources—in other words, *all* resources!—will cause large-scale violence between and among countries in the very near future.

[1]Cassandra was a prophetess in Greek myth who told the truth about the future, but who was cursed such that no one believed her.

As Charles G. Darwin (1960, 463) and Nils Petter Gleditsch (1998, 393–394) have noted, however, using the future as evidence is generally weak scholarship. Proposals that *most* modern warfare is about resources (Westing 1986*a*) ring hollow as well, since the explanatory power of a variable approaches zero if it is found in every observation. Thus it falls in the realm of careful research design as to which conflicts might be *proximally caused* by a scarce resource or a relatively abundant resource, and if the conflict-causing effects are related to the relative abundance or scarcity. Some authors find that water scarcity increases the likelihood of conflict (violent or otherwise), while others (Wolf and Hamner 2000) propose that the number of violent interstate conflicts over scarce resources numbers less than ten since the dawn of civilization.

In this text, I examine four questions: does water scarcity lead to violent conflict between states? Does water scarcity lead to non-violent (i.e. political) conflict between states? Can scarce resources engender cooperation despite traditional neorealist expectations? How could drought bring countries to "hydro-cooperation," when most existing theory predicts violence over increasingly scarce water resources—and how could countries overcome the problems of collective action and the temptation to shirk on obligations created by a treaty? I find that water scarcity is significantly and consistently correlated with a *decrease* in the likelihood of violent conflict, and that it does not affect the number and intensity of conflictual events. I also find that water scarcity reduces the level of general cooperation between countries, but that shared water scarcity *increases* the chances for water-specific cooperation, even though all other forms of cooperation drop off during droughts. These findings run contrary to much of the conventional wisdom surrounding resource politics.

I draw my background conditions from international relations theory, and avoid relaxing most of the assumptions of realism in order to explain observed behavior without proposing a new paradigm, though I do not view the state as a unitary actor. I follow Wolf (1995), who expects states, preferring self-reliance to costly cooperation, will develop their resources unilaterally until they approach or overstep the renewable limits imposed by nature. Because the natural world is subject to ebb and flow, the annual rainfall and agricultural crop will suffer occasional catastrophic shortfalls; the accompanying 'wet years' and 'bumper crops' encourage overuse and the use of marginal areas for food production or extraction. Once states have built an infrastructure to utilize all the *average* annual freshwater supply, shortfalls can be devastating. These catastrophes can only be buffered by surplus from neighboring riparian countries *until all of the renewable resource is in use*. At that point, a drought means that none of the international users can withdraw as much as their economic infrastructures need or expect. The upstream state generally has an easier time meeting some of the demand because it can withdraw more from a river before the waters reach further downstream. Downstream states often suffer, yet they would behave similarly if they were located upstream. Domestic politics during these droughts can precipitate international demands as farmers or other pressure groups demand relief from the extreme conditions.

The worsening scope of these natural disasters is guaranteed, since people have no compelling reason to limit water use in the wet years. Sustained droughts eventually cause a die-off or migration until the population is more or less locally sustainable. At some point, migration is not possible because conditions are no better elsewhere (or political considerations prevent refugee migration). This point in a given interstate relationship results in a political crisis.

It is at this point that most scholars predict violent conflict. In a weakened state, countries may choose to make war rather than devote resources to recovery and prevention of future disasters. Recovering from and preventing these events is expensive and requires unpalatable measures: especially in countries that have not made an industrial transition, even 90% of a population may be involved in agricultural production. Irrigation is expensive for the return on investment, compared with investment in, for example, heavy industry or manufacturing. People believe that with "enough" water, their situation would improve such that they could return to a profitable livelihood. Why not just take the water sources and reservoirs with military might?

While the temptation to take water by force may be strong (especially as a diversionary tactic), the *observed evidence* for this expectation is surprisingly weak (Wolf and Hamner 2000, 123). Unfortunately, many of the conventional theoretical explanations for cooperation in the face of scarcity take a simplistic and potentially circular route. The policy sphere is rich with descriptions and explanations of treaty-making and conflict resolution among neighbors; the bulk of the evidence suggests that countries are willing to cooperate when faced with worsening scarcity, and that sharing resources can be accomplished without depending on hegemonic stability or force of arms.

Active cooperation can take two forms: first, existing supplies can be reallocated or their quality improved; second, new supplies can be created by reclamation, dams, or changing the existing evaporation/transpiration cycles (draining swamps or covering canals, e.g.). The immediate crisis of water supply crystallizes the situation and forces leaders to consider cooperative actions or make new demands and bring about a political/military crisis. But why will states that normally conflict agree on environmental topics? Why will some states share water or fisheries access that we expect would not? Why will some states fail to cooperate on an issue when they have otherwise good relations?

In the next two chapters, I provide background on theories of the world that address international behavior and domestic behavior that affects international relations. I explain the logic underlying the realist conclusions about "resource wars" and set up later tests of these hypotheses. I then propose several hypotheses that circumvent the circular arguments that plague cooperation theory. These hypotheses draw from and extend Olson's (1965) *Logic of Collective Action*, Ostrom's (1990) *Governing the Commons*, and others.

In the fourth chapter, I describe the data I gathered and the methods used to collect and analyze the data. For instance, because of a paucity of digital maps, it was necessary to create a set of annual maps of the world's political boundaries. The sources and methods used to create these maps are explained, along with the fundamentals of geographic information systems (GIS).

In the fifth chapter, I statistically analyze the effects of acute water scarcity (periodic drought) on the likelihood of military conflict between country pairs. Most existing theory sides predicts a decline in diplomatic relations when natural resource supplies are restricted suddenly. I test the idea that natural resources worsen, or else do not affect, interstate relations first. I find that water scarcity does not correlate with an increased likelihood of violent conflict between states, but rather a strongly *decreased* likelihood of military or violent conflict.

Chapter 6 continues the analysis of conflict by using costly conflictual events (not just the military ones) to examine the outcomes of a drought in one or both countries. Here again, the results show that neither the number of events or intensity of those conflictual events rises during a drought.

But conflict tells only half the story. Some argue that cooperation will increase during water stress events because countries understand water's importance, the benefits that can accrue from cooperation, or the grave consequences of military conflict. In Chapter 7 I find that, as with conflictual events, countries seem to tend to their domestic issues more than engage in international cooperation under drought conditions. So not only do countries avoid conflict during drought, they generally seek less cooperation as well.

In the eighth chapter, I statistically analyze the possibility that cooperative events specific to water resources occur more often between states during periods of acute scarcity. I examine the signature of water-specific resource-sharing treaties as the possible outcome of acute water scarcity. Though *general* cooperation drops under drought conditions, the likelihood of a water sharing treaty rises sharply during shared droughts. This behavior among states is more or less exclusive to water supply treaties. In other words, dam construction or fishing treaties do not also become more likely during a drought, but only water supply treaties. Thus, despite the pain of a drought and the additional difficulties of ceding some measure of autonomy by entering into a shared obligation with a neighbor, water treaties are still more likely than under normal rainfall and soil moisture conditions.

In sum, tests of the malthusian hypotheses turn out to have little merit; rather, a given state's propensity for engaging in conflict rises as available water quantities rises (compared to expected annual averages). And when both states share a drought, the likelihood of military conflict or violence drops sharply. Overall, I find little support for the malthusian hypotheses, but incomplete support for the cornucopian hypotheses.

Chapter 2

Literature Review

> The view which he has given of human life has a melancholy hue, but he feels conscious that he has drawn these dark tints from a conviction that they are really in the picture, and not from a jaundiced eye or an inherent spleen of disposition.
>
> *Thomas Malthus, 1798*

This chapter provides background on the science and theory behind the political effects of water resources. Resources affect political behavior at all levels: locally, regionally, and internationally. I discuss the current state of the literature on natural resources and, more specifically, water as both physical and political substances, what makes them worth fighting for, and why states might not violently conflict, choosing cooperation instead. First, I discuss malthusianism, its relation to realism, and the realist theory that most closely describes the effects of Malthus's proposal on the actions of states, lateral pressure theory. I will critique the realist theories as well. Next I explain the commons dilemma and how it might lead to war. I also provide additional explanations for the outbreak of war over resources that do not use realist theory as their primary motivation. I then discuss how states might deal with scarcity when it occurs, unilaterally or by costly cooperation with a neighboring state. If a state is able to pursue cooperative gains with another state, I explain the mechanisms by which this cooperation can occur and persist, and why water resources are particularly well suited for this 'orthodox cooperation.'

Much current scholarship and the popular press paint a frightening picture of coming resource conflicts. Gleick (1993*a*, 1998*b*) and Klare (2002) are among those authors explicitly predicting military conflict resulting from freshwater needs. Toset, Gleditsch and Hegre (2000) have empirical results that find freshwater shortages (among other water-related variables) can increase the likelihood of military conflict between countries, as do Hensel, McLaughlin Mitchell and Sowers (2006). Tir and Diehl (1998) offer some statistical confirmation of the malthusian ("resource wars") hypotheses. And, there is one known war over access to canals along the Euphrates and the fresh water in them, in 2500 BCE between the Sumerian states of Lagash and Umma (Cooper 1983). Most, though not all, of the known water conflicts to date have occurred at the sub-state level (Wolf and Hamner 2000, 124–128). Generally the likelihood of conflict is much greater within a country: see Renner (2002) and Peluso and Watts (2001) for examples. While water conflicts tend to be sub-state, there is a body of evidence that supports water scarcity *increasing* the level of cooperation even between erstwhile enemies (Wolf 1995, Amery and Wolf 2000, Lowi 1993, Feitelson and Haddad 2000).

All of Earth's resources, including water, are finite. Under conditions of scarcity, even risky attempts to improve a state's food production or GDP may be more attractive options than sitting idly, waiting on a coup or an unfavorable election: a leader might decide that "war was less risky than a cold, hungry peace" (Clancy 1986, 26). Similarly, water scarcity and its effects echo since at least 2500 BCE, when the Sumerian city-states of Lagash and Umma fought a war over access to freshwater (Cooper 1983). Prior to the 19^{th} century, agricultural production was closely tied to military power (Gilpin 1981, 111–112), was a primary source of wealth (Goemans 2006), and thus natural resources or the structures to use them were prime targets for invaders or rebels. In the 8^{th} century BCE, "the specialized knowledge of flood-control which the irrigation engineers of Babylonia and Assyria had acquired by age-long experience could be turned to warlike purposes. The systematic ruin of an irrigation system was one of the Assyrian methods of punishing a defeated enemy" (Postel 1999, 24).

What about water resources make them worth fighting for, or cooperating over? Do countries fight because of relative water *abundance*, relative water *scarcity*, or both? How is water overuse, scarcity, and resource degradation a threat to global political stability? Why do states not proactively address scarcity before a crisis? At what point will states cooperate to mitigate resource scarcity/-ies, and what will precipitate these initiatives? Finally, what shape will the cooperation take? Who will benefit most from cooperation? Can states sustain the cooperation? Can they avoid further damage to the environment, or is it impossible to prevent overuse of renewable resources such as fresh water? This chapter addresses these questions by examining existing literature and finds a lack of consensus about the causes of resource conflicts. Most authors who expect there to be resource wars between countries provide little empirical evidence, and those that do have an excessively broad definition of 'resource wars.' The remainder of this chapter will first address the ecological explanations for resource competition, then moving to resource-specific theory from the realist paradigm that offers one explanation for interstate resource wars. I also present theories that relax the assumptions of realism. Next I discuss pathologies of realism's explanation for resource wars and offer some explanations for why resource scarcity might not lead to violence. Last, I look at ways in which states will address resource scarcity without a resort to war, including cooperation via a treaty.

2.1 Natural Resources and Malthusianism

If the Earth can renewably support a finite number of people, then population over that limit will ultimately die from starvation. While it is possible, using nonrenewable energy sources, to temporarily extend the 'carrying capacity' of the Earth (Catton 1980), there is a limit to how many people can live on the earth. In local ecosystems, the carrying capacity may vary greatly. In 1798, Thomas Malthus offered a simple explanation for human misery, and the likely results if population continued to grow. Malthus addresses humanity's ability to increase its food production, but claims that agricultural production can only increase at a linear rate, while population, if not constrained, increases exponentially. At some point the population will starve until its number is below the number that can be fed by the land (Malthus 1960, 9). See Figure 2.1.

From Malthus' original theory about population and carrying capacity, Charles Darwin's (1936 [1859]) *On the Origin of Species* proposed that competition and one species' competitive advantage over another enables different species to survive while others fall extinct. Joseph Grinnell (1904, 375–377), and later Garrett Hardin (1960, 1292) further refined Malthusianism in the animal world. They found that competing species cannot co-exist for long; the more prolific user of resources, and thus the more prolific breeder, in a given niche, will win out. This "competitive exclusion principle" means that a population must grow at least a little faster than similar competing species, or die. If a population chooses to balance birth and death rates, they will slowly become proportionally smaller than all neighbors who have positive population growth rates. Stagnation does not lead to balance,

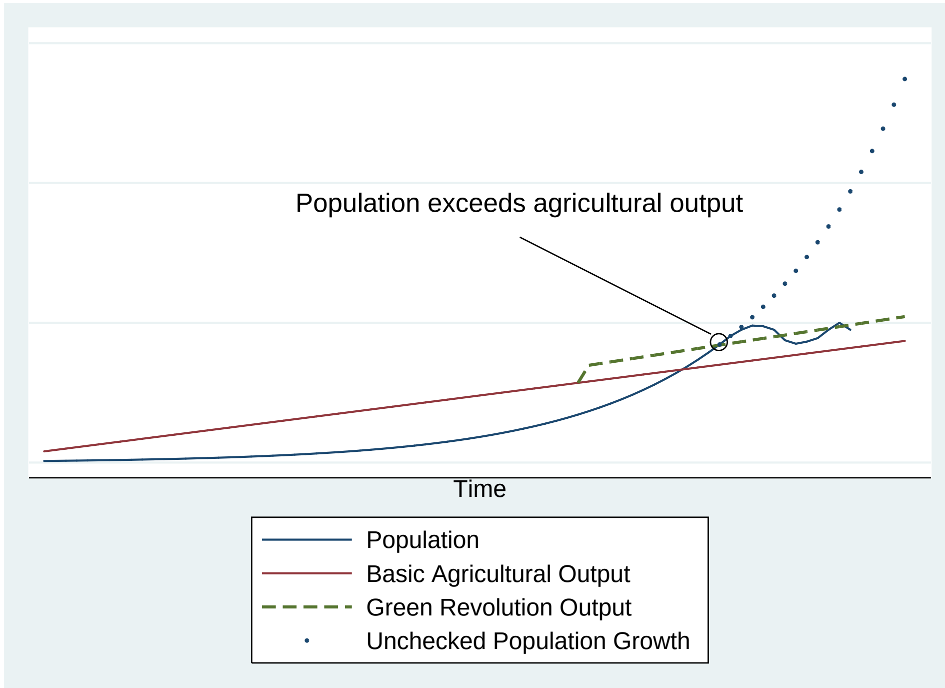

FIGURE 2.1: Graphical explanation of Malthus' theory, including the possibility of a "Green Revolution."

but rather ruin. At some point, territory becomes the restricting element on a given population's growth; then, the state must attempt to take an adjacent state's territory (Choucri and North 1996). Otherwise it will be crowded out or overrun by its neighbors.[1]

So, as a result of greater consumption and/or efficiency, some populations will tend to prosper, expand, and crowd out other populations. But while *local* ecosystem limits can be exceeded by clever adaptation such as importing food or using petroleum-based fertilizers in agriculture, there is still a *global* limit. If the population of the earth (depending on individual consumption levels) rises above this "carrying capacity" (Catton 1980), some members of the species will die off un-

[1]Hitler (1941, 168–179), in *Mein Kampf*, used a similar explanation, including statements about soil fertility, population growth, increased consumption, and natural selection (in this context, more properly "eugenics" or "social Darwinism") to explain the need for German *lebensraum* and to justify his expansionist policies in the 1930s.

til it is possible to feed everyone, assuming an ideal distribution of food. In this zero-sum context, biology and ecology lead to social science: they who survive will be those who can consume the most resources most efficiently and prevent others from doing the same. Zero-sum situations leave little room for peaceful co-operation as countries need more resources to feed their populations and fuel their power base.

States that prosper by prodigious use of resources (efficiently or not) have an incentive to *not* restrict the use of resources merely because others wish it. Overuse, as a policy, is a good way to build power and maintain local or global hegemony. A 'dog in the manger' state can remain stronger by using resources and preventing their use by other states.[2] Only after the renewable limits of a system have been reached or exceeded will groups, or states, address the hard restrictions of entropy and finiteness. The power that comes from expanding consumption and increasing efficiency results in a prisoner's dilemma game, resulting in a "race to the bottom" (Oates 1972).[3]

These hard limits on global population and resource use lead to the obvious need to restrict global population to a sustainable level. But our current understanding of human rights includes a right to reproduction and makes restrictions on population growth entirely voluntary. Olson's (1965, 2) most important conclusion is that "rational, self-interested individuals will not act to achieve their com-

[2]By 1968, Hardin had reached similar conclusions: pure or representative democracy endangers any moves towards restrictive or sustainable resource use in the long run, as those populations that reproduce faster (using more aggregate resources than its previous competitor) will displace slower-growing populations, and will implement policies, directly or by voting, supporting this larger group's breeding habits (Hardin 1968, 1246). Hardin implicitly supports a "green dictatorship."

[3]The idea of the "race to the bottom" originated from United States Supreme Court Justice Louis Brandeis in Liggett Co. v. Lee (288 U.S. 517, 558-559, 1933), but is used here in the context of the prisoner's dilemma rather than of state competition for investment. Liggett Co. v. Lee, though it dealt with tax rates on chain stores, is not related to the chain-store paradox of Selten (1978).

mon or group interests." His logical proof that, because of rational preferences for personal gain, public goods will be provided at sub-par levels, or not at all, if the benefited group is larger than a handful of actors. Downs (1957, 46), for whom voting was participating in a collective action, predicted the same thing. This idea of the rational egoist logically extends the expected outcomes of population ecology into the political realm. If the good of the largest group (the global population) benefits from a decision to consume fewer resources but this result lessens the prosperity and/or survival chances for a local group or individual, then the good of the largest group will suffer as each individual or small group acts in its own self interest.

2.2 Realism and Natural Resources

It is a short step from Malthus, population biology, and the tragedy of the commons to realism and lateral pressure theory. Malthusian tenets echo throughout lateral pressure theory: as population, money and production capacity grow, so does a state's consumption of resources and its military power. As state power grows, a state becomes better able to acquire more resources, either economically or militarily—making it a potential threat to its neighbors (Carr 1964, Waltz 1954). States ultimately have only a resort to force to preserve themselves, and the impact of natural resources on a state's military and economic power cannot be ignored.

2.2.1 Lateral Pressure Theory

States, according to Choucri and North (1972, 1983, 1996), therefore seek to secure ample supplies of those raw materials that might otherwise limit the growth their power. Choucri and North call this idea *lateral pressure theory*, and it provides a theoretical explanation for resource-based interstate violence. States that can use their power to gain access to resources will do so, whether by force or more subtle means. Especially when a specific resource (obviously including fresh water supplies) is a limiting factor to development, countries will seek access to that resource by any means necessary, including imperialism and war. Potential examples include Great Power imperialism during the 19^{th} and 20^{th} centuries, Japan in the first half of the 20^{th} century for oil (Schroeder 1958, 53), Germany's 1940 invasion of Norway for access to Swedish iron ore (Kersaudy 1990, 46, 78),[4] the United States' presence in Southeast Asia (Ehrlich and Ehrlich 1972, 426), and the Israeli bombing of a Syrian dam in 1966 to prevent the Arab's attempts at upstream diversion of rivers (Lowi 1993, 130). Some natural resources greatly enhance a state's economic/military power, making a state unlikely to give up these resources and more likely to militarily pursue resources that will enhance its power Choucri and North (1972, 1996).

Compounding the resource consumption issue is that many economic activities create a greater demand for natural resources as individual and country-wide consumption rises. See Figure 2.2 for a basic diagram defining scarcity. Increased demand can create scarcity for other countries and can give countries with rare resources, such as South Africa, leverage with regards to trading partners who need such resources (Kaempfer, Lehman and Lowenberg 1987, Clarizio, Clements and Geetter 1989). Of course, such valuable resources also make the source countries targets for conquest. Without available, inexpensive substitutes for resources, and with little bargaining space (because all states want more of the resource), realists

[4]Van Evera (1999, 109) and Lowi (2000, 163), similar to Westing (1986*c*), propose that Japan and Germany sought resources and empires to sustain their economic and military power. They sought to create autarkic conditions to avoid economic strangulation by an Allied blockade. The British were well aware of this issue, as about half of Germany's iron ore came through two cities, Luleå in Sweden and Narvik in Norway, but Narvik's port remained open all year because of the warm Gulf Stream waters, while Luleå's port on the Gulf of Bothnia froze for four months in the winter (Moulton 1966, 42–49).

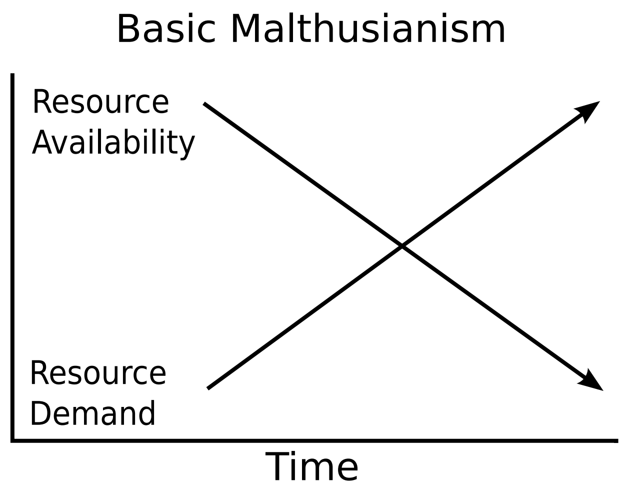

FIGURE 2.2: Graphical Explanation of Scarcity; Adapted from Homer-Dixon (1999)

predict that conflict and violence will increase. Natural resources such as fresh water could goad an actor into a war of conquest, especially if the resources can be captured and used without great cost of acquisition or oversight. Liberman (1996) and Van Evera (1999) call this condition *cumulativity*. Cumulativity makes war more likely when conquest or acquisition is easy and oversight costs are low. Natural resources are all the more likely to cause problems between countries when the resources are militarily/economically valuable and located near boundaries: "Peace is most frail if many resources are highly cumulative and lie exposed near national frontiers. Small territorial gains can then be more easily parlayed into larger gains, and small territorial losses can spell disaster" (Van Evera 1999, 109).

2.2.2 Resource Scarcity or Abundance?

Problematically, the literature usually does not distinguish between relative resource *scarcity* and relative resource *abundance* as a cause for conquest or violence (de Soysa 2000, Le Billon 2001). Relative scarcity may cause tensions, but attacking an arid country for its water makes little sense when one could peacefully invest in either desalination or efficiency gains. Similarly, most authors fail to distinguish between *acute* scarcity and *progressive* scarcity. Acute scarcity is expected to last for a finite time period after which, ostensibly, the resource level should return to its expected average levels of availability. Acute scarcity has several advantages over *progressive* scarcity for studying conflicts of resource scarcity, in that progressive scarcity could have human causes and introduce endogeneity problems.

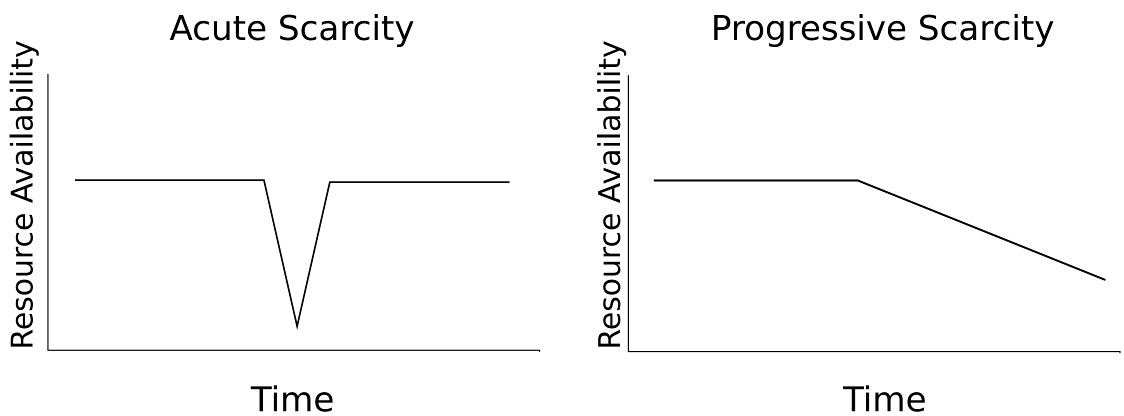

FIGURE 2.3: Acute versus progressive scarcity

Provided one includes territory as a natural resource, Westing (1986*a*, 1986*c*) and others argue that demand for natural resources is possibly the *only* cause of interstate violence. But violent conflict is a rare event, and I disagree with Westing's assessment of World Wars I & II as resource conflicts,[5] except in the broadest sense. Levy (1995, 38) comments that

> Arthur Westing's work on the environment and war has consistently adopted this highly encompassing view of the term. This definition may have some degree of logical coherence, but it fails the test of usefulness. Under Westing's classification, virtually every war counts as

[5]See Appendix 2 of Westing (1986*b*), where the list of 'wars and skirmishes involving natural resources' includes World Wars I and II. Both wars, according to Westing, were partly caused by population pressures in Europe (204–5). Contrast Westing's list with Wolf and Hamner's (2000) list that includes only seven international incidents of violence related to freshwater access, none of which directly escalated to war.

> an 'environmental' war, because natural resources of some sort have figured to some degree in almost every belligerent's war aims.

In other words, vaguely assigning causality for all wars to one factor reduces the explanatory power of the variable to zero.

2.3 Resource Scarcity as a Cause of Conflict

If one expands the idea of "resource" to include territory, then the literature on "resource conflict" becomes much broader. At the most basic, territory (and the resources it contains) provide *willingness* or *motivation* to conflict with the territory's current owner. Contiguity of disputed or desired territory provides a low loss-of-strength gradient for military forces and increases the relative likelihood that a country's attempt at conquest will succeed. Starr (1978, 2005) proposes that a relatively high chance of success, or an existing pretense for conflict such as an enduring rivalry, raises the *opportunity* for a state to seek conquest. Starr (2005) notes the influence of prospect theory (Kahneman and Tversky 1979, Tversky and Kahneman 1982, Levy 1997, Levy 2000) on territorial conflict. Prospect theory proposes that people more highly value sure outcomes (such as objects already possessed, rather than those with some moderate chance to acquire), and also that once an object or outcome is acquired, this new level of territorial extent or resource endowment nearly immediately becomes the new perceived status quo.

> "The new acquisition of territory (because it is so highly valued) produces almost immediate endowment effects. Because of these endowment effects, when a country takes territory, we find that *both* sides now frame the situation as one of losses.... In turn, both sides become risk acceptant with regard to the escalation or militarization of the conflict. Thus, there is increased willingness and an increased probability of es-

calation to militarized conflict" (Starr 2005, 399).

Starr proposes that, as predicted by prospect theory, territorial acquisition (perhaps as the result of resource scarcity in the attacking country) can quickly recenter a country's understanding of its status quo territorial extent and can produce an escalation spiral from which it might be difficult to recover, since the territory was obtained from some country that wants that territory back. In domestic politics, a similar phenomenon could exist when a period of increased rainfall reverts to the average, or slides into a drought. Once the local population adjusts its expectations to the new, momentarily higher average rainfall, they will feel entitled to the same amount of available water during periods of heretofore average rainfall, even during a drought. A period of wetter-than-normal conditions, followed by a drought, spurred a great deal of domestic policy in the western United States in the late 1800s. Once the situation reverted to the normal, lower amount of rainfall, citizens felt deprived and sought redress from the national legislature (Stegner 1992, 215–217, 296, 298, 312–316). But if there are not solutions available at the national level, a state might seek sources of water from outside its borders. In this manner, domestic forces could lead to war in a manner different from lateral pressure theory, since realism nominally claims that domestic politics are substantively inconsequential in matters of national survival (Waltz 1979, 106–107).

2.3.1 The Commons Dilemma

Another potential cause of conflict over shared resources is Olson's 'commons dilemma,' where cooperation to avoid harming a resource (or to make efficiency gains) is possible but unlikely because actors cannot credibly commit to cooperate on agreements—even agreements both sides know to be superior to the alternatives. Suspicion that the other player(s) are cheating on the agreement can cause or worsen rifts in relations, possibly leading to confrontation and violence, and can render states unable to stop overusing a resource, leading to more rapid declines in resource availability.

Though Homer-Dixon is not explicit about the links to Putnam (1988), Gourevitch (1978), or Olson (1965), his ideas are similar to these authors, and somewhat similar to lateral pressure theory. Similar to the generic commons dilemma, Homer-Dixon (1994, *inter alia*) proposes that "environmental scarcity" is caused by three factors and leads to violence in a variety of direct and indirect means, potentially stemming from a tragedy of the commons. Scarcity is caused by: decreases in environmental quality or quantity; population growth; and unequal access to resources. The resulting scarcity leads to migrations and "environmental refugees," and a decline in environmental productivity. Groups may conflict over access to the resources, resulting in ethnic conflicts or civil war, weakened states, and "deprivation conflicts," potentially across international boundaries. When resource scarcity affects enough of the population, various groups will seek a political or violent redistribution of the resource. Ultimately, the expansion of resource use affects other adjacent states. Violence comes not explicitly from the need for resources, but from the changed perceptions of the other state as "zero-sum" competition becomes coercive and negative.

Homer-Dixon's causal mechanism resembles Choucri and North's (1996) subset of realism; relations between states worsen as a result of environmental degradation or deprivation. Deprived states view their resource situation as one that restricts the growth of the state's power and thus, hampers the state's ability to effectively defend itself and achieve desired outcomes for its survival and prosperity. At some point, a sharp drop in the resource's immediate availability may create an unstable situation resulting in an attempt to acquire resources by force. And even if countries do not go to war because of changes to their resource stocks or as a result of environmental degradation, it remains possible that the additional stress or uncertainty caused by such changes makes war more likely. Lowi (2000, 163) says that "most conflicts can be traced to a variety of causes; and in conflict settings, environmental factors tend to function as intervening variables." So, while water resources might not have caused the 1967 Six-Day War between Israel and Syria, Jordan, and Egypt, "they were part of the package of issues that, as a package, established the conditions that made war likely" (Lowi 2000, 161).

Stuart Bremer (2000) offers that sometimes interstate conflict results from *chance*, "when two or more events or forces that are not causally related to one another accidentally align to produce an effect much larger than either could produce separately" (Bremer 2000, 33–34). He concludes that fighting should be considered the result of a process in which chance plays a role. Chance certainly affects the distribution of annual water resources, and thus chance affects interstate relations as rain falls or refuses to sprinkle, and rivers flow or trickle. These variations in water availability provide opportunities for conflict, or for cooperation: a drought may provide the impetus for states to cooperate despite conflicting desires for autonomy and water use, or the drought may exacerbate existing tensions—perhaps themselves a result of months or years of drought—and lead to violence.

2.3.2 Rationalist Explanations for War

Fearon (1995) offers several explanations for war initiation based on a rational-actor theory. One reason for war is that all involved states cannot divide the benefits of any possible agreement in such a way as to satisfy all states. However, linkages with other issues (side payments of whatever stripe) provide a partial solution to the problem of indivisibility. Thus indivisibility could less account for a water war, but could better account for conflict over control of the Suez Canal. Disagreements about relative power in the dyad could account for war. If one or both states believe they can successfully—and at an acceptable cost—defeat the other, war becomes more likely. Similarly, if one side underestimates an opponents willingness to fight (for any reason) then war becomes more likely. Thus if one state underestimates the salience of water as a contentious issue, then two states could clash over water resources. Naturally it is in the interests of a state to misrepresent how much it values water to convince (bluff) an opponent of its willingness to fight.

States may also fight for strategic gains. Fearon suggests that states fight most often for territorial reasons because of territory's military value. Also, a state could launch an offensive to take a piece of territory which would provide it with significant bargaining leverage at a later date.

2.4 Problems with Realism

There are problems with the use of the resource conflict scenarios in predicting or explaining conflict. Because resource characteristics vary, conflict theories such as neorealism have poor transportability across resources. Water may be just as critical to an infrastructure as petroleum, but the amount of hydro-conflict is far below what Realism and its variants suggest (Wolf and Hamner 2000, 123–128).

It is easy to predict or threaten violence caused by resources with a high domestic or strategic value. However, if a country is hit by a famine or drought, it may be difficult to initiate a resource war: military readiness may suffer; neighboring states (especially those unaffected by the current natural disaster) may be more powerful; or there may be a high cost of losing cooperative benefits between countries. Other factors reducing the benefits of war include: the impossibility of exclusive access to a given resource; reputational costs or international pressure; and lower risks or greater payoffs for a cooperative outcome. Therefore, while military conquest is still an option for states faced with environmental or natural resource shocks, I expect they prefer to stabilize their domestic turmoil and military decline through bargaining rather than a risky attack. Mistakes in bargaining are sure to occur, and thus war remains possible, even over smaller resource 'pools.' Additionally, there is some point at which the value of war is higher than any resource allocation, and at that point violence will result, absent side payments.

2.4.1 Domestic Influences

Most theories predicting ecoviolence focus on intrastate/civil conflicts rather than international dimensions of conflict. Ullman (1983) coined the term "environmental security," and hypothesizes that environmental scarcity will cause domestic unrest and potential adventurism as people compete for increasingly precious resources and demand relief from their government. Alternately, a perceived need for autarky or for the security of some local resources, the stress caused by shortages may increase a country's propensity to engage in expansionist activities. Homer-Dixon (1999, *inter alia*) uses this argument to explain the possibility that civil unrest may generate interstate violence, not just intrastate violence.

Hauge and Ellingsen (1998) did a study on intrastate violence and resource scarcity, among other issues. In their article they found some correlations between civil violence and water scarcity and other environmental factors, including deforestation. However, some scarcity issues do not translate well (if at all) to international conditions; though deforestation could lead to adventurism by a country, a war to conquer territory would quickly destroy the resource; the same is true for other territorial uses.

Issue salience has some credence as a cause of war: the more salient the issue, such as territorial sovereignty or strategic resources, the more likely conflicts over that issue lead to violence (e.g. Huth 1996, Starr 2005). Issue salience may not matter as much as previously expected, as Fearon (1995) doubts its usefulness as a criterion for war initiation. Gourevitch (1978, 1996) proposes that self-interested domestic forces that would lose economically during a violent conflict with a given neighbor will rally to *prevent* any war, including resource conflicts. By doing so they act rationally to preserve their financial interest in trade, good relations, and open borders. Multinational corporations, trade lobbies, and major exporters will seek to avoid war because of the economic consequences. These groups stand to lose large amounts of revenue with trading partners during a conflict, since the trade might be interrupted by a blockade, or the trade might be with the target state(s) in the conflict. Worse, longer-term damage could be done to economic infrastructure. "Trade and economic interdependence create bonds of mutual interest and a vested interest in international peace and thus have a moderating influence on international relations" (Gilpin 1987, 56). Putnam (1993, 63) says "a good democratic government not only considers the demands of its citizenry (that is, response), but also acts efficaciously upon those demands (that is, effective)," but the same is true of an autocratic government and its *selectorate*, the portion of that country's home population capable of keeping a leader in power (Bueno de Mesquita, Morrow, Siverson and Smith 1999, 793). Of course, domestic politics can work for war *or* peace; those forces that gain from violent conflict could attempt to exacerbate relations and foment war (Mills 1956), but neither of these mechanisms are available under classical realism.

2.4.2 Internal Politics

LeMarquand (1976, 888–889) offers a system of explaining cooperation in river basin management, based on bureaucratic and political inertia: "since most international river issues are concerned with middle range objectives that are not essential to national survival, policy for these issues is moderate." Despite the cries of the population, and the threat of coup, revolution, or general unrest, one or two years of drought are unlikely to radicalize policy. But if a state does not militarily occupy new territory to respond to its population's needs, what will it do? Can there be resource scarcity without international conflict and/or violence?

2.5 Resource Scarcity Without Violence

War might be *less* likely than some scholars predict; how might states address scarce water issues without territorial expansion via a war? These options include internal efforts, trade, treaties, and doing nothing. For states that choose treaty negotiations and perhaps conclude a treaty, I outline a proposed process for those situations, and list the likely outcomes from such a process.

2.5.1 Hegemonic Stability

As Choucri and North, Gleick, Homer-Dixon and others have indicated, conquest can be a useful tool in keeping supply ahead of demand for certain resources. This means of addressing need has been declining in popularity since 1945, however. Still, in an anarchic system, power is the ultimate arbiter, and if a state needs a resource badly enough and cannot acquire it by means other than violence, violence will follow. Of course, the stronger country might use implicit or explicit threats or pressure to maintain the peace or dictate the terms of sharing (Mearsheimer 2001, 138,152). A state need not use military force to blackmail: "the actual or threatened cutoff of trade, finance, or technology can be a potent means of leverage over other states" (Gilpin 1987, 76). A hegemon might also make some concessions or contributions to the stability of the system, even at some cost to itself, as such actions would help it maintain primacy in the local or global system. Keohane's (1980, 1984) hegemonic stability theory allows both for the possibility that strong states might set up cooperative systems and that those systems could continue on even absent the attention or continued hegemony of its original patron state.

2.5.2 Potential Destruction of the Resource

Others argue that states will recognize that violence can destroy a water resource, making it an undesirable target for conquest. Some states would have to destroy a target's water infrastructure in order to gain extra water, or at least occupy enough of the target's territory to acquire more water storage and catchment areas (Soffer 1999, 248): Israel's capture of the Jordan headwaters in 1967 was quite effective, though Appendix A presents an argument that water supply was hardly a deciding factor in Israel's expansion into the Golan.

While water and water-bearing territory may be an objective of conquest, it can also be used as a weapon, especially by an upstream opponent (United States Army Corps of Engineers 1953). 'Weaponizing' water creates unusual motivations for attacking states. Water is generally only useful as a defensive weapon. If a downstream state attacked and destroyed a dam to stop the target state from hoarding the water, the flood wave might do considerable damage to the attacking state; but if the defending state released a huge flood wave against a military force attacking to secure extra supplies of water, the defender is giving the attacker what he wants (albeit not in a controlled, sustainable manner).

2.5.3 Inability to Wage War

Some states may be too crippled or overmatched to wage war. Perhaps the state's military power is small and the target state is a regional or global hegemon; perhaps environmental conditions have crushed an agrarian economy, and the state's military readiness has fallen because the troops are hungry or without weaponry. The case of India and Bangladesh falls into this category: India diverted the Hooghly river, claiming the need to flush sediment from its port at Calcutta, despite readily available dredging possibilities that are commonly used elsewhere. East Pakistan (later Bangladesh) strongly protested, especially when India began using the water for irrigation instead (Islam 1997, 327). Further, in 1975, the two countries "entered into an interim agreement to try the barrage for 41 days, with the final commissioning of the barrage condition on a mutually acceptable solution being found. However, India never stopped its operation, despite the absence of any such solution" (Islam 1997, 327–328). Bangladesh's military is dwarfed by that of India, such that any attempt to militarily move against India would be futile and counterproductive. The two states eventually did sign a series of smaller treaties, culminating twenty-one years later when India relented and the two countries signed a treaty that very explicitly laid out the water sharing and delivery schedule.[6]

2.6 Water and Cooperation

Instead of conflict, there are theoretical reasons that states experiencing exogenous water stress might cooperate instead. States might choose to cooperate over water issues alone, or the effects of the drought might create opportunities for

[6] "Treaty Between the Government of the People's Republic of Bangladesh and the government of the Republic of India on Sharing of the Ganga/Ganges Waters at Farakka." Signed on December 12, 1996.

more general cooperation between states as they try to cope with the water shortages. Cooperation, as defined by Keohane (1984, 51–52)[7], is not the same thing as Harmony among actors.

> Harmony refers to a situation in which actors' policies (pursued in their own self-interest without regard for others) *automatically* facilitate the attainment of others' goals.... Where harmony reigns, cooperation is unnecessary....Cooperation occurs when actors adjust their behavior to the actual or anticipated preferences of others, through a process of policy coordination. To summarize more formally, *intergovernmental cooperation takes place when the policies actually followed by one government are regarded by its partners as facilitating realization of their own objectives, as the result of a process of policy coordination.*

Can actors' preferences for unilateral water use be changed under drought conditions? If so, how would water stress account for these changes? In this section, I propose that water issues can be effectively used to foster cooperation between states, even states that have an acrimonious relationship or that would otherwise be unable to coordinate their policies and submit to some limits on their national sovereignty. I also describe the theoretical basis for such policy coordination and explain why water as a natural resource and as an international issue may be more likely to result in cooperation than other natural resources or issues.

2.6.1 Orthodox Cooperation

Young (1989, 59) describes the collection of realist expectations of the world that are not violated when examining observed or potential cooperation as the "orthodox account." Anarchy, self-help as the only means to survival, and violence as the

[7]See also Stein (1983, 117).

final resort are all included as accepted conditions in the orthodox account without argument. Keohane (1984), Axelrod (1984), and Oye (1986), for instance, all provide theoretical explanations of potential cooperation that occurs despite these realist conditions being true. Keohane (1984) provides a basis for examining the possibility of cooperation because of a drought. He expects that *reputation, transparency, transaction costs* and *economies of scale* (or other benefits from cooperation) will make it possible for regimes and institutions to oversee policy coordination between or among countries despite divergent preferences and the threat of reneging on an agreement. Additionally, Axelrod and Keohane (1985, 232), building on Axelrod (1984), provide additional possibilities supporting the creation of cooperative regimes: *long time horizons, regularity of stakes (iterated interactions), reliability of information about the others' actions,* and *quick feedback about changes in the others' actions*. These four characteristics of interaction are known collectively as "the shadow of the future."

Institutions tasked with supporting mutually beneficial cooperation among states use features from the orthodox cooperation arguments to initiate, coordinate, and maintain cooperation, despite the preferences of some states to defect (that is, act unilaterally). Policy coordination can yield beneficial, Pareto-improving outcomes unavailable via unilateral action. Whether from economies of scale, reduced transaction costs, information provision, or reputational gains, orthodox cooperation benefits both parties involved.

The unilateral water situation—one in which there is neither coordination nor orthodox cooperation between riparian partners—is best described as Harmony, in Keohane's terms. While unilateral water development does not actively *contribute* to the attainment of others goals, it does not *interfere* until there is a water shortfall, and thus fits the definition of Harmony. After a water shortage occurs, the situation will change to either Discord (policies are unable to be reconciled) or Cooperation (policies can be coordinated despite divergent preferences).

Nearly all water issues have potential Pareto gains available from policy coordination. Functionalism (Haas 1956) suggests that states will seek to achieve common interests and goals, but these gains may require countries to give up some measure of autonomy to achieve, which from the realist perspective is either unenforceable or undesirable and easily abandoned. These cooperative gains may require side payments to a neighbor, or even a reduction in overall water-related benefits in exchange for a guaranteed flow of benefits during a drought. The outcomes, even though beneficial, may depend on domestically unpopular actions for either or both states. As such, there may be pressure to renege or defect on the agreement. Therefore, in addition to providing an improvement in the current or future water conditions between states, these agreements must also "make it in the *interests* of countries to behave as every country would like them to behave.... Successful environmental proection in the horizontal, anarchic international system will usually require a *strategic* manipulation of the incentives" (Barrett 2003, 18).

Durable cooperation over water issues is made more likely by four characteristics of water (besides the potential for Pareto-improving outcomes) that change the strategic incentives to cheat: water resources can increase the shadow of the future or make bargaining easier. These characteristics are *renewability, non-portability, divisibility*, and *transparency*.

Renewability: The longer the timeframe, or "shadow of the future," the more likely it is that cooperative behavior will emerge as a rational alternative to continued conflict or non-cooperative behavior. Thus if a resource is known to be renewable, there is more incentive to cooperate because the shadow of the future is longer. The variability of a renewable resource also enters the calculus of states. If rainfall or river flow is highly variable, countries may decide that a more stable supply is better than a periodically greater supply contrasted with occasionally desperate shortages.

Non-portability: If a resource is easily portable (making profitable theft possible), then a state suffering a particular scarcity is more likely to attempt to steal that resource, or occupy the territory on which it exists. Resources which are unprofitable to steal *require* territorial control to adequately use, thus requiring a land war or a sharing agreement. Moving water is expensive and creating the infrastructure can take a long time. Portable examples include gold or gems and valuable animal or plant species, but not water. Water's "lootability" (Renner 2002, 12ff.) is low.

Divisibility: Per Fearon (1995), indivisible resources obviate an equitable division, notably along power distributions (Powell 1999). Thus, even a state with a relatively poor chance at victory might initiate a war, if only to call attention to its plight. Resources that can be divided easily and in a number of ways mean that states can achieve a "fair" (Barrett 2003, xiii–xiv) division of that resource.

Axelrod and Keohane (1985), Fearon (1994, 1995, 1997), Powell (1999) and Morgan (1994) model strategic interstate bargaining, with force as a risky final resort. Easily divisible natural resources make negotiations smoother, since states could bargain for arbitrarily small amounts of water[8] whereas control of a government is not normally divisible. Divisibility is key to interstate cooperation over water resources, and disputes are unlikely to erupt over very small amounts of a resource because their marginal value is far below the potential costs of a diplomatic or military conflict.

Toft (2003*a*, 2003*b*), Goddard (2006), and Walter (2003, 2006*a*, 2006*b*) make the

[8]See also Fisher, Ury and Patton (1991).

counter-claim that because territory is easy to divide, that states will work much harder to make *no* concessions, lest they be considered an easy target by other potential claimants. "Such states are preoccupied not with homelands but with precedents" (Toft 2003*a*, 18), because territorial losses will weaken a state's power and prestige. Loss of territory containing valuable resources fresh water resources could all cost a state power and prestige, and thus it is reasonable that states might strategically choose to make no concessions despite the easy divisibility of these resources. States might also choose to extract side payments to balance the loss of a resource that might be *politically* indivisible at the beginning of the negotiations.

Powell (2006) proposes that even if one side views a territory as indivisible, or bargains as though it is so, there are outcomes that both sides would prefer to war, provided part of the territory's value would be destroyed during the war. As such, even indivisible territory is negotiable. Because water resources can be harmed, perhaps irreparably, during warfare, then a war over water should be less likely since the winner would suffer both the costs of war, and have less water available to them at the conclusion of the conflict. Side payments (that is, Pareto-optimal outcomes) are not necessary to avoid conflict but are preferred to the costs of fighting. Powell also adds that most games do not count the costs of preparing for war and maintaining a strong military as relevant to the cost equation, but clearly such costs are real, adding to the cost of even being able to make a military threat. In sum, extrapolating the arguments of Toft, Walter, and Powell to include water resources is a small jump.

Transparency: The ability detect noncompliance with an agreement is important for successful cooperation (Axelrod 1984, 140). Accurate and current data about a resource reduce stress between states, since states expect unmonitored opponents to defect on agreements. If data acquisition is easy, accurate, and if both parties agree on the data's validity, then compliance with any agreement is observable and violations are less likely because each state expects that violations will be observed (Chayes and Chayes 1995, 151, 273). Chayes and Chayes (1995, 135) call this combination of data and data-gathering 'transparency.' Once violations are observed, the guilty country's reputation as a reliable partner will be tarnished (Keohane 1984, 94). Data about a multi-country resource is not easy to acquire unilaterally, but institutions such as treaties can provide "information about the distribution of benefits among members" (Martin and Simmons 1998, 745) over and above the enforcement functions. Water resources are easy to measure with some degree of accuracy, and there are independent observers available for the data collection. Hydrology is an established field of scientific inquiry, and the standards of data collection are known to all parties. With such information, states can distribute a scarce resource and keep track of each partner's consumption. The observers may also have influence on the decision-makers by way of information asymmetries stemming from their professional training (Keohane and Nye 1974). Haas (1992) names these groups of less-political experts as *epistemic communities*.

2.6.2 Prospect Theory

If a state plans to make a proposal to a neighboring state, then it has chosen not to internally adjust to water scarcity, at least not exclusively. In general, states seek to achieve means to augment and stabilize their water supplies, find non-water means to compensate for lower water availability, and improve their water infrastructure vis-à-vis their neighbor(s). Kahneman and Tversky (1979) describe prospect theory, and how "people underweight outcomes that are merely probable in comparison with outcomes that are obtained with certainty. This tendency, called the *certainty effect*, contributes to risk aversion in choices involving sure gains and to risk seeking in choices involving sure losses" (Kahneman and Tversky 1979, 263). In other words, leaders prefer certain outcomes that are minimally positive, or at least positive compared to a given situation. Prospect theory also discusses the related effect, *loss aversion*, in which people value what they have more than something they do not have of similar worth (Levy 2000, 195). Loss aversion is relevant in two ways: first, populations are highly sensitive to declines in the expected levels of their water resources; and second, that a guaranteed quantity of water each year is more attractive to an actor or population even if, on the average, it is smaller than a more highly variable quantity of water each year. In addition, a continuing negative outcome such as a drought can induce attempts to remedy the situation that are not certain to succeed, because the alternative outcome, i.e. enduring more drought, is certain to be negative. This push-pull effect can strongly encourage cooperation that can improve a country's water situation. Populations expect their leaders to take action to remedy negative situations. As a drought worsens, or lengthens, leaders are under more pressure to improve the conditions. Lodgaard (1992) further explains why leaders strongly desire a predictable and controlled water resource:

> Security policies centre on the twin notions of *predictability* and *control*. Predictability is necessary to identify clouds as soon as they begin to form. Long horizons are preferable: security planners must try to see as far into the future as possible. Control is needed to enable corrective action once undesirable developments are discovered. For small states with only weak means of control, predictability assumes extra importance.... Environmental considerations centre on the notions of predictability and control, just as much as military considerations do. Here, there is a conceptual kinship which makes it natural to use the

> term ‘security’ in both connections. Disequilibrated ecological systems tend to behave in unpredictable and potentially damaging ways: thus, establishing predictability is of high priority (Lodgaard 1992, 19–20).

Domestic instability harms military readiness. Domestic unrest can harm a country’s GDP, and that decline cuts military budgets and readiness. Population decline or refugees reduces available military manpower. Demand-side management can be expensive.[9] These elements of predictability and control can offset the reticence of a government to negotiate and cede some measure of autonomy through the treaty: while cooperation is slow and may not improve a country’s economic or domestic political situation before the drought ends naturally, even the *knowledge* that cooperation and consistency is forthcoming can have economic benefits.

2.6.3 Motivated Leaders

Water treaties and other water-specific cooperation are more likely during a drought because of leaders’ or populations’ short-sightedness (“endowment effects”) during wetter periods. Prospect theory proposes that people view losses with proportionally greater weight than a similar amount of gain, and quickly reset their “zero” level to the new, higher balance if a gain is incurred. During wet years, populations are less likely to view a water treaty as a good idea, since it cedes some measure of self-determination and possibly water to a neighboring state. This same mechanism can be used to the advantage of a political entrepreneur during a severe or sustained drought: an agreement that stabilizes a water budget removes the uncertainty that comes with annual variations in rainfall

[9] Demand-side management costs more than the alternatives in the short term. For developing agrarian economies, improving water efficiency through technology is difficult, relatively expensive, and has marginal returns.

and stream flow.[10] This potential benefit carries more influence during a drought, since if the agreement were in place, the country would be better off at that point.

Also, during a drought, politicians who acknowledge the drought and the need for changes run a lower risk of reprisals from the selectorate. Under normal conditions, politicians who admit there is a scarcity problem put themselves in a risky position as the "bearer of bad news;" opposing politicians who claim that there is no problem will have a strong support from those groups, like agricultural workers and companies, who stand to lose if water rationing, re-allocation, or new water pricing become policy. These domestic pressure groups rationally oppose agreements that would benefit the country as a whole (Martin and Simmons 1998, 748). However, during a drought, the taboo of demand reduction can be addressed. This change allows leaders to openly discuss cooperation, even costly cooperation, with neighbors with less fear of political reprisals.

Supranational entrepreneurs, or "two-level network managers" (Moravscik 1999), can also take advantage of the pain of a drought and information asymmetries between countries or between leaders and their selectorates. More broadly, effective treaties will bring multiple levels of governments and their citizenry into the new treaty institution. Once a treaty is concluded by diplomats or water ministers, the implementation and maintenance begins. Scientists or experts, who have an informational advantage over politicians (Haas 1992) can consult across governmental lines and inform the institution's choices. More than one governmental organization or bureaucratic unit (Keohane and Nye (1974) refer to these as "transgovernmental" actors) can recommend courses of action less dependent on politics and based more on coordination and, later, collegiality among the organizations. These experts can also act during the negotiation phase, proposing unconventional solu-

[10] See also Yoffe, Wolf and Giordano (2003, 1124).

tions or better efficiencies. In sum, creating a formal institution, such as a treaty, is vital to the success and durability of the treaty (Chayes and Chayes 1995, 274).

2.6.4 Is Cooperation Sustainable?

Once cooperation is in place, the breakdown of cooperation (and likely abandonment of previous gains) is unlikely; states are aware that they risk losing all previous cooperative gains through a violent conflict. Organizations such as the World Bank have in the past provided assistance (exogenous side payments) for capital-intensive projects such as dams.

Detecting cheating is nearly impossible for some economic agreements, but not so for water agreements; as noted above, data gathering for water resources is easy and reliable. States signing a water treaty will expect that cheating will be detected. The easy detection of cheating may kick off a virtuous cycle: the functional community involved in managing the treaty's obligations will form into stronger institutions, using information asymmetry as a means of influence (Keohane and Nye 1974, Haas 1992) and reducing the political nature of the resource cooperation and management.

Under cooperation, there is both an institutional inertia and a larger cost of abrogation: loss of the resource benefits, reputational costs, and possibly diffuse or specific retaliation. Chayes and Chayes (1993, 177) point out that treaties lock in states, who stay in the treaty arrangement when realism dictates they should abrogate the treaty.

Barrett (2003) would counter that states need treaties that are flexible and can be re-negotiated as the earlier treaties weather and age; some might be the same as having a weak treaty, which gives states the option to re-negotiate when they have a stronger position. On the other hand, one of the main conclusions of Barrett's book is that "we cannot expect to realize a first best outcome every time. The problem is not just that past agreements have been poorly crafted. The problem is more fundamental: first best outcomes are not always attainable" (Barrett 2003, xii).

Most treaties, once put into force, are likely to remain in force. At some point, no further sustainable gains from cooperation will be available; as cooperation advances, the efficiency gains are increasingly expensive. Where gains can be achieved cheaply and through institutional channels, cooperation will continue and be robust until the gains become asymptotically small. Even at that point, conflict remains unlikely, because of the momentum of sunk costs and the costs of reneging on the previous cooperation.

In sum, water, as a natural resource, lends itself to orthodox cooperation theory and durable, reciprocal, iterated cooperation. Water scarcity does not *cause* countries to minimize the negative effects of water scarcity through cooperation, but it does affect the potential outcomes. Other variables are important in addressing the difficulties of one country and its attempts to improve that situation; water is only one of them. But droughts (even multi-country droughts) are particularly conducive to solutions unavailable to or ineffective at dealing with countries at other times.

2.7 How Will States Address Scarcity?

If states decide that war will provide inferior gains compared to doing nothing or cooperation, they must still overcome collective action problems and non-war conflicts about resource distribution. In this section, I discuss non-cooperative and cooperative responses to scarcity. A state could act on its own to internally adjust to the drought. Or it could attempt to find positive-sum solutions to the problem, in order to make a neighbor state interested in cooperating despite their preferences not to.

2.7.1 Unilateral responses

During any given non-drought year, states will continue to develop water resources unilaterally until they bump up against the limits of the resource and/or the resource use by a neighbor. This behavior generates no hydrologic or bureaucratic ties to neighboring countries who share the water resource ("co-riparians")—limiting the impact of the "liberal peace" (Russett and Oneal 2001). Such a situation occurred between the United States and Mexico in the 1890s, developing into an awkward diplomatic situation. The United States was aggressively developing irrigation in the arid West, in response to three serious drought years (Stegner 1992, 296, 312–316). The Mexican foreign minister claimed that the waters of the Rio Grande, at times, never reached the boundary at El Paso/Juarez, although the Mexicans had enjoyed at least 20 cubic meters of water per second from the river prior to the 1853 treaty of Guadalupe Hidalgo; water was so scarce, he claimed, that the river was dry by June 15^{th}, and that no crops could be grown.[11] The United States Attorney General, Judson Harmon, declared that neither Mexico nor the treaty had any influence over the internal activities of the United States. Harmon claimed: the treaty did not address water supply, only navigation; international law imposes no obligation upon the United States for activities within its boundaries, despite the downstream effects; and therefore, the US would make no

[11] 21 Op. Att'y Gen. 276 1894–1897.

concession to Mexico.[12] Later negotiations produced the treaty of 1906,[13] but in the meantime, Mexico had no diplomatic recourse; it was left to "internal adjustment" to address its needs.

The Turks have adopted the Harmon Doctrine more or less universally: Turkish Prime Minister Demirel, at a press conference, said

> Neither Syria nor Iraq can lay claim to Turkey's rivers any more than Ankara could claim their oil. This is a matter of sovereignty. We have a right to do anything we like. The water resources are Turkey's, the oil resources are theirs. We don't say we share their oil resources, and they cannot say they share our water resources. (Bulloch and Darwish 1993, 74–75).

States may also have recently completed an interstate agreement, such that a new one is impractical or unattainable. States may have other priorities that are more pressing than drought, again depending on the bearing of the selectorate. The state may choose to internally adjust to the drought, voluntarily or not. It may develop new sources of water, such as Libya's water mining project, the "Great Man-Made River." The state may also prioritize conservation, efficiency gains, or drought-resistant crops.

[12] 21 Op. Att'y Gen. 274 1894–1897. Barrett (2003, 52) calls this situation "an example of a unidirectional externality; drainage into this river by the United States harmed Mexico, but use of the river by Mexico did not affect the United States. . . . Unidirectional externalities are *asymmetric* by definition: if the upstream country dumps wastes into the river, the downstream country will be harmed; but if the downstream country pollutes the river, the upstream country will be unaffected. Reciprocal externalities need not be asymmetric, though they usually are, at least to some degree."

[13] Convention between the United States and Mexico: Equitable Distribution of the Waters of the Rio Grande, May 21, 1906.

2.7.2 Treaties

Treaties can make the political situation more stable, and thus enhance security, even if the treaty is imposed by a hegemon. As noted above, stability is desirable for states, based on prospect theory and the idea of the rational actor. This security can offset the costs of new infrastructure, maintaining an international organization, and/or heightened security and vigilance near an international border. The treaty could, on the other hand, merely reflect the status quo (Downs, Rocke and Barsoom 1996), resulting in no aggregate gains from cooperation, or the treaty could reflect the distribution of power among the treaty signatories: "agreements—if they can be had—generally reflect the underlying distribution of power" (Powell 1999, 94). Just as in economic settings, a hegemon may bear some costs to itself to keep the system—a system that works to the hegemon's advantage—stable: Barrett (2003, 256) refers to "virtuous feedback" and the positive externalities of states choosing to develop alternatives to, say, chlorofluorocarbons (CFCs). Other states can benefit too and dilute the individual costs of research, raising the likelihood that states will comply with agreements for which improved technology is available. Absent blackmail, hegemons may *lead* where they cannot impose their will.

Without hegemonic influence, countries can still overcome collective action problems, since although each side must monitor the other(s) to avoid cheating, the benefits can be greater than those from singular action. Ostrom (1990) proposes that not all shared resources involve an Olsonian collective action dilemma as he constructs it, and that cooperation is more likely than Olson's theory expects. His definition of a common resource differs from Ostrom's: "the term 'common-pool resource' [CPR] refers to a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom 1990, 30).

She argues that Olson's theory is useful for "large-scale CPRs in which no one communicates, everyone acts independently, no attention is paid to the effects of one's actions, and the costs of trying to change the structure of the situation are high" (1990, 183). Many situations are not bound by these conditions. Communication and observation/detection are easy regarding natural resources. States have a variety of options for addressing CPR issues: privatize the resource (by agreement or force); conserve the resource and exclude all users; adopt a free-market solution among a small or broad group of buyers; or work out a sharing solution. Any sharing solution must address problems of the commons and of collective action like uncertainty, commitment, allocation, cheating, and punishment.

Even solutions like privatization do not always provide the best outcome. Cooperation can be cheaper than privatization: naval defense of a fishery will probably cost more than the annual fish catch is worth. Recognized, clear property rights can succeed where simple claims fail. If all parties have agreed-upon limits, transgressions are easier to avoid and redress. Cooperation involves bargaining and working out assurances that partners will not cheat on the agreement in stressful times, or will be caught if they do cheat. Resources that are easy to reliably *observe*, like water, can prove to a state that it is not receiving a sucker's payoff, that its cooperative gains are safe. The initial efficiency gains are usually inexpensive to realize and involve little loss of autonomy. These small gains pave the way for larger gains and allow states to establish themselves as reliable members of a regime or institution.

Treaties may be only "statements of general principle, while others contain detailed prescriptions for a defined field of interaction. Still others may be umbrella agreements for consensus building in preparation for more specific regulation" (Chayes and Chayes 1993, 176). If treaties are not merely dictated by strong states, durable cooperation will contain some set of these elements: treaties will have joint monitoring and data collection; international organizations and their accompanying bureaucracies will oversee the efforts of both states to comply with the treaty, and report on their findings; and the treaty will show that states understand that their shared resource is renewable and subject to damage by misuse or neglect. Some treaties will have side payments to offset losses by one side; these side payments may have non-water externalities or concessions, providing a more diffuse exchange of obligations, or perhaps only goodwill (Axelrod and Keohane 1985), though goodwill is not quantifiable.

Depending on the level of development among the signatories, other factors may come into play; development disparity may open new avenues for cooperation or it may restrict cooperation possibilities. Developing countries may not have adequate water storage facilities (less true now than in the past, but still applicable compared to the West), so some treaties will tend towards storage infrastructure. Technology transfer is also important to developing nations, and conservation or efficiency-improving technology can greatly offset water needs. As development levels rise, industrialization affects the water quality and supply; a country may not need *more* water from an upstream neighbor, it may need *cleaner* water. More-developed countries have the ability to offset the Pareto gains by providing cleaner water to neighbors (the United States did this in 1971 under Nixon; Singapore does it for its *upstream* neighbor, Malaysia, in return for water supply).

2.8 Conclusion

The background in this chapter provides the underpinnings of the hypotheses I test in the dissertation. In short, war is expensive and may not bring relief to a drought-stricken country; cooperation is difficult, but water's characteristics may make water-specific cooperation more likely, and more durable; droughts provide additional leverage supporting water cooperation on an otherwise reticent government and/or domestic population; but spillover goodwill, reciprocity, and spillover cooperation are difficult to observe, much less prove.

Chapter 3

Theory

> It is a paradox that the water pessimists are wrong but their pessimism is a very useful political tool which can help the innovator. The water optimists are right but their optimism is dangerous.
>
> *Tony Allan, 2001*

3.1 Overview

Some authors expect cooperation and others expect conflict during periods of environmental stress; however, the testing of these hypotheses has been, to this point, flawed. In this chapter I propose hypotheses and mechanisms that describe the conditions under which states may conflict politically or even violently, and under which conditions they may cooperate and behave less belligerently. I explain why violent conflict and territorial conquest for freshwater is unlikely, why general cooperation may decrease during droughts, and why specific kinds of water cooperation may arise during periods of drought.

Other authors have attempted to explain why states will or will not fight over water, and will or will not cooperate over water, but my theoretical approach is novel because it is more comprehensive than others and better grounded in social science theory. Others confuse conflicts and disputes where water is a *tool* of war, or a component of a territorial dispute, with a conflict over access to fresh water *for its use as water*. I examine water as water, not as a weapon or boundary.

This chapter has five primary sections: first, I classify resource conflict types to better focus the definition of "water conflict" or "water war;" second, I discuss scarcity, and explain why I examine *exogenous* scarcity as a potential cause of interstate conflict or war; third, I discuss the mechanics of water conflicts, and the reasons that violent water conflict is not likely to occur; I offer a theoretically-based explanation predicting an increase in the level of cooperation between countries during a drought; and finally, I outline the mechanisms supporting water cooperation rather than military confrontations over water issues.

My primary point is that a state will not go to war because the relief that would come from the capture of a neighbor's water supply will not come soon enough, regardless of the success in battle, to offset the losses that would come from non-violent alternatives such as substitution or other internal re-allocation of existing water supplies. War is always a risky choice, and even if there is success, the ability of a state to use its newly-captured water will be constrained by the lack of infrastructure, strained finances from the war, and the state's immediate need for the water. In nearly all cases, a state could cheaply and more easily—and on the same time scale as violent conflict—build desalination plants or improve efficiencies. War is expensive and uncertain. Conservation, efficiency, and desalination are more certain and far less expensive.

However, having an inadequate water supply is not a guarantee of cooperation; state policies or preferences for water use will be in conflict especially during times of drought, making policy coordination more difficult based on domestic demands and expectations of prior levels of use. Whether these concerns arise from a large population (in a democracy) or a much smaller population of elites, or a single autocratic ruler, they are likely to restrict the focus of a ruling government to the immediate needs of the country. As such, the level of international interaction (conflict *and* cooperation) drops during scarcity events.

Finally, a state is *more* likely to experience a water-specific cooperative event during a drought. Despite the loss of some independence that comes with the obligations stemming from a new agreement, a new agreement stabilizes the future expectations of water supply, even supply during a drought. All parties engaged in economic activities prefer a stable, smaller supply to a more random yet sometimes larger supply. Because of the cost of efficiency gains and admitting that water is in short supply, expensive efficiency programs or rationing/reduction in consumption by consumers will not be advocated until situations become desperate, populations can afford the changes, and forward-thinking, entrepreneurial leaders have an excuse to implement these changes. A drought provides such opportunities.

In this dissertation, I will test four hypotheses, each with two sub-hypotheses. The main four hypotheses are:

> H_1: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **change in the likelihood of a military conflict** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*

> H_2: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **decrease in the level of conflict** *it initiates, compared to a state sharing a water resource that is not experiencing scarcity.*

H_3: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **change in the level of cooperation** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*

H_4: *A state experiencing a period of acute scarcity experiences an* **increase in the likelihood of the formation of a treaty addressing water issues** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*

The basis for these hypotheses is laid out in this chapter, and expanded and tested in chapters 5, 6, 7 and 8.

3.2 Resource Conflict

If water conflict is a possibility, there are multiple potential motives for an attack. In this section I offer a general typology of resource conflict, to distinguish among various conflicts all labeled "resource conflicts" or something similar. This typology does not distinguish between conflicts of *scarcity* and *abundance*, but rather the *use*, *role* or *objective* of the resource in the conflict. This list attempts to explicitly define and usefully characterize each type of resource conflict. For instance, conflicts over diamonds are different from burning oil wells, but if one abstracts the cause of the conflict and removes the resource's name from the analysis, the list can provide a useful typology of conflicts over natural resources. From this list, I eliminate several conflict sorts as highly unlikely to occur over water resources. Next, I explain the logic underlying the remaining conflict types.

Table 3.1 lists a description of each conflict type, the political units potentially involved in the conflict, and distinguishing or limiting characteristics of each conflict type. Gleick (1993*b*, 1998*a*, 2000*b*, 2002) offers several categorizations similar to this one, as does Sosland (2007, 5), but this list is superior because my categories are more concrete and have less overlap between them. Gleick (2002, 195) acknowledges that his categories are imprecise because “international security is not a clean, precise field of study and analysis.” However, the overlap between his categories may blur the causal analysis for a conflict involving water resources. These categories are meant to be discrete but not exclusive; some actions may meet more than one criterion (‘weapon’ and ‘strategic military objective’), but the categories should be distinct from one another. Haftendorn (2000) offers a different typology of water conflict, choosing to distinguish between conflicts of use (shipping, hydropower, and flood prevention), pollution issues, relative scarcity, and absolute scarcity. This typology, as an example, skips over several important issues. For example, “conflicts of use” are not limited to natural resources, and neither are negative externalities such as pollution. Haftendorn also ignores the question of whether the scarcity is endogenous or exogenous. I address this topic below, in section 3.3.

3.2.1 Theft or Piracy

Some natural resources are popular with pirates, thieves, or illicit traffickers. These natural resources can be easily moved and sold. They are valuable in small quantities of weight or volume. Such natural resources include: gems; precious metals; select animal products such as rhino horns, elephant tusks, and tiger skins; and high value plant products, such as opium poppies or coca leaves or their refined substances. There is some trafficking in petroleum as well (Wahab 2006). Theft or piracy is usually limited to those resources that can be looted or plundered, are easily transported, and are easily convertible to cash. These resources are likely targets for pirates, raiding parties, extrastate or local non-state actors,

TABLE 3.1: Natural Resource Conflict Typology

Type	Description	Level	Distinguished By
Theft or Piracy	Natural resources capable of *easy transportation and conversion to cash*, such as gems, precious metals, animal products, and high value plant products will be targets.	intrastate, interstate, extrastate	The substance or resource must be easily transportable and easily convertible to cash.
Strategic Military Objective	The resource affects warfighting and economic capability; disrupting or damaging the infrastructure related to the resource reduces the state's fighting ability. Capturing resources or reducing negative externalities benefits the attacking state.	intrastate, interstate, extrastate	Resources augment the target state's power. Occupation is possible and maintainable. Benefits are transferable.
Tactical Weapon	The event harms or kills enemy citizens or soldiers. It destroys or disables military-strategic assets (e.g., burning oil wells, breaching dams, burning forests).	intrastate, interstate, extrastate	Resources must be capable of injuring or killing people and/or causing harm to structures.
Territorial or Boundary dispute	The event is a dispute over territory, though resources can blur the line between what is and what is not territorial. A valuable natural resource in a historically contested area could reignite the dispute.	interstate	Resources may be irrelevant to the dispute; some causal ambiguity, as international disputes often have a territorial component.

and perhaps organized state militaries. The cash resulting from these products can be used for its possessor's interests.

But even small quantities of water are heavy and as such require significant expenditure of energy to move. This requirement makes water expensive to move. Soffer (1994*b*, 969) notes that a cubic meter of water trucked from Lebanon to Israel would require the trucks to navigate a dangerous road and would cost between

USD $4 and USD $12.50, compared with about USD $1 to desalinate seawater at that time. Soffer (1994*a*, 971) also notes that no Lebanese government officials have complained about Israel robbing the Litani. Current prices of new desalination output have dropped below USD $0.53 per cubic meter (Service 2006).

If an agreement already exists dividing up quantities or percentages of water among states in a river basin, then water could be stolen by an upstream riparian. Data gathering in a watershed would be difficult to falsify consistently and credibly, though data collection can have large errors even absent any collusion (Wolf 1995, 95–96). Remote sensing technology and automated streamflow measurement increases the likelihood of any inconsistency being identified. Some states classify or classified streamflow data as a military secret (Gleick 1993*a*, 98), and if successful, upstream states could take more water than their allotment. However, in the presence of an agreement, data gathering measures would certainly be part of the water management process. Numerous treaties in the Transboundary Freshwater Dispute Database explicitly mention shared data gathering in the agreement.

3.2.2 Strategic Military Objective

Water resources can be a military objective that, if crippled or captured, may undercut the warfighting or economic capacity of the country, and augment those capacities of the invader. Dams produce hydroelectric power and provide reservoirs for irrigation. Similarly, desalination plants or sewage treatment plants are single points of failure for an urban water system that, if lost, could inflict great pain on the citizens of a country and greatly benefit the populations of the occupying country. Gleick's (2002) list of water conflict incidents includes numerous examples of water infrastructure as a military target. Again, as with water used as a weapon, harming the water infrastructure of another country does nothing to slake the thirst of one's own country, and may cause harm in other countries as pollutants, untreated waste or salt move downstream.

Captured water resources could be used as bargaining chips or as a new source of water for the aggressor country. As I note above, these new sources of water would take years to develop in most cases, except where a full upstream reservoir can be captured and the water slowly released.

3.2.3 Tactical Weapon

Water has been used as a weapon in violent conflicts. But any use of water as a weapon would make it less likely that the water could be used to remedy drought conditions: attackers depend on water's rapid movement and momentum to impart destructive physical force on a desired target, or else they foul the water with chemical or biological agents, denying water's beneficial uses to, or incapacitating or killing, enemy soldiers. The most studied use of water as a weapon is the Allies' use of airplanes carrying specialized bombs to destroy three dams in the Ruhr valley during World War II (Kirschner 1949, United States Army Corps of Engineers 1953). In these raids the Allies successfully destroyed several dams, and in so doing destroyed large areas of cropland and several factories. The water behind the dams was unimportant to the Allies except as a weapon.

The Dutch have a long history of flooding their own lands to slow or stop the progress of invading armies. They were prepared to do so in World War I and belatedly did so in World War II (Kaufmann and Jurga 1999, New York Times 1914, Time 1939, Van Valkenburg 1940, Mason 1963). The retreating Nazis also flooded the Netherlands during late 1944 (Letter 1944). The Soviet practice of "scorched earth" during their retreat from the Nazis, later reciprocated by the

Nazis, included the destruction of the Zaporozhe dam, on the Dnieper river in the Ukraine (Paterson 1992, 9), though while the loss of electric power generation was significant, the destruction of the reservoir meant that the German army's engineers had an easier time crossing the river (Clark 1985, 136), so the use of water as a weapon or defensive tool failed in this instance. US President Richard Nixon contemplated the use of nuclear weapons against North Vietnam, and considered nuclear and non-nuclear bombing of the North Vietnamese dike system, which would have drowned between 200,000 (Tannenwald 2006, 716) and 1 million people (Time 1985), but ultimately the US did not target the dikes for bombing (Pape 1990, 125). Gleick (2002) provides a list of historical incidents where water was used as a weapon or as a target of aggression.[1]

The use of water as a weapon or tool of war, however, makes the water less useful to its employer after the attack. Crops must be watered gradually and over a long period of time. A flood carries off topsoil and drowns plants. Catastrophic releases of water from upstream will only exacerbate drought conditions by ruining cropland, destroying infrastructure, and killing people and livestock. These effects are counterproductive in the context of a drought. Water's use as a weapon excludes its use to quench a drought. Using water as a weapon is therefore unrelated to scarcity.

3.2.4 Territorial or Boundary Dispute

Water has value in a territorial dispute or boundary dispute only insofar as it marks a boundary. Hundreds of water treaties (some in the Transboundary Freshwater Dispute Database) mark boundaries with bodies of water. Rivers are excel-

[1] In order to provide a complete list, some of the Gleick's entries are redundant or self-citing. Some other incidents either loosely concern water or are more theatrical than tactical. The number of entries in the list should not be taken as data to establish that water scarcity is a cause of war.

lent defensive barriers against tank and troop movements, though perhaps less so since the rise of aviation. Occupying both sides of a river would mean a relative decrease in the security of the occupying country, not only because the defeated country would eventually try to retake the territory, but because the defense of that territory would be more difficult without a natural defense like a river.

Even in peacetime, rivers as boundaries are terribly inaccurate and difficult to measure or monitor, as they meander and permanent markers cannot be affixed directly to, or above, the river boundary. Ideas like marking the middle of the channel or the deepest point in the channel (called the "thalweg") are inaccurate and highly variable (Gleditsch 1952). See Figures 3.1 and 3.2. In short, while inaccurate or shifting boundaries and mineral wealth under a piece of territory may be possible causes of conflict, conflating water resources with a boundary or territorial dispute falsely links water to conflict. Sometimes, states fight over water because water is the boundary, not because the water is a valued military objective.

3.3 Water Scarcity

In the previous section I established the different categories of conflict that involve water resources. I proposed that water's presence as a *boundary* involved in the conflict, or use as a *tool* of conflict, is conflated with water as an *objective* of conquest, especially since there are very few known conflicts or clashes that were a direct result of water scarcity (Wolf and Hamner 2000, 124–128). In this section, I examine water as a potential objective of conquest. If the capture of water is an invading army's goal, we must know whether water *scarcity* or water *abundance* drives the conflict. If the conflict arises because of water scarcity, then it will be valuable to know whether the scarcity is *endogenous* or *exogenous*. I propose that only exogenous scarcity is a viable cause for violent conflict, and that therefore the

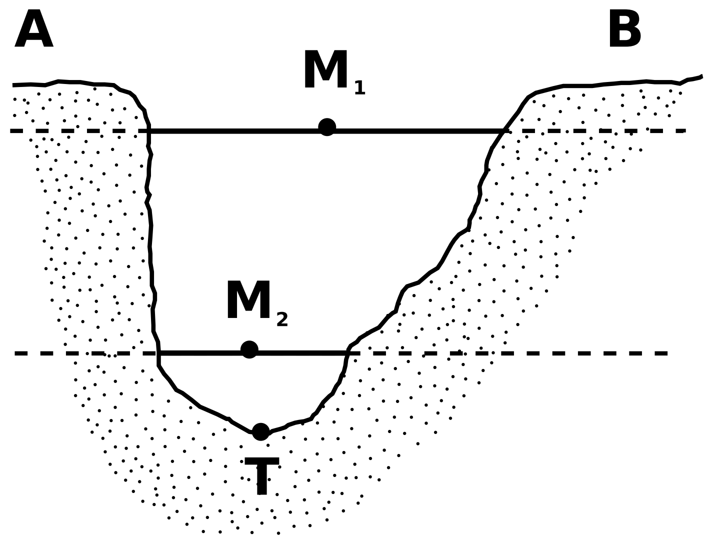

FIGURE 3.1: The problems of using the middle of the river as a boundary, adapted from Bouchez (1963). As the water level drops in the channel, the exact middle of the river (points M_1 and M_2) shifts. The thalweg (point "T"), the deepest point within the channel, is more exact but still changes its position over time, and in streams with multiple channels, or very wide channels, the deepest point in the river may shift hundreds of feet in a few days. See Gleditsch (1952) for more.

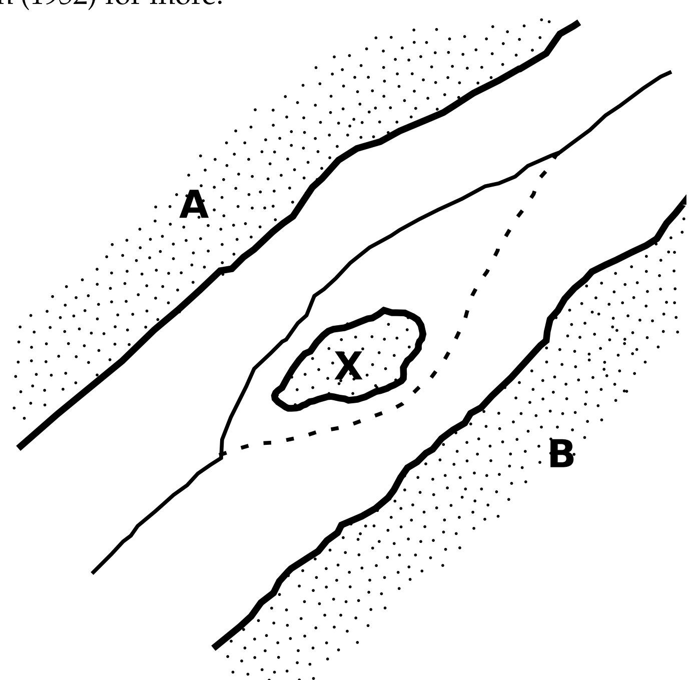

FIGURE 3.2: Another problem with using the middle of the river as a boundary between countries A and B, also adapted from Bouchez (1963). If the thalweg moves to the opposite side of island 'X', then the boundary moves with it and the island should, by strict definition, belong to country A. See Gleditsch (1952) for more.

ill-defined, nebulous "scarcity" or "aridity" that some authors use as a *casus belli* is too vague to be useful or else actually incorrect as a potential cause of war.

Water scarcity affects upstream states and downstream states differently. Upstream states have the first opportunity to take the water (or pollute it) and thus could, *ceteris paribus*, adjust to a drought by passing less water downstream than before. A stronger upstream state will be able to take more water for itself without concern for threats from a weaker downstream neighbor or neighbors, absent threats, intervention, or international pressure. The policy of the United States towards Mexico resulting from a water crisis starting in 1894, now called the Harmon Doctrine after United States Attorney General Judson Harmon, is the embodiment of such a policy.[2]

During times of water stress, a downstream hegemon will expect its share of the more-scarce water to decrease very little compared to the share of those upstream. A strong state across the river or downstream from a weaker rival would be able to forcibly stop its neighbor from taking more water, but at great cost compared to the cost of conservation, desalination, or negotiation. Under situations of water scarcity, these factors affect the propensity for violent conflict. The military threat is real, and the hegemonic exertion of power (military or not) is expected since such actions are rational for the downstream state. Under these conditions, cooperation might be forced, a sham, or heavily subsidized. Water cooperation generally does not favor the upstream state, nor the weaker state (Frey and Naff 1985, 78).

But what is scarcity? What are scholars talking about when they use the concept to justify potential violent encounters in the future? Is not water, as a finite economic good, already scarce? Some authors avoid a careful yet broadly useful definition of water scarcity. This current lack dilutes any useful conclusions that

[2] 21 Op. Att'y Gen.,274–283, 1894–1897. See Section 2.7.1 for more.

could otherwise be drawn from their work. Authors usually fail to distinguish between *endogenous* and *exogenous* scarcity, nor do they examine temporal variations in water availability.

3.3.1 Endogenous Scarcity

Endogenous scarcity is caused by population growth and economic activity. This sort of scarcity increases slowly, as more people immigrate or are born in a country, and as more agriculture and industry activity takes place. States can better adjust to the gradual creep of endogenous scarcity than the unexpected shock of a drought. Endogenous scarcity arises partly because of a general preference for unilateral (autarkic) development; states use as much water as they want to improve economic output until they can no longer allocate additional units of water for a negligible cost. At that point, endogenous scarcity takes hold and countries begin to allocate newly-scarce water to the most efficient economic activities. For example, ditch irrigation of crops is water-inefficient compared to center-pivot irrigation, drip irrigation or sub-surface irrigation. Each of these advanced forms of irrigation, respectively, costs more but also saves more water for the same crop output. Rather than irrigate, countries can also import grain to offset endogenous water scarcity. This economic practice makes use of what some call 'virtual water' (Allan 2001) or 'phantom [crop] acreage' (Catton 1980). In this manner, agricultural products can be obtained without using any local water or cropland.

Certainly scarcity is a function of supply and demand, or rather, water availability and population withdrawals. Further complicating the question of scarcity is *re-use* versus *consumption*, and the issue of water *quality*, all of which have an impact on the amount and usability of the resource in a given system. The effects of these three factors depend on the development and industrialization level of the country. Some industrial uses do not require high-quality water, and can tolerate salt content roughly double that of the 500 parts per million (ppm) maximum salt content of potable water (Postel 1999, 92). Irrigation of some crops is possible using mildly saline water (Postel 1999, 107), but irrigating with even slightly saline water results in salinization, as salt accumulates in the topsoil. The only way to avoid salinization of the soil is to depend only on rain or non-saline irrigation water, which are, respectively, unpredictable and expensive.

3.3.2 Exogenous Scarcity

Exogenous scarcity is a sharp reduction in supply caused by an external force, such as a temporary or long-term climate change, damage to the resource, or an upstream user suddenly diverting a large amount of water. The existing civil systems and infrastructure are unprepared for a sudden reduction in supply. As such, this sort of scarcity can upset the normal routine and cause a crisis. These crises are not caused by political or human factors, and are essentially random from the perspective of those affected by them. This randomness contributes to the difficulties of preparing for droughts.

Because of the cost and complexity of the issue—and the negligible benefits to improving the water supply, for which there is an unlimited demand—ignoring water scarcity is probably the preferred, and cheapest, course for most leaders, and some domestic institutions. Only after a sustained and painful drought will leaders act on the domestic pressure to improve the water situation, admit that a drought is a problem, and perhaps look to international cooperation to ease the pain associated with the drought. This economic turbulence and social concern derails politics as usual, and enables cooperation-minded leaders to use the drought as leverage to create a mutually beneficial water sharing or cooperation, despite their preferences to not cede some sovereignty to an institution. Even leaders not inclined towards cooperation may decide that they would rather not be seen as helpless or apathetic by the country's population.

Some authors expect that this situation leads or has already led to violent conflict (Frey and Naff 1985, Schmida 1985, Stauffer 1985, Klare 2002). Domestic unrest could encourage leaders to seek war with another country to rally an unhappy populace around the flag and provide an outlet other than the government for their anger, though the "diversionary war" literature generally finds otherwise (Levy 1989, Russett 1990, Russett 1993, Oneal and Lian 1993, Richards, Morgan, Wilson, Schwebach and Young 1993, Leeds and Davis 1997, Dassel and Reinhardt 1999). Or, countries could actually seek to take the water resources it needs by force, because there are no opportunities to gain the resources any other way. In the case of Israel with respect to her neighbors, the idea has been given a specific name: a "hydraulic imperative" (Naff and Matson 1984). The term is more or less a re-statement of lateral pressure theory.

But periodic scarcity and the difficulties it imposes on states can make states more willing to cooperate, especially when experts agree it is possible. While pressure groups will always lobby for special treatment, and governments will resist costly, sovereignty-restricting cooperation, it is still possible that the effects of prospect theory and fatigue will make cooperation possible even between hostile neighbors.

> A few years ago concerned scientists in all the countries in the [Middle East] region began uncoordinated but matching campaigns to force the politicians into awareness of the situation, and at least to begin discussing what should be done. Then in the winter of 1992 came one of the worst things that could have happened: after three years of the

> most severe drought the area had ever known, there were the best rains for years. . . . It was a setback. As the land dried and cracked, as farmers saw their crops fail and industrialists had their supplies rationed, gradually the people and the politicians had been forced into understanding that they faced a crisis, that swift action was needed to avert disaster. Then the rains came, the earth greened, the desert flowers bloomed and the dire warnings of those who understood the situation were silenced by the welcome drumming of rain on the roof. The problem could be ignored for another year or two (Bulloch and Darwish 1993, 19).

This quote also provides one example of a situation where three years of unprecedented drought led not to war but to the beginning of cooperation, a finding also presented by Yoffe, Wolf and Giordano (2003, 1124). While the drought's abatement derailed the cooperation, it was an important step, and in a region where cooperation is difficult. Also noteworthy is politicians admitting that there was a crisis. Acknowledging scarcity within a country is difficult for leaders. Solutions that involve sacrifice (demand-side solutions), such as conservation or negative population growth, are unpopular or heretical. Domestic special-interest groups demand relief from the government and will support other politicians who promise it. As such, political figures ignore water scarcity when possible, or advocate supply-side solutions.[3] such as dams, aquifer storage, wastewater recovery, and desalination. None of these fixes are inexpensive, but are cheaper, at least to the politician, than demand-side management.

[3]Schnaiberg and Gould (1994) call these "techno-fixes" because they rely on technology and generate a reliance on technology, and its dependence on fossil fuels, as the solution to all such problems. Schnaiberg and Gould (1994) propose that technology is not the answer to all problems, and is a deceptive savior. The Green Revolution in agriculture is one such "techno-fix," just as nuclear-powered desalination plants were General Electric's promise for Middle East peace during the 1960s (Weinberg 1994). These technical proposals mask the real problems of population growth, waste, and per-capita consumption levels.

Acknowledging that the scarcity exists means promoting a plan to resolve or improve the situation. Yet such plans reduce bargaining leverage with a neighbor in the event of water negotiations. If, as they planned, Israel actually added 800 million cubic meters (MCM) to their annual water budget using desalination (Israel Ministry of Foreign Affairs 1994), not only would there be pressure to give up some water allocations (particularly from occupied areas) to those states that had not undertaken desalination, but there would be increasing pressure on Israel to continue its development of desalination—potentially reducing the military budget and energy budget, not only to protect the desalination plants and move the water, but to pay for the desalination plants and pumping.

While additional sources of cheap, clean water are always attractive, endogenous scarcity generally does not represent a useful *casus belli*. Endogenous scarcity is more or less a constant—once all the average renewable fresh water available to a given country is in use, water will always be scarce and therefore explaining conflict with endogenous scarcity is akin to explaining a rare event with a constant value. Countries prefer to re-allocate water to more efficient uses rather than mobilize for war, despite the connection between increased consumption and growth, prosperity, and national happiness.

3.3.3 Technology and Desalination

In 1985, Schmida (29) warned that "Israeli destruction of the Maqarin dam, under construction in Jordan, is possible," and both she and Halawani (1985) proposed that Israel might also divert Litani water from Lebanon. Over two decades later, through at least one difficult drought, Israel has taken no such moves (Elmusa 1996, 71), despite little progress on other political issues in the region. Why not? At least one possible answer is technology.

Modern, mechanized warfare roughly costs between USD$166 million[4] and USD$430 million per day,[5] according to Stiglitz and Bilmes (2008, 9), with some estimates as high as USD$1 billion (Soffer 1999, 249), to prosecute, not counting the costs of reconstruction. The cost of a new desalination plant is about USD$1 billion (Soffer 1999, 249). A plant capable of handling 300,000 m^3 per day could produce the equivalent of the *entire annual flow* of the Jordan river system in about 13 years. Current costs of desalination are around USD$0.53 per cubic meter (Service 2006). At this cost, Israel could desalinate the equivalent of the Litani river for about USD$360 million per year plus the costs of pumping and distribution. Their initial capital outlay would be about $6 billion, or the equivalent of between 6 days and one month at war. This figure meshes with the opinion of Israeli general Avraham Tamir, who helped "outline Israel's strategic needs in 1967 and 1982" (Wolf 2000, 92). Tamir said "why go to war over water? For the price of one week's fighting, you could build five desalination plants. No loss of life, no international pressure, and a reliable supply you don't have to defend in hostile territory." Soffer (1999, 249) offers a very similar conclusion.

Stauffer (1985, 77) figures that Israel's annual benefit from waters captured since 1967 amounts to between USD$1.2 billion and USD$1.8 billion, based on a quantity of 700 million cubic meters (MCM). Even granting the somewhat inflated figure of 700 MCM (Wishart 1989, 47), more modern desalination methods, such as those already producing fresh water in Ashkelon (Service 2006), would cost about $371 million instead for a similar quantity of water, plus the costs to build the desalination plant.

Technology, however, cannot efficiently and cheaply protect against sudden,

[4]USA in Viet Nam, average.
[5]USA in Iraq, 2008.

unexpected shortfalls in annual water availability. Exogenous water scarcity, defined as scarcity not caused by the system affected by the scarcity, offers a better explanation for incidence of water conflict than does slowly increasing scarcity. Since exogenous scarcity represents an external shock to a normally equilibrated system, drought events cause upheaval and instability easily avoided under the business-as-usual endogenous scarcity (Frey and Naff 1985, 76–77).[6] The population migrations, weaker crop yields, and need for conservation are omnipresent above a given threshold, but these problems are known, gradual (though worsening) and expected. There is a special case where an upstream neighbor deliberately induces an exogenous shock, as Turkey did to Syria and Iraq in 1975 (Haddadin 2001, 468) and 1990 (Libiszewski 1994, 9). Turkey filled some dams with Euphrates water, reducing the outflow to Syria and Iraq to a trickle.[7] Here again, friction over water issues has not led to interstate violence.

3.4 General Conflict

Those scholars proposing that water-based conflicts are likely to erupt (or have already, in the case of the Golan Heights) fall into one or two categories: those who expect that abundant water resources make an attractive target for revisionist states, or those who expect that local water scarcity drives desperate states to attack neighbors in an attempt to avoid total economic and social collapse.

I propose instead that violent conflict is unlikely to follow from water scarcity for several reasons. First, no matter its strategic value, water is *not* irreplaceable

[6]Frey and Naff do not mention it, but this mechanism is similar to Eldredge and Gould's (1972) "punctuated equilibrium" mechanism from the field of evolutionary biology. They argue that exogenous shocks to a species' environment provide the conditions for a new subspecies or species to emerge as more competitive. See also Gould (1980), and Gould and Eldredge (1986, 1993).

[7]This act caused friction and disagreement between the downstream riparians and Turkey (Soffer 1999, 249–250), but "friction is not the same thing as war" (Anderson 1991).

or lacking substitutes in a local area or region; these adjustments exist, but cost money. In areas lacking a large agricultural base, both cropland and fresh water are substituted with imported food, which can be cheaper than locally grown crops if the local climate is harsh. In areas near the ocean, desalination can make up the difference between scarce rainfall or well water for the needs of a seaside population. So, locally at least, energy, money, and/or trade can accommodate water scarcity, though these depend on money.

Second, a war to take a neighbor country's water will not provide immediate relief to a parched population. Conquest is expensive, destructive, and rarely quick. Organski and Kugler's (1980) power transition model predicts that a state in economic distress, and therefore weakened, might strike its neighbors to avoid having to fight them on worse terms in the future. However, overrun populations must be policed and insurrections put down. Infrastructures must be rebuilt, and if water must be re-routed, a victorious country must build and defend a water delivery infrastructure that could take years to complete, with substantial costs. Projects that allow the inter-basin transfer of water easily run to the tens of billions of US dollars (Biswas, Kolars, Murakami, Waterbury and Wolf 1997, 105, 116, 133, & 135). It is unlikely, but possible, that a reservoir could be captured and its contents released gradually to slake the thirst of a downstream conqueror.[8] And all of these caveats assume that the conquest succeeds! Force, regardless of the power differential between states, is still a risky proposition with no guaranteed outcome.

Military force also brings a host of negative outcomes along with any control of new water resources, and a country's leadership would be aware of these con-

[8]The destruction of an upstream dam to release its contents, while it avoids the need for invading or maintaining a presence in a country, would produce more chaotic results than a downstream country might desire. Further, it is unlikely that a large modern dam could be successfully destroyed without great military effort.

sequences. Even before international organizations had significant influence on states' activities, offensive military operations tend to generate balancing behavior by other countries (Walt 1987). Such balancing behavior by one or more states might create a worse international political situation than a drought does.

Outside of the water-specific influences on the likelihood of military violence, other influences affect the chance of a military conflict between countries. These have been dealt with admirably in the literature and I do not propose to 'test' them in search of new results, but rather to incorporate them into a test to ensure that no water variable serves as a proxy for another variable, or that no relevant omitted variable changes the results of any tests.

Overall, the time scale of the relief that military power offers is too long to prevent the negative consequences from a drought, and a country's population or selectorate is unlikely to support a pre-emptive attack to capture water resources during a wet year, or even during the first or second year of a drought.

The restraint offered by institutional ties, trade ties, and regime similarities is probably strong and significantly reduces the likelihood of international violence, as shown in dozens of articles and books. However, these factors might or might not reduce the likelihood of a water war. I propose that the strongest factor reducing the likelihood of violent water conflict between states comes from the inability of force to rapidly relieve the symptoms or causes of the pain associated with acute water scarcity.

The first and second hypotheses address the likelihood of military and violent conflicts given an exogenous (externally-induced) water shortage. These hypotheses cover several plausible outcomes of water-induced stress between countries. First, water might have no general statistically observable effect on international relations. Or, if water scarcity has an impact, it might generate greater levels of military conflict. Water scarcity might instead suppress military conflicts between countries, as states re-focus their attention on domestic solutions or policies likely to bring more immediate relief.

Second, even absent military conflict and/or violence, states might experience an increase in the number of conflictual events, or an increase in the intensity of these negative events. There might be greater numbers of small, simmering conflict events, or a spike in the intensity of nonviolent negative events. Again, my proposed explanation does not predict these outcomes, but it is important to test all possible negative outcomes of periodic water scarcity.

> H_1: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **change in the likelihood of a military conflict** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
>> H_{1a}: *A state experiencing a period of acute scarcity involving a shared water resource is* **more likely to initiate military conflict** *compared to a state sharing a water resource that is not experiencing acute scarcity.*
>>
>> H_{1b}: *A state experiencing a period of acute scarcity involving a shared water resource is* **less likely to initiate military conflict** *compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
> H_2: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **decrease in the level of conflict** *it initiates, compared to a state sharing a water resource that is not experiencing scarcity.*
>
>> H_{2a}: *A state experiencing a period of acute scarcity involving a shared water resource initiates* **fewer conflictual events** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*

> H_{2b}: *A state experiencing a period of acute scarcity involving a shared water resource initiates* **a lower overall intensity of conflict** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*

I expect that H_1, H_{1b}, H_2, H_{2a}, and H_{2b} will not be rejected because the analysis will produce statistically significant results supporting these hypotheses.

3.5 General Cooperation

During a drought, a country experiences economic distress and may see social unrest, environmental refugees, or other negative outcomes related to the drought as discussed in Section 2.3. Each country may attempt to address the overall losses due to the drought by looking inward for solutions, looking outward for assistance or gains from cooperation, or both. Governments can also do nothing, though I assume that domestic political pressure will produce some attempts at improving the situation. Non-zero-sum outcomes are nearly always possible, and as mentioned before, the worsening situation may encourage cooperation of any stripe that could bring improvements to the economy and social situation in the stricken country. These cooperative improvements (that usually involve the loss of some degree of sovereignty) might not be as desirable under average or good economic conditions, but would be welcomed as relief from the drought's effects. Keohane (1984, 122–123) offers the possibility for cooperation between states that is self-interested (rational, egoistic) but not dependent on immediate or equal exchange between the cooperating partners. If both countries have a trading relationship (itself cooperative in nature), then the economy of one affects the economy of the other; the less-deprived state might take a minor loss on some cooperative agreement (say, a tariff) in order to improve the economy of the trading partner, with an understanding that the loss cannot be offset immediately, but rather in the future, and not necessarily in the same arena.

Water issues are not tied to every aspect of international cooperation, and are not expected to influence cooperation one way or another in most areas. Water *scarcity*, on the other hand, may negatively affect the economy, supply and demand for goods, but not, say, the demand for protection or for free trade, especially if populations and leaders adopt the stance that free trade will allow consumers to offset the water shortage with 'virtual water' from abroad. Supporting this idea, Giordano, Giordano and Wolf (2002) find modest evidence for diffuse reciprocity—linkages between water cooperation and larger forms of cooperation, though they do not specify drought conditions as a condition of the diffuse reciprocity. There is thus some theoretical expectation for exogenous (periodic) water scarcity to have an impact on the likelihood of more general cooperative activity between countries.

The cooperation-related hypothesis, H_3, proposes that the level of cooperation changes under drought conditions; it is possible that relations may sour, but this measure is different from the effects proposed in H_2 because state relations may become more positive in sum, rather than only become less violent or conflictual. No previous study has used measures of conflict and cooperation to examine the effects of water scarcity on international relations in this way, so hypothesis H_3 takes a broad approach to examining interstate relations and cooperation.

> H_3: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **change in the level of cooperation** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*

> > H_{3a}: *A state experiencing a period of acute scarcity involving a shared water*

> *resource will initiate* **more cooperative events** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
> H_{3b}: *A state experiencing a period of acute scarcity involving a shared water resource will initiate a* **higher aggregate intensity of cooperation** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*

3.6 Water-specific Cooperation

As seen in Chapter 2, water cooperation and policy coordination is both possible and easily maintained because of water's characteristics, gains from cooperation, the effects of prospect theory, and the weakening of motivated pressure groups.

3.6.1 Domestic Treaty Approval

The treaty negotiation and outcomes must be acceptable to a country's home population. The creation of a proposed new treaty is a "two-level game" (Schelling 1960, Gourevitch 1978, Putnam 1988) and may require some special conditions for success. In states where water use or extraction is responsible for a large percentage of the GDP, selling a redistribution of resources to a domestic population may not be easy. In fact, sharing waters with a neighbor is not always a good idea for leaders:

> Domestic support for Sadat's plan to share/sell Nile water to Israel was so poor that two separate coup plots sprang up against Sadat. . . .The domestic concerns for the Nile were too strong despite the possibility for a stronger peace with a powerful neighbor (Bulloch and Darwish 1993, 79–97).

Additionally, the Afghan treaty with Iran sharing waters of the Helmand river may have contributed to Daud Khan's successful coup, as he used the agreement for rhetorical purposes (Kākar 1978, Dil 1977).

But Wolf (1995) and others (Bulloch and Darwish 1993, *supra*) offer evidence that even between Arabs and Israelis, political/technical cooperation over desperately scarce water occurred as early as the 1970s. "In such cases of overwhelming importance, Jordan is prepared to deal with the enemy" (Lowi 1993, 165). How can leaders successfully sell the idea of cooperation to a testy home population? Does prospect theory (Kahneman and Tversky 1979, Tversky and Kahneman 1982, Levy 1993, Levy 1997, Levy 2003) predict that home populations will be more or less likely to accept a proposed agreement? As noted in Chapter 2, I posit that the desire to enhance the predictability of a natural system and even out the shocks of occasional water scarcity may give a leader or a country the necessary domestic political backing to create a costly bilateral or multilateral cooperative agreement *once the country has endured a painful, shared drought for several years*. Exogenous scarcity reduces the likelihood of inward-looking solutions to a drought and promotes cooperation. The drought may not be a necessary or sufficient condition to conclude a treaty, but it should provide an increase in the ability of all leaders to successfully negotiate.

Figure 3.3 is a graph depicting two proposed relationships between drought level and the likelihood of international cooperation over fresh water resources. The X-axis indicates water scarcity, with conditions becoming drier as the position on the X-axis moves from right to left. The Y-axis reflects the percentage chance that two states will engage in non-trivial cooperative behavior over fresh water resources. Lateral pressure theory predicts the thinner line, with states cooperating when the resource is plentiful (and restricts no one's growth of power). Lateral

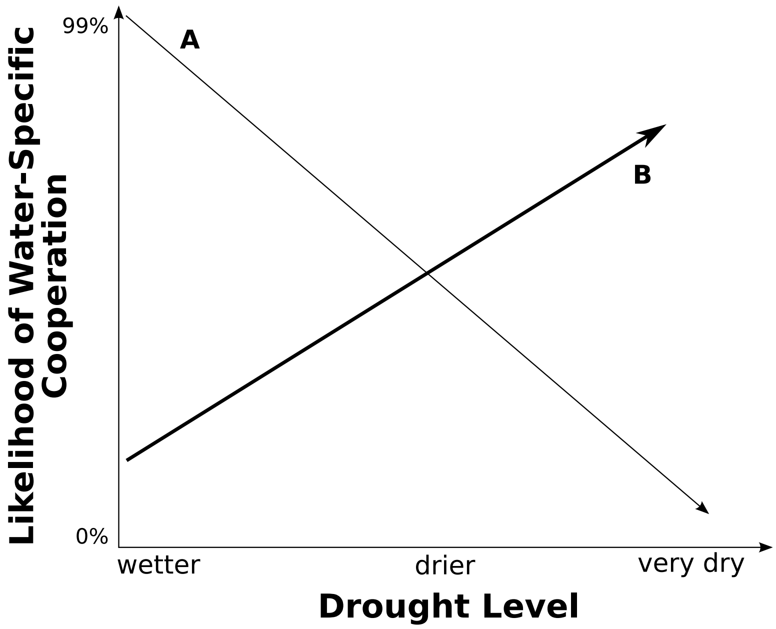

FIGURE 3.3: Two relationships between scarcity and cooperation. Line "A" is typical of lateral pressure theory, whereas I propose the mechanism is more similar to line "B." That is, rather than cooperation becoming less likely as drought worsens, I expect states will exploit gains from cooperation and cooperate despite their conflicts of interests.

pressure theory expects that as water becomes more scarce, there is a higher likelihood that water becomes the resource most limiting the growth of a country's power. If water restricts the growth of a country's power, cooperation becomes less likely, though not impossible: as the resource becomes more scarce, cooperation becomes more difficult as relative gains become a serious concern. If, on the other hand, exogenous shocks to a country's water resources provide needed impetus to conclude a treaty, then the logic of cooperation should look like the darker line in Figure 3.3. The dark line stops short of 100% likelihood of cooperation since state behavior is harder to predict as situations become more dire.

> H_4: *A state experiencing a period of acute scarcity experiences an* **increase in the likelihood of the formation of a treaty addressing water issues** *with an adjacent state, compared to a state sharing a water resource that is not experiencing*

acute scarcity.

> *H_{4a}: Acute water scarcity* **increases** *the likelihood of water treaty formation; this impact intensifies as the* **intensity of the acute scarcity increases.**

3.7 Conclusion

The world is rarely black and white. Scholars predicting violence or a new age of cooperation regarding scarce water sometimes ignore the political realities of internal and international relations. In this chapter I offer a new explanation for water conflict and cooperation that avoids the traps of absolutism while maintaining a careful, rigorous explanation for why states will not succumb to war over water, and yet why cooperation may elude them. The primary motivations for states are security and stability. Both of these are negatively affected by water shortages and improved by the benefits of water treaties. While a selectorate's short-sightedness and risk aversion may restrict some cooperative gains and agreements, these factors can be used to improve the cooperative outcomes after a drought has begun.

Testing these hypotheses requires a new set of data. To this point, no one has been able to accurately address exogenous droughts in a statistical analysis because of the data that most water researchers use. Further, those who would examine drought do not have maps that accurately reflect the size and shape of the state before it assumed its current shape and areal extent. In the next chapter, I discuss the means I used to create accurate annual maps of the world from 1947 to present, and to modify an existing but little-used drought data set that provides accurate drought data in small slices of time and area. Using these two data sets allows me to accurately test my hypotheses in Chapters 5, 6, 7, and 8, without the data and methodological problems encountered by others.

Chapter 4

Water Scarcity Data and Methods

> The map is not the territory ... The only usefulness of a map depends on similarity of structure between the empirical world and the map.
>
> *Alfred Korzybski*

To properly test the hypotheses in this dissertation, one must use several types of data in addition to the more common covariates: international conflict data, international cooperation data, and accurate but temporally regular water scarcity measures. In this chapter, I discuss issues related to measurement of the key independent variable for this study, namely water scarcity. This chapter will explain why measures previously used in the literature are inadequate for this study and the methods by which a new and better measure was obtained.

4.1 Water Scarcity

An ideal measure of water scarcity would be finely grained, spatially and temporally; it would reflect the water availability in a given country and possibly in a given first-order civil division (provinces or states), both absolutely and with respect to average conditions. This measure would contain proportions of water that were coming from outside the country, and would also contain measures of how the country uses its available water.

Heretofore, water scarcity data used in quantitative studies have most often come from the World Resources Institute (WRI), which gets most of its data from the Food and Agriculture Organization (FAO) of the United Nations, and/or the United Nations Environmental Programme (1986, 2000, 2005, among other years). For example, Hauge and Ellingsen (1998) describe their freshwater availability variable thusly: "Data on the [freshwater availability] variable are based on one year of information for the period 1980–1992, and have been copied for the remaining years of the period 1980–1992. The categorization of the variable follows Shiklomanov (1993)" (307). Hauge and Ellingsen group water availability into low, medium, and high water availability per capita. Low is 0–5,000 cubic meters, medium is 5,000–20,000 cubic meters, and high is greater than 20,000 cubic meters per capita per year (1998, 307).

Using data in this manner, from a one-time survey, has a serious shortcoming. These data are annual averages of available freshwater in a given country, using a combination of internal and "exotic" (originating outside the country) river flows. *These figures do not vary from year to year*. The only practical way to reflect water scarcity with the WRI data is to divide by a country's population,[1] tying water scarcity to population growth, but not providing any information about annual variations in rainfall or temperature.

For example, 12.75 million people lived in Afghanistan in 1971, and the country had an annual expected average of 60,000 MCM of fresh water availability.[2]

[1]Falkenmark (1989) created a "water stress index" to denote varying levels of access to water based on the number of people in a state divided by the number of million cubic meters (MCM) of annually renewable water. Falkenmark establishes the water stress threshold at 1667 people per million cubic meters per year.

[2]One United Nations online source in the Office for the Coordination of Humanitarian affairs

Dividing the population by the water supply shows that Afghanistan had roughly 212 people per MCM that year, putting the country substantially within the water scarcity threshold of 1667 people per million cubic meters (MCM), *using average figures from a one-time survey*. Those unaware of an ongoing drought would have been surprised that the drought may have, at least in part, destabilized the Shafīq administration in Afghanistan (Kākar 1978, 209–210) and paved the way for Daud Khan's coup (Dil 1977, 473–474).

The problems with using these non-varying data become worse if one wishes to do any time-series analysis, for they represent a one-time survey.[3] These data do not reflect the true nature of water resources in the country. Average water data do not count temporal variations in rainfall or stream flow. In all, the World Resources Institute/FAO data is a poor choice for statistical analyses involving time-series data. Atmospheric and precipitation variations change constantly and have impacts that are not tied to population levels, except perhaps as it influences migrations on a longer time scale. By dividing a static water figure by population, one may introduce problems of multicollinearity should one attempt to also include population measures in a statistical analysis. Real droughts are more or less random events. Neither the WRI data nor population figures are random in the least, and these facts will negatively affect the analyses of those who use the WRI data. Proxy variables, such as the percentage of a country's land area contained within a river basin (Espey and Towfique 2004), do not address the actual water availability either. Rather, they estimate the potential share of a river's flow that will be available to that country. Again, these quantities are not variable and thus

puts this number at 75,000 MCM.

[3] The WRI apparently changed the way they code freshwater supplies at least once; Syria's water supply in 1986 is listed as 35.3 Billion Cubic Meters (BCM) and in 1987 is listed as 7.6 BCM. This inconsistency is not variation but rather definitional. This change in reporting makes Syria appear radically more water-stressed than the year before, which is not the case.

attempt to explain a variable phenomenon with a constant value.[4]

4.2 Drought Data

In contrast to the problematic WRI data, Aiguo Dai et al. (2004) have developed a set of drought data, using a calibrated model based on rainfall and temperature that approximates the global soil moisture conditions. This drought measure is expressed as the "Palmer Drought Severity Index," or PDSI (Palmer 1965). While drought is not the same measure as stream flow, drought gives a clearer picture of local conditions, and, in this case, allows better temporal granularity and coverage of water availability in the world. The PDSI measures *meteorological drought*, meaning the "cumulative departure (relative to local mean conditions) in atmospheric moisture supply and demand at the surface. It incorporates antecedent precipitation, moisture supply, and moisture demand... into a hydrological accounting system" (Dai, Trenberth and Qian 2004, 1117). The PDSI has a range of about $[-9.0, 9.0]$. Negative numbers indicate worse drought, or less moisture in the soil. Positive numbers indicate more moisture in the soil.[5] The PDSI makes some assumptions that make it a biased predictor towards *worse* drought, such as assuming that evaporation/transpiration occurs at the *potential* rate, i.e. the highest possible rate of loss.[6] The PDSI is most accurate during the warm months, when drought is likely to be at its worst. If the resource-wars hypotheses posed by others (and tested in chapter 5) are correct, the PDSI measures of water stress will

[4]Espey and Towfique acknowledge the issue in their article and specifically mention the lack of existing, temporally variable, water data.

[5]Again, note that PDSI values are moisture levels *relative to average local conditions:* Dai et al. note that "quantitative interpretations of dryness or wetness for a given PDSI value depend on local mean climate conditions. For example, a PDSI value of +4 may imply floods in the central United States, but only moderate rainfall (by central U.S. standards) in northern Africa" (Dai, Trenberth and Qian 2004, 1118).

[6]Following Thornthwaite (1948).

correlate with an increased likelihood of militarized disputes between neighboring riparians. The PDSI accounts for wetter conditions, though it is a less accurate measure of greatly above-average soil moisture or flooding. If there is a statistical association between wetter conditions and better relations in a given dyad, the PDSI should allow that relationship to show through, though the standard errors will be slightly larger. Nevertheless, the PDSI measures provide a means to overcome the deficiencies of previous research using poor data on water availability.

This drought data also helps eliminate the problem of the uneven distribution of water within a country and within social strata. Even if Afghanistan has access to 60 billion cubic meters of fresh water in a given year, the water is not distributed evenly across the land, nor do all citizens have equal access to that water. Because the drought data measure soil moisture, mostly as a result of rainfall, these data provide a fair assessment of the water availability for everyone in a given area.

While the spatial coverage of Dai et al.'s data is sparse from 1870 through the early 20^{th} century, after 1945 it offers virtually complete coverage of the Earth's land masses, outside of the polar regions and Greenland, from 60°S to 80°N, through December 2002. Their model also offers *monthly* temporal granularity for drought levels; this excellent temporal coverage removes the necessity of using invariant water availability data,[7] such as that from the World Resources Institute.

However, the Dai et al. measure is not computed at the level of country or any other political unit. Instead, the drought data[8] are expressed as a grid of cells 2.5° on a side—approximately 81,000 square kilometers (km^2) each, or roughly the size of South Carolina or French Guiana. The grid covers most of the Earth's land mass.

[7] The temporal coverage of all other independent variables necessitates the aggregation of drought data to the annual level, a level still greatly superior to no variation at all.

[8] Until recently, their data were only available in an obscure binary storage format. The data are now available in a text format at `http://www.cgd.ucar.edu/cas/catalog/climind/pdsi.html`.

Each cell in the grid has a numeric drought value assigned to it. This grid is called a *raster* image (see Figures 4.1 and 4.2). Raster data is the spatial cognate to *discrete* scalar data; raster data changes at the regular boundaries of each pixel/each cell in the grid. Raster data is made up of pixels, each with one value. The data value does not vary within each pixel; rather, the value of each pixel is an average value over the pixel's entire area.

FIGURE 4.1: Raster image of drought conditions in June, 1971. Lighter grays indicate worse drought. The boundary of Afghanistan is provided as a reference. Note greatly-deficient rainfall over Afghanistan. This severe drought was a factor cited in the overthrow of the Afghan monarch (Kākar 1978, Dil 1977) but did not result in expansionist behavior by the monarch or his successor.

4.3 Country Maps

In contrast to raster data (cells laid out in a regular grid pattern, with discrete geometric boundaries between each cell), country boundaries are spatial cognates to *continuous* data: vector points and lines can be located anywhere on the map, with great precision, and can form irregular shapes. The drought data, expressed in large squares, do not conform to country boundaries, and many countries will contain more than one raster cell (pixel) containing drought information. To ensure the accuracy of the drought data for each country, it is necessary to have accurate

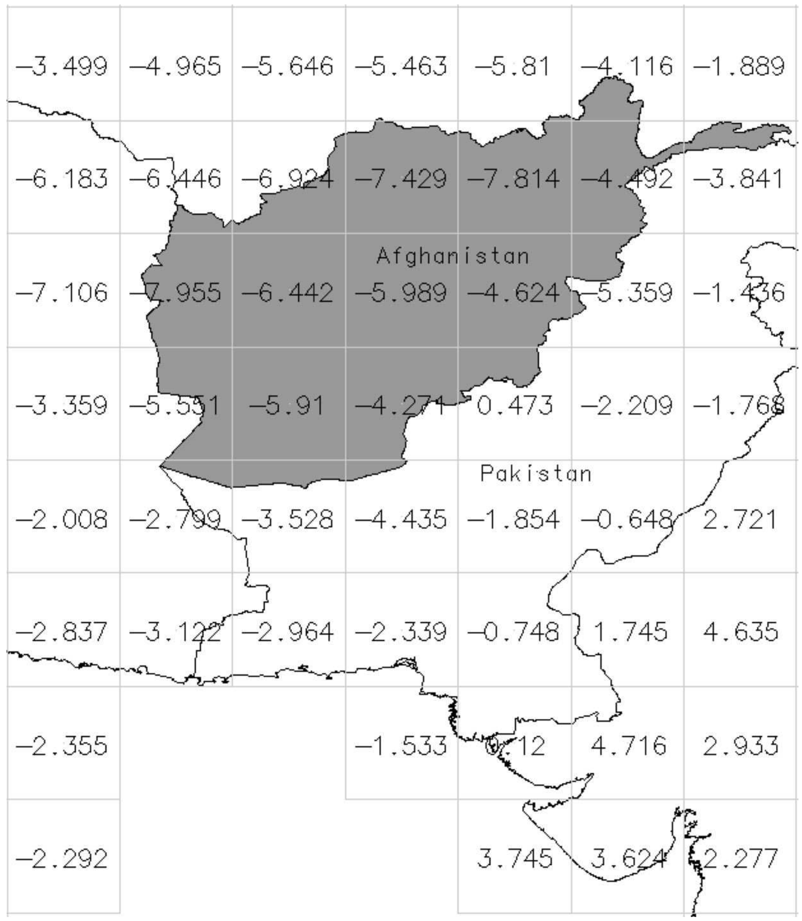

FIGURE 4.2: PDSI values in a mixed raster and vector map, June 1971. The PDSI raster map is superimposed on a political boundary map. Note the strong drought (large negative numbers) over Afghanistan.

measures of a country's shape and boundary extent for *each* time period. Such a collection of maps avoids what Monmonier (1996, 54–57) calls *temporal inconsistency*: "inaccurately dated or temporally inconsistent maps can be a particular hazard when the information portrayed is volatile." Put another way, one cannot expect accurate statistical results using a 2001-vintage map to measure the areal extent of the Soviet Union, which dissolved ten years earlier. Accurate digital maps, reflecting annual changes, of worldwide political boundaries were not available or did not exist. I therefore independently set out to create annual political maps of

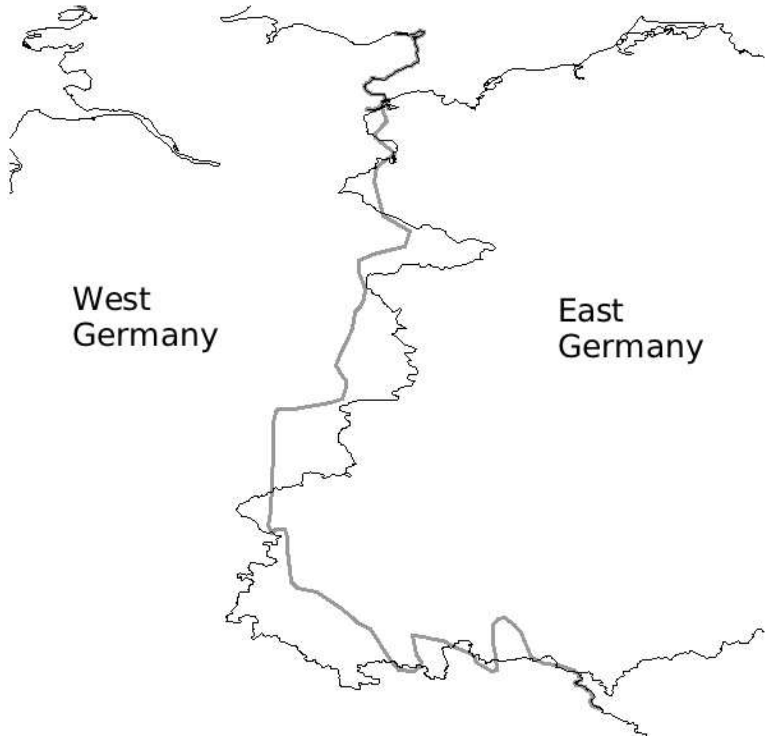

FIGURE 4.3: O'Loughlin et al.'s (1998) historical GIS coverage's East Germany boundary versus the boundary I digitized. Their boundary is a thicker line, in gray.

the world since 1947. Digital maps of the world are available as far back as 1992, but the temporal coverage (even recently) is coarse-grained or nonexistent. For example, Yoffe et al. (2004) use five static maps to reflect "significant changes in boundary locations" over five time periods of varying length. These maps, originally from O'Loughlin et al. (1998), improve on using only modern boundaries, but some of the boundaries are noticeably inaccurate. See Figure 4.3 for an example. To ensure that the drought figures for each country were accurate, it was necessary to make a set of maps with higher spatial and temporal resolution than what was then available.

Using the Territorial Change Database (Tir et al. 1998) as a guide to the relevant changes, I created digital maps marking the territorial changes greater than 300 km^2 since 1947. There were several exceptions to the Territorial Change Database

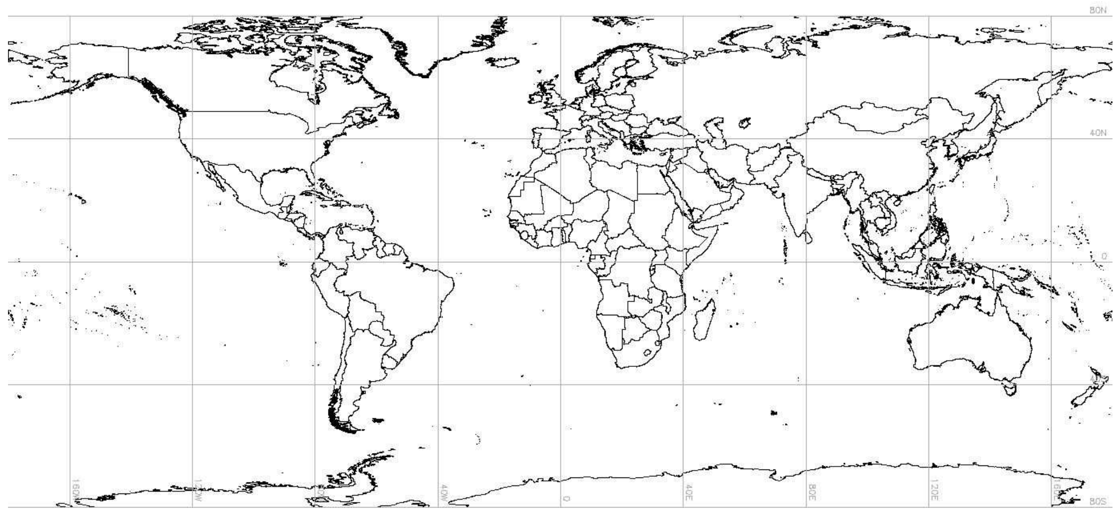

FIGURE 4.4: Vector map of world political boundaries in 1990. As described in the text, 71 changes to the 2001 map were required to create this version.

coding. These exceptions are listed, with explanations, in Table 4.1; some Territorial Change Database entries were ephemeral, while others codified existing situations or upheld challenges to a state's sovereignty.

Maps of country boundaries, rivers, or roads are commonly stored in a *vector* data format, meaning that they are composed of lines with a given location, direction, and that have meaningful intersections with other lines. Vector data is best for geospatial data that consists of lines (rivers, roads), points (streetlights, graveyards, or buildings), or shapes with hard boundaries (lakes, city boundaries, icepack). Vector data has a high capacity for precision. Vector data is therefore ideal for political boundaries (see Figure 4.4) that require both great precision and accuracy. However, its capacity for *precision* can lead to misleading statements or expectations about its *accuracy*,[9] especially where boundaries might shift gradually, as river boundaries do. In such cases, a vector's location may be fixed yet

[9]See Mandelbrot's (1967) "How Long is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension."

TABLE 4.1: Variances with the Territorial Change Database

Change / Omission	Explanation
All changes smaller than 300 km^2	Changes of less than 300 km^2 are considered irrelevant to a country's weighted drought index.
1947 South Asia Partition	Unable to locate a suitable, unbiased map of the original agreed-upon partition.
1956 Kurile Islands (USSR & Japan)	Though the USSR (and since, Russia) agreed to return several of the Kurile Islands once a peace treaty was concluded between the two nations, such an agreement has not occurred and administrative authority has not been returned to Japan. No map change made.
1956 Sinai	Not mentioned in the TCB. However, the territorial change was ephemeral and thus not included.
1960 Mali Confederation	The Mali Confederation only lasted a few months. Senegal left the Confederation in August 1960. The map shows the states independently of each other starting in 1960.
1960 Honduras–Nicaragua boundary dispute	ICJ upheld the 1906 territorial award to Honduras by the King of Spain. No map change necessary.
1968 Kashmir	The territorial changes were very fluid until codified in December 1971 at Simla. No map change made until 1972.
1973 Golan Heights	Israel's 1973 expansion in the Golan, unlike the 1967 expansions in the Golan and the Sinai, did not result in new settlements. No map changes made.
1973–1974 Sinai	The changed boundaries from October 1973 to January 1974 were ephemeral. The map reflects the slightly more durable change (1974–1978) by marking the boundary at the Suez canal as of January 1974.
1975/1981 Iraq – Saudi Neutral Zone	The agreement was concluded in 1975 but the diamond-shaped neutral zone was not divided and sovereign until 1981. Map change delayed until 1981.

incorrect, despite its precision. Further, vector data have a poorer capacity than raster data to display or store gradually-changing (gradient) data like elevation, slope, pollution levels, or forest composition. Therefore, drought data are best stored in fine-grained raster data, and political boundaries are best stored in a vector format, but updated often.

Creating accurate annual political boundaries in a digital format varies in difficulty. In some cases, the digital maps can be easily modified. In others, the task is formidable. Each map was built working backwards from a 2001-vintage digital base map. There were four different territorial change situations, each requiring a different technique, seen in Table 4.2. Each change was performed by hand, using a computer-based geographic information system (GIS) and database.

For each change not found in an existing digital map coverage, a paper map, usually a consumer-grade National Geographic map, was acquired, scanned, registered, and digitally traced (see Figure 4.5). The changed boundary portions were then merged into existing maps. Changes involving decolonialization or the deletion of boundaries were substantially easier, and did not involve new cartography with old maps. In all, over 200 map edits were made using the GRASS GIS software.[10]

4.4 Merging Country Maps and Drought Maps

Once both the political maps and drought maps are created, it is possible to compute accurate drought levels for a country in a given month or year. As civil wars are beyond the scope of this dissertation, and international wars are fought country to country, it is desirable to express the drought data at the country level.

[10]GRASS GIS (`http://grass.itc.it`) is free/open source geographic information systems software that can be used in a supercomputing environment.

TABLE 4.2: Types of Digital Map Edits

Change Type	**Example**	**Explanation**
Owner changes	Islands; some newly independent states	Change polygon database entry to reflect new owner
Merging adjacent polygons	Annexation	Delete boundary vectors; remove old polygon data from database
Boundary change (already digitized)	East Timor, 1976 & 2000	Extract boundary vectors into separate file; overlay vectors onto unchanged map; build new polygon topology; add polygon data into database
Boundary change (coordinates)	Oman & Yemen, 2000	Obtain or enter the geographic coordinates of the new boundary; overlay new boundary; delete old boundary; build new polygon topology; add polygon data into database, if different
Boundary change (not digitized)	Burkina Faso, 1986 German Democratic Republic, 1945–1990	Locate suitable large-scale paper map; scan map; digitally rectify (project) map grid to a geographic coordinate system; digitize changed map boundaries; overlay vectors onto unchanged map; build new polygon topology; add polygon data into database

It is possible that an extreme drought in one part of the country could influence a state more heavily in its international behavior, but the perception of any leader initiating a conflict or war would include the evaluation of the entire country rather than one portion of the country. Further, the country's military or power assets are not local or regional in nature: they are possessed and used at the country level, not the basin level. Lastly, most data used to evaluate states in the international system are only available at the country-level, somewhat constraining the ability of the researcher to examine others levels of analysis. In sum, the drought data are aggregated to the country level, though multiple levels of analysis are possible for future research, using the techniques described below.

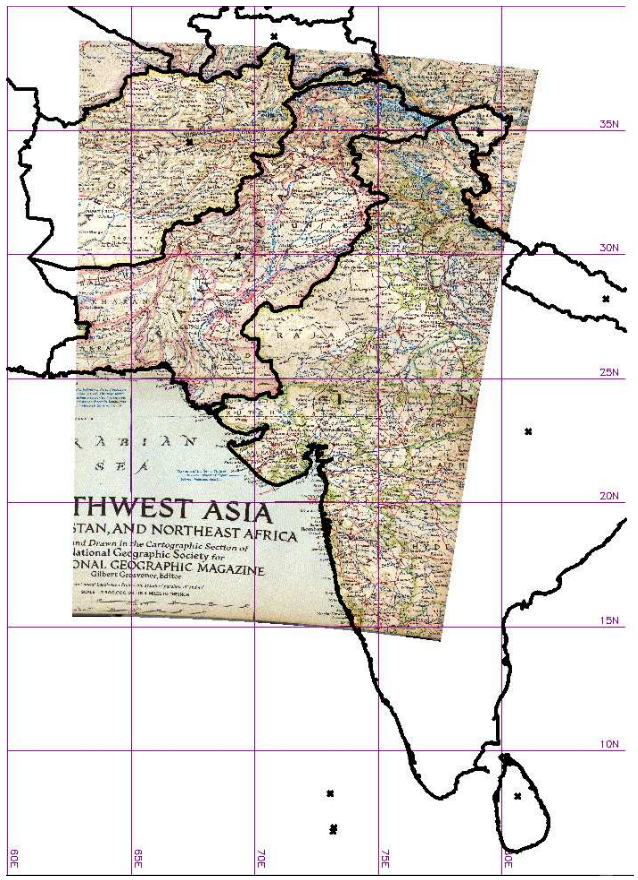

FIGURE 4.5: Digitizing a paper map. Here, the purpose is to map Kashmir boundaries in 1952, after the 1949 cease-fire but before further changes in the 1965 conflict.

To obtain an average drought value for a country, it is necessary to integrate both the political boundary (vector) layer and the drought (raster) layer into a single map, using a GIS method called *overlaying*. Overlaying two maps is like taping two transparent maps on top of each other and having a new map as a result, with the vector features from both maps intersecting each other. There are multiple types of overlaying operations (see Figure 4.6).

To extract the rainfall data by country, the drought data are converted to a vector grid consisting of square polygons along the boundaries of the raster pixels. Then both maps are overlaid such that only the polygons with both the grid lines (drought information) and the map boundaries (political information) are kept: the

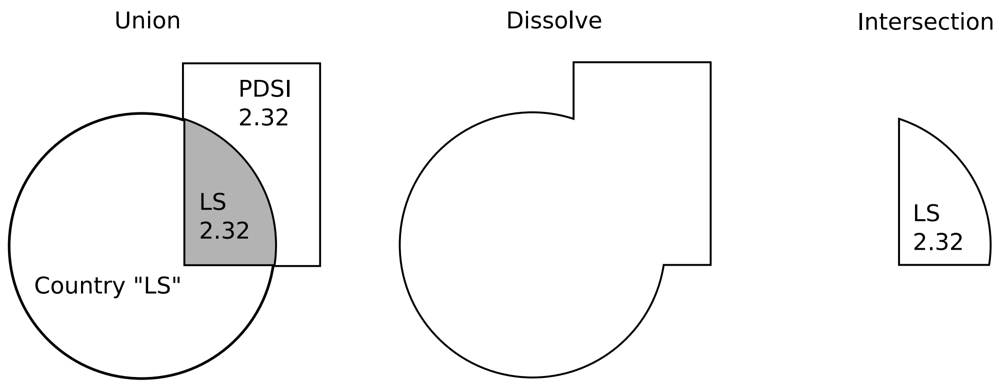

FIGURE 4.6: Topological overlays. The rectangle represents one raster pixel/cell with a drought value of $+2.32$ and the circle represents the boundary of country "LS."

new map contains all the information from both component maps. This method creates polygons that have both accurate boundaries *and* drought values, using the "intersection" method seen in Figure 4.6. These polygons are used to create an average drought value for the whole country.

Consider Figure 4.2, a combined map of Afghanistan in June 1971: Afghanistan covers portions of 19 grid cells on the drought map. Three of the cells are entirely contained within the country (with values -6.44,-5.99, and -5.91, each denoting a very strong drought). To generate a single average drought level for the country, multiply the country area within a given grid cell by the drought value of the cell. Add all of these values together and divide by the total area of the country to get the average drought level for a given month. Put another way, the average drought conditions for country c in month t can be computed by weighting the area of each polygon of the country (a_i) as a proportion of the total area of the country (A_c) and multiplying that proportion by the drought level of the polygon ($pdsi_i$), then summing:

$$PDSI_{ct} = \sum_{i=1}^{n} \frac{a_i \times pdsi_i}{A_c}$$

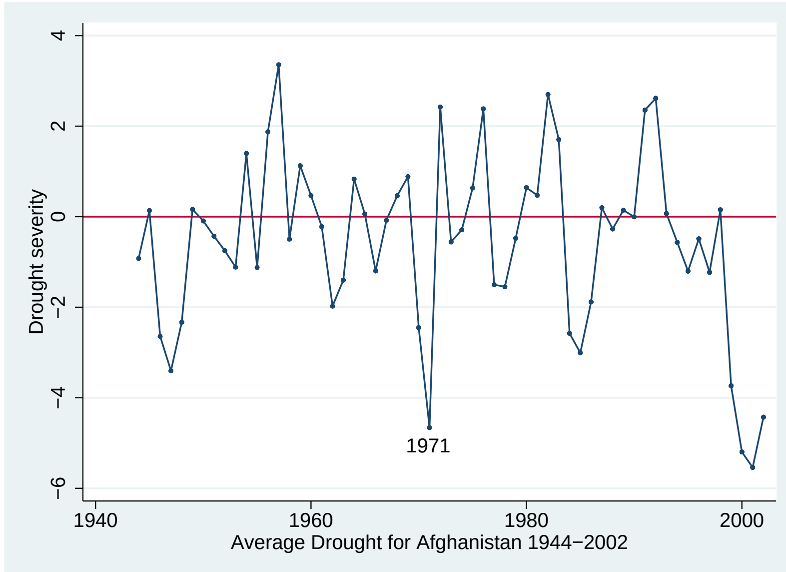

FIGURE 4.7: Afghanistan annual average drought levels for 1944–2002. This graph shows the problem with assuming that water availability is always at the average (zero).

Once these data are summed, the new Palmer Drought Severity Index variable can be included in the various quantitative tests to see the correlation between drought and international conflict and cooperation. See Figure 4.8 for an example of an overlay used to generate data for my analyses. The computed PDSI values are graphed, grouped by country, in Appendix B. See Figure 4.7 for one example of the graph for a single country: Palmer Drought Severity Index levels in figure 4.2, some as low as -8, result in a country average of -5 during June, 1971. These data are consistent with the reports of Dil (1977) and Kākar (1978) and show the contrast in accuracy between using a one-time survey to predict water availability versus having monthly data.

4.5 Merging Country Maps and River Basin Maps

Once the level of drought in each country or dyad is known, one can test the correlation between individual and shared drought levels and outcomes like cooperation, conflict, or treaties. However, states sharing water resources may constitute a fundamentally different subset of country-pair observations than those country pairs that do not share water resources. Countries divided by a watershed boundary like a mountain range will have fewer opportunities for interaction because of the difficulty of traversing the physical barrier. Second, these countries will have fewer opportunities for cooperation or conflict on water-related issues. Finally, the military capture of water resources would be less likely across a large boundary that makes transport of water difficult and expensive.

I took the international river basin map created by Wolf et al. (1999) and overlaid their map with my new annual country maps. Again, using GIS software, I determined which countries shared which basins, and which pairs of those countries were physically adjacent by land or by a river boundary, for each year between 1947 and 2002. The dichotomous variable indicating that the countries in a dyad share a river basin will be used to create an interaction variable for the statistical analyses in later chapters. I computed approximate percentages of each country's land area within each river basin shared with each dyadic partner. That is, the resulting data contain information about whether a given pair of adjacent states share any river basin or basins, and how much of each country's land area lies within a shared basin.

4.6 Conclusion

In this chapter I have described my key independent variable (water scarcity) and two secondary variables (territorial extent and shared basin membership), and the steps required to create them. To overcome the limitations of previous studies and the lack of reliable political boundary data and temporally variable drought data, I undertook the following tasks: I obtained and properly formatted monthly drought data, creating raster maps; I made over 200 edits to existing political boundary data, so I now have a GIS database of temporally and spatially accurate political boundaries spanning nearly 60 years; and finally, I merged these two sets of data together, creating a drought value for each country in each month from 1948–2001. Graphs of drought values for each country, 1948–2001 are reproduced in Appendix B. These data—the political boundaries, the basin-country information, the drought data, and the monthly weighted average drought levels for each country—improve the ability of scholars to ask spatial questions, and partially address Gleditsch's (2001) request for "major improvements in systematic data collection—a Correlates of War project for the environment" (270).

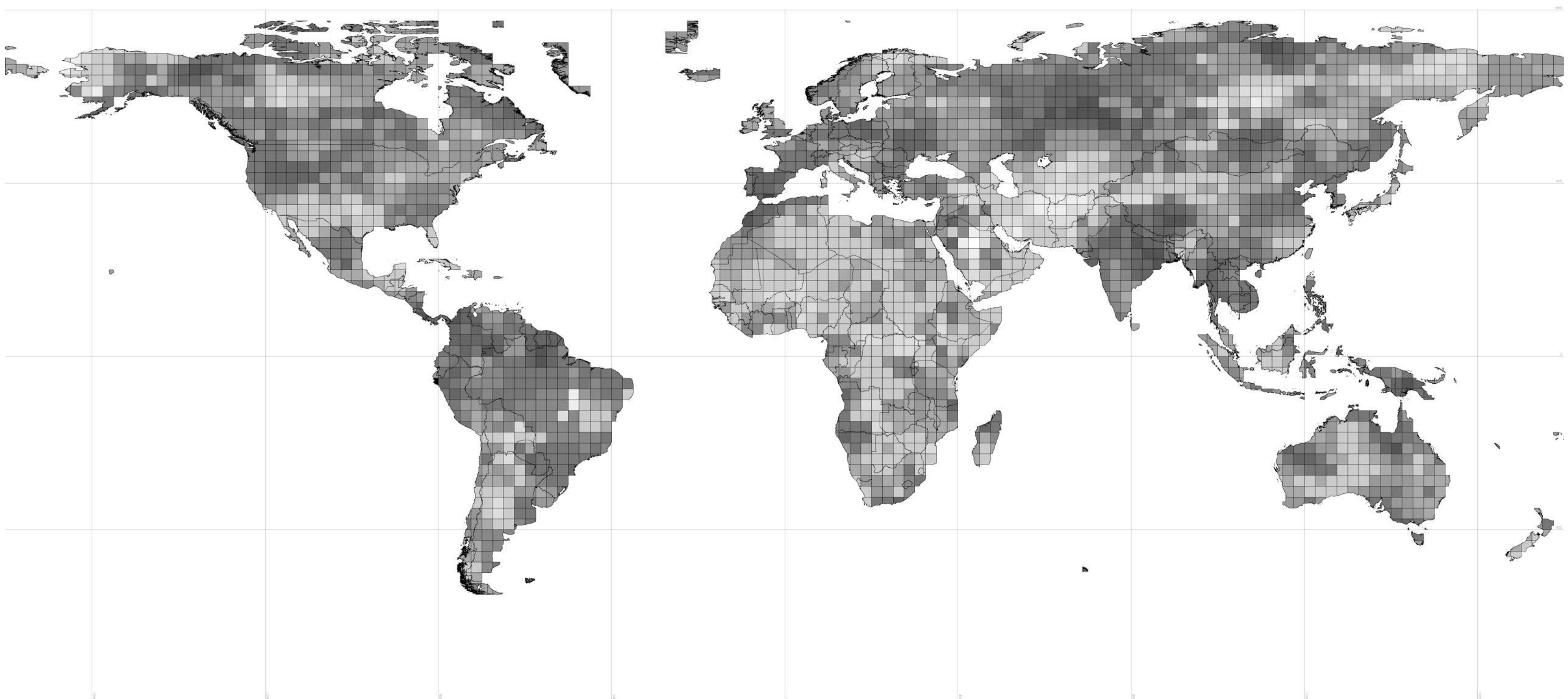

FIGURE 4.8: Combined Map of Drought and Political Boundaries, June 1971. This map combines political boundaries with the gridded data of drought conditions in June 1971. Lighter shades of gray indicate stronger drought, and darker shades indicate greater soil moisture. Note the strong drought over Afghanistan and Iran, and the plentiful rainfall over the Indian subcontinent and Southwestern China.

Chapter 5

Drought and Military Conflict

> Many of the nations of North Africa and the Middle East lack sufficient supplies of fresh water....In these areas, conflict over water is a recurring and often violent phenomenon.
>
> *Michael Klare*

> The only problem with these theories is a complete lack of evidence.
>
> *Aaron T. Wolf*

The statistical tests in this chapter test the realist "water war" hypotheses by examining the effect of changes in water scarcity on the probability of militarized disputes and violent militarized disputes. Most of the debate between the realist camp (also called the "malthusians" or "neomalthusians") and the neoliberal (sometimes called the "cornucopians" in the environmental context) centers on the belief that resources are a zero-sum game, and that a greater *quantity* of resources is always better than *more efficient use* or resource *substitution*. This zero-sum game ignores or minimizes gains from trade, substitution, sharing, technological improvements, and negative externalities from conquest. Lateral pressure theory, first described by Choucri and North (1972, 1983, 1996), is a resource-specific subset of realism. Lateral pressure theory provides some easy yet unidimensional answers to the question of scarcity. Unfortunately, it allows easy post-hoc theorizing when a given country chooses peaceful alternatives to violent conquest. The neoliberals, using institutional theory and game theory, can offer an explanation for why institutions arise, stick, and potentially prevent violence, but to this point, the literature does not strongly reinforce neoliberal theory with regard to natural resources.

Some authors (Hauge and Ellingsen 1998, Toset, Gleditsch and Hegre 2000, Stalley 2003, Gleditsch et al. 2006, Hensel, McLaughlin Mitchell and Sowers 2006) have found statistical correlation between resource scarcity and an increase in the level of civil or international violence. In this chapter, I attempt to replicate the statistical tests of Stalley (2003) and Gleditsch et al. (2006), who find evidence in favor of lateral pressure theory (realism). I examine their findings using the new data described in Chapter 4. This series of tests seeks to establish the change in the likelihood of international military conflict or military violence due to drought.

The statistical tests in this chapter reveal that water stress is correlated with a significant, substantial *decrease* in the likelihood of all forms of military conflict, violent or not. These results are different from merely finding no support for the malthusians' dire predictions that water scarcity will lead to war. Rather, they imply that either states with more water are more prone to adventurism, states with less water are hesitant to engage in military activity or brinksmanship, or both.

5.1 Water and Violent International Conflict

Many authors have made more and less dire predictions about potential wars over water. This process intensified as the Cold War drew to a close and the search for new diplomatic opportunities (and the government funding that accompanied them) began. The subject of resource conflict in the academic literature dates to at least Slade (1923).[1] Even earlier, Kaiser Wilhelm identified water as a need for Middle Eastern development in 1896 (Tuchman 1956, 291). At the start of World War II, Axis powers needed other natural resources in addition to oil: iron by Germany, and rubber and tin by Japan (Westing 1986*c*, 205). Nixon (in 1953), Eisenhower, and Lyndon Johnson all justified their anti-communist activity in Asia in terms of natural resources (Ehrlich and Ehrlich 1972), though they did not limit their explanations to natural resources. Also, throughout the Cold War, America supported the South African apartheid government because of substantial mineral wealth there.

Water conflict has been an issue since at least 2500 BCE (Cooper 1983), but that earliest occurrence seems to be the only *war* fought over access to water thus far.[2] The conflict occurred between the Sumerian states of Lagash and Umma, near the Tigris river, over access to irrigation canals. "Urlama, King of Lagash, from 2450 to 2400 BC, diverted water from this region to boundary canals, drying up boundary ditches to deprive the neighboring city-state of Umma of water. His son Il later cut off the water supply to Girsu, a city in Umma" (Gleick 2006, 5). This conflict was eventually settled by a peace treaty, large portions of which were discovered and re-assembled by Cooper (1983).

Wolf and Hamner (2000, 126–127) have identified 7 incidents, as of 1999, where water resources were a likely cause of interstate action where military violence occurred or was threatened. None of these incidents led directly to war, including the Israeli bombing of a Syrian dam site in 1965. The list is reproduced in Figure

[1] Slade spoke exclusively of petroleum.

[2] See Appendix A for a discussion of the 1967 Arab-Israeli Six Day War as a "water war."

5.1. Other actions, claimed to be evidence of a water-motivated expansion, do not stand up under closer scrutiny: for example, Israel's invasion of Lebanon in 1982 actually resulted in a net *loss* of Israeli water resources, since Israel began pumping water into two Lebanese villages from its own reserves to the South (Wolf 2000, 92–93). Furthermore, Israel had the chance to destroy Lebanese water installations and did not, despite a potential increase in Israeli water if they had (Amery 2000, 143–145). Iran and Iraq fought several wars, and the Shatt-al-Arab canal was the focus of some conflict: however, the canal's use is for navigation, not irrigation. Thus, though conflicts occur in the deserts, those who claim water scarcity causes conflicts are selectively examining cases; there are many deserts, and yet people only talk of "water wars" in the Middle East and South Asia. There *is* a global history of water-related violence—but at the sub-national level. And water issues obviously can inflame tensions or cause incidents, leaving the way open for water issues to lead to war, despite little evidence of actual wars being fought over water resources.

Water resources and "hydro-strategic" territory are important political and strategic concerns; indeed, water issues are unusually charged topics among countries, even those with adequate water resources. Further, water assets make attractive military targets: dams are easy to attack and, if sufficiently damaged, can cause extensive, even catastrophic secondary flood damage. In WWII, the British Royal Air Force bombed several dams in the Ruhr Valley, flooding and disabling downstream areas (Kirschner 1949, United States Army Corps of Engineers 1953, Bergström 1990). During the Korean War, the North Koreans released a torrent from the Hwachon dam, wrecking a railroad bridge and impeding UN forces' progress (Hoyt 1985, 67–68). Many other examples of using water as a weapon exist (Gleick 2000*a*, 182–191). As noted in Chapter 3 one should not, however, confuse strategic or tac-

TABLE 5.1: Water Conflict Incidents (From Wolf and Hamner, 2000)

Dates	**Parties**	**Description**
1948	India, Pakistan	Partition leaves the Indus divided in an awkward, convoluted fashion. Disputes over irrigation worsen tensions in Kashmir, bringing the riparians 'to the brink of war.'
Feb 1951 – Sep 1953	Syria, Israel	Exchanges of fire over Israeli water development near the Sea of Galilee
Jan 1958 – Apr 1958	Egypt, Sudan	Egypt moves to capture disputed Sudanese territory. The 1959 Nile Waters treaty, and a new Sudanese government, reduced tensions.
Jun 1963 – Mar 1964	Somalia, Ethiopia	Several hundred are killed in a territorial dispute that includes areas of critical water resources in the Ogaden desert.
Mar 1965 – Jul 1966	Israel, Syria	Exchanges of fire over the 'all-Arab' plan to divert the Jordan River headwaters away from the proposed Israeli National Water Carrier. The Syrians stop construction on the diversion in July, 1966.
Apr 1975 – Aug 1975	Syria, Iraq	Syria and Iraq transfer troops to their common border after very low flows on the Iraqi reaches of the Euphrates, caused in part by Syria filling reservoirs, raise tensions. Saudi Arabia mediates the tensions.
Apr 1989 – Jul 1991	Senegal, Mauritania	Two deaths of Senegalese citizens over grazing rights along the Senegal River inflame ethnic and land-reform tensions. Several hundred are killed. Both countries restore order with their military forces.

tical military action with competition for scarce resources. Control of resources for the sake of an immediate military advantage is different from control of resources or territory for economic production, especially since military action may harm or destroy access to a resource, or the resource itself.

This chapter addresses the question of how water scarcity affects the likelihood of violent interstate conflict, or of interstate cooperation. In it, I statistically test the idea that changes in immediate water availability affect the likelihood of interstate conflict (H_1), and whether those changes, if they exist, are associated with a greater likelihood of interstate conflict or violence (H_{1a}).

> H_1: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **change in the likelihood of a military conflict** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
> > H_{1a}: *A state experiencing a period of acute scarcity involving a shared water resource is* **more likely to initiate military conflict** *compared to a state sharing a water resource that is not experiencing acute scarcity.*
> >
> > H_{1b}: *A state experiencing a period of acute scarcity involving a shared water resource is* **less likely to initiate military conflict** *compared to a state sharing a water resource that is not experiencing acute scarcity.*

The expectations of realism, seen in Chapters 2 and 3, are clear: a state must break through constraints on its development and military power or face extinction. The expected outcome of resource scarcity is therefore that states will use their power to gain access to resources, whether by force or more subtle means. Especially when a specific resource is a limiting factor to development, countries will seek access to that resource by any means necessary, including imperialism and war. Examples supporting lateral pressure theory include Great Power imperialism during the 19^{th} and 20^{th} centuries, Japan in the first half of the 20^{th} century (especially the conquest of the petroleum-rich Indonesian territories), Germany's

1940 invasion of Norway (iron), the Israeli bombing of a Syrian dam in 1965 (water), and Iraq's 1990 invasion of Kuwait (oil). Huth (1996, 75) finds statistical evidence supporting the initiation of a territorial dispute with the presence of valuable natural resources, including water, or outlets to the sea in the disputed area.

Homer-Dixon (1991, 1994, 1999) proposes that conflict can result from a variety of environmental sources, including several based on freshwater. He lays out complex possibilities of resource depletion and creates scenarios where violence might result: agricultural shortfalls; economic decline caused by the unsustainable use of resources or global warming; population displacement, or the creation of "environmental refugees" (Jacobson 1988); and disrupted institutions and social relations caused by the preceding three elements. Alternately, the unrest caused by scarcity can spill over into neighboring states as environmental refugees migrate away from areas of scarcity and into neighboring countries. Sometimes the unrest results in a civil war or localized rebellions, though the problems do not expand into the international realm. Some authors, including Homer-Dixon and Percival (1996) and Homer-Dixon (1999, 69) believe that this case is far more common than international resource conflicts.

Most of Homer-Dixon's work points towards internal unrest and civil war, but he and others (Starr and Stoll 1988, Klare 2002, *inter alia*) propose that internal factors can destabilize a state and lead to interstate conflict. Gleick (1993*a*) also explicitly predicts military conflict caused by water scarcity, and differentiates between upstream and downstream states when examining conflict and its causes. Toset, Gleditsch and Hegre (2000) have empirical results that find water shortages, among other related variables, can increase the likelihood of military conflict between countries. In addition, there is the possibility of diversionary conflict, covered by Levy (1989), as a result of resource scarcity. Whatever the source of the international violence, I examine only international concerns because of the differences between civil and international violence.

Generally, the resource conflict literature predicts the likelihood of international cooperation dwindles as the resource becomes more scarce (see Figure 3.3 on page 70), with possible exceptions for non-military coercion by powerful states.

Stalley (2003) bases his test on two of Homer-Dixon's paths to conflict: the most direct, "State A experiences scarcity in resource Y and takes action against state B that threatens state B's access to resource Y" (38); and, the "instability" argument, "state A experiences shortages, which in turn creates refugees who pour across a border, increase ethnic tension, and/or lead to conflict" (38). Stalley never references Choucri and North (1972, 1996), Van Evera (1999), Frey and Naff (1985), or realism to flesh out the causal logic of being the initiator in a resource conflict, though lateral pressure theory is clearly an ideal theoretical source. Homer-Dixon has stated (1999, 5) that environmental scarcity, however, is far more likely to cause violence at the sub-state level.

Stalley also assumes that resources are available on the other side of the border, which is not necessarily the case. Most notably, Stalley uses the same water scarcity measures as Hauge and Ellingsen (1998), which, as noted in Chapter 4, are neither temporally variant nor independent of population levels. The World Resources Institute data for water are categorized into "annual within-country renewable fresh water sources" and "annual expected inflow of fresh water." Egypt, for example, has almost no rainfall with 7 inches per year, but the Nile carries up to 50 *billion* cubic meters (BCM) into Egypt each year. Stalley does not say which measure he uses (or if he uses the two measures combined), but if, like (Gleick 1993*a*, 102–103), he only uses annual renewable within-country measures, the situation is artificially dire for many states.[3]

Stalley uses Militarized Interstate Disputes data for his dependent variable, and finds some support for Lateral Pressure Theory in his empirical tests, but only in the aggregate—when numerous environmental stresses affect a state, he finds a greater likelihood that a state will engage in conflict with a neighbor. When he separates the environmental stresses into individual regressors, water stress is found to be insignificant.

Toset, Gleditsch and Hegre (2000) use Hauge and Ellingsen's (1998) water data, plus a set of river boundaries collected by Toset. They use MID for their dependent variable as well. They code water scarcity differently than other authors, setting 10,000 cubic meters per capita per year as the threshold for water scarcity (985). They find stronger evidence that water scarcity in one or both neighboring countries significantly contributes to the outbreak of a militarized interstate dispute covering a large time period (1880–1992). Though their water data cover only 1980–1992, and again these data do not vary,[4] their results provide solid support for the realist idea that water scarcity is correlated with and may indeed contribute to interstate military conflict (986,991). They also find support that rivers as boundaries are associated with a greater likelihood of conflict over and above that of mere contiguity (986,989,991).

Gleditsch et al. (2006) use rainfall data to create a dummy variable for the pres-

[3]Gleick (1993*a*) predicts international conflict based on the amount of water from upstream sources, called "upstream dependence." Such likely conflict initiators include Egypt, with 97% of its total river flow coming from upstream, Hungary (95%), the Netherlands (89%) and Bulgaria (91%). Contrast this with Israel (21% of total river flow originating outside of its borders), Jordan, (36%), and Pakistan (36%). There has been a lack of conflict before and since 1993 in the states with major upstream dependence (though Egypt has some political friction with other Nile riparians). The greater conflict incidence among some states with a lower dependence on upstream water may merit more specific testing for Gleick's hypotheses.

[4]They do not, however, use population as a measure in their tests, avoiding the potential collinearity with population and water stress.

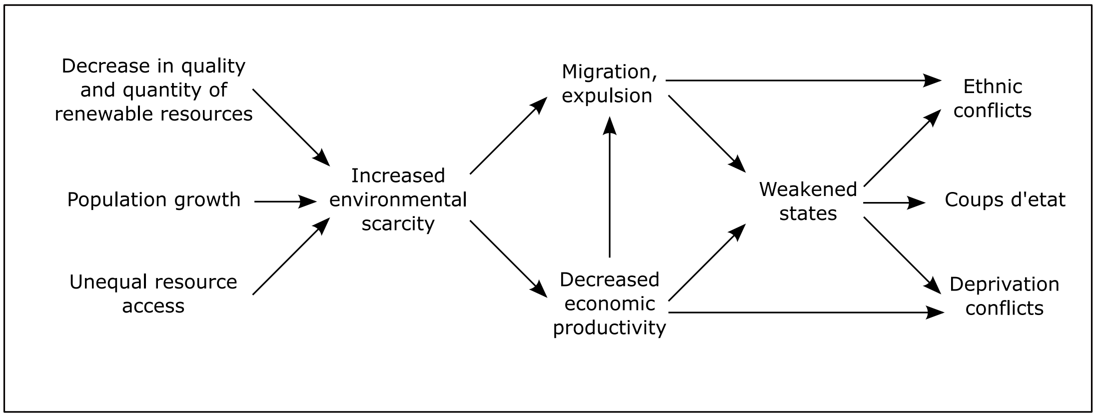

FIGURE 5.1: Homer-Dixon's (1994) Environment and Conflict Model.

ence of a drought in the past five years from 1968–1998. They found no significant correlation for their drought variable, but did find a series of significant variables that support the malthusian/realist theory. However, the presence of drought was not significant and the dummy variable for "a dry country" was significant at the $p < 0.001$ level. Merely having a shared river basin was much more likely to be associated with a military conflict, however, and a shared basin reflects neither drought nor plenty, but merely association. Their dependent variable only used MID (international military conflict) data.

Given these three studies as background, I examine the following hypotheses from Chapter 3, using the new data described in Chapter 4 and additional sources of data for the dependent variables in each hypothesis. This chapter tests the realist "water war" hypotheses, leaving the less-restrictive set of two "conflict" hypotheses for the next chapter.

> *H_1: A state experiencing a period of acute scarcity involving a shared water resource experiences a* **change in the likelihood of a military conflict** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*

> H_{1a}: *A state experiencing a period of acute scarcity involving a shared water resource is* **more likely to initiate military conflict** *compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
> H_{1b}: *A state experiencing a period of acute scarcity involving a shared water resource is* **less likely to initiate military conflict** *compared to a state sharing a water resource that is not experiencing acute scarcity.*

Hypothesis H_{1a} is the most generic malthusian/realist hypothesis: it states that states needing water will take it if they can, using force if they must. As populations are nearly always growing, endogenous water stress will rise regardless of periodic changes in water availability, so the pressure to increase the amount of water must also increase. I examine this hypothesis using established data on military conflict, with decades of temporal coverage; these data provide ample opportunity to find support for the claims of malthusian authors. If the data and quantitative analysis support this hypothesis, or fail to reject it, then the possibility exists that military violence may not only accompany drought and water scarcity, but be caused by it. If the data and analyses show that military conflict is less likely during a drought, then the results will reject the realist expectations, at least for the time period covered by the data.

5.2 International Conflict Data

To examine Hypotheses H_1, H_{1a}, and H_{1b}, I use the Correlates of War Militarized Interstate Disputes data (Ghosn, Palmer and Bremer 2004). The MID data provide a sort of standard for replication, since many articles about the causes of conflict use the MID data. MID data allows me to set a baseline for comparison, both to others' work and my own in later chapters. MID provides a variable describing the highest level of hostility achieved by the initiating state of a given state pair (or *dyad*) during a given crisis. These levels range from 0 to 5. Hostility level 5 is an armed conflict with over 1000 killed in battle. Level 4 is violent clashes between government armed forces. The dataset spans 1816–2001 but because of data availability, I examine only 1948–2001.

5.3 Militarized Interstate Disputes Tests

5.3.1 Dependent Variables

To test Hypothesis H_1, the dependent variables using the MID data (1948–2001) take two forms. Each measures the presence of military conflict between two adjacent countries that are contiguous by land (having no physical distance between at least one boundary). A pair of countries must be adjacent by land since transporting water across any distance is very expensive compared with even desalination (Wolf 1995, 78) and therefore is an uneconomic course for a country. Adjacent countries share at least one water resource in most cases, providing the opportunity for a water conflict.

I use two dichotomous dependent variables for the analyses in this chapter. The first dependent variable measures the initiation of *any* militarized conflict between two adjacent countries in a given year, expressed as a MID hostility level of 1 through 5. This range of hostility levels includes both nonviolent events and violent events. The second dependent variable measures the presence of a *violent* militarized conflict between two adjacent countries in a given year, expressed as a MID hostility level of 4 (violent clashes) or 5 (war, with over 1000 battle deaths). The first dependent variable will capture saber-rattling and small incidents such as mobilizations in addition to violent actions. The second dependent variable is a clearer test of the water-war hypotheses, as it measures only violent clashes between opposing military forces or all-out war. If drought is associated with an increase in violent conflict between states, then the malthusian hypotheses will have strong support. If there is no impact or a negative impact on the likelihood of violent conflict, then the water scarcity variables will fail to support the water-war hypothesis.

5.3.2 Unit of Analysis

The data are set up into directed dyads—adjacent country pairs with each state listed once as the initiator, and once as the target, for each annual time period. Two versions of the dependent variable were used: violent military events (MID hostility levels 4 or 5), and all militarized interstate activity (MID hostility levels 1–5). Each of these outcome types was included as a binary (dichotomous) variable in its own logistic regression analysis. In other words, either there *was* an event of the given hostility level in the directed dyad in the given year, or there *was not*, and there is a separate regression for each binary dependent variable.

5.3.3 Methodology

Because the dependent variables are binary, I use logistic regression. Because country pairs have unique features that may not be captured by the covariates, it is possible and desirable to cluster observations together, by dyad, to account for intragroup correlation. And because logistic regression does not innately account for the effects of time, I follow Beck, Katz and Tucker (1998) and include a series of dummy variables to account for temporal effects.

The country pairs are clustered, to account for differences across dyads. In effect, clustering declares that the observations are independent across the clusters but are not independent within those clusters. Further, because the relationships within each country pair may be different, I do *not* include both sets of directed dyads in each cluster; for example, the power relationship between the United States and Mexico has, since the late 19th century, been one of hegemon to minor power. To treat the relations as identical between the US as initiator towards Mexico, and US as target from Mexico, is a mistake. While the military capabilities variables could provide some explanatory power against a specific issue, it presupposes that military power extends into all realms. Mexico's 1973 successful claim against the United States regarding salinity levels in the Colorado does not reflect the military power levels of either country, but rather the United States' wish to not be seen as a bully to the rest of the world.

Similarly, because of temporal effects and the great difficulty in modeling them theoretically or endogenously (Beck, Katz and Tucker 1998, Carter and Signorino Forthcoming), I use one method proposed by Beck, Katz and Tucker (1998) and include a series of dummy variables specifically to account for the effects of time. There is one dummy variable for each count of years between dependent variable events—that is, there is a dummy variable for *one* year at peace, *two* years at peace, *three* years at peace, etc., where "peace" is defined as the absence of a MID with a hostility level of 1–5, or a MID with hostility level 4–5 in the more restrictive tests.

As a defense against model mis-specification, I use robust standard errors, but I have also run these analyses with several different analytical methods and found few differences among the model results. A series of Cox survival time analyses were also run as a second robustness check on the initial logit results. Beck, Katz and Tucker (1998) note that binary time-series cross-sectional data (abbreviated "BTSCS") *is* survival-time data, though the difficulties in analyzing and parsing the substantive significance of the results compared with the ease of interpreting results, and the ubiquity of logistic regression in software packages, make survival models less attractive. However, the value of a robustness check cannot be overstated. Finally, because my hypotheses provide the possibility that water resources have effects in more than one direction (either suppressing or fostering conflict), I use two-tailed tests in these analyses.

5.3.4 Water Variables

Palmer (1965) defines drought as a condition in which a given area receives less than the expected amount of water in a given time period. Palmer's measure allows for regional variations in rainfall and soil moisture. As such it is not an absolute measure, but relative for a given area. A large amount of rain in Brazil or Thailand may still be less than expected, while a small amount of rain in Tunisia could still be above the average. A Palmer Drought Severity Index (PDSI) of less than zero means a country has a lower soil moisture level than average, but I expect the impact of a drought will be felt more noticeably when the PDSI sinks to -2 or less on the PDSI scale. Setting the break point at zero would assume that countries are highly sensitive to even minor variations in soil moisture levels, while setting a break at -5 would assume that only exceptionally strong droughts would have any impact on military activity.

The water/drought variables take several forms, to accommodate a variety of theoretical underpinnings. The Palmer Drought Severity Index for each country is converted into a series of variables. See Table 5.2. These variables reflect five possible mechanisms by which water stress could be converted to active military conflict. These variables take two forms, individual-level and dyad-level water stress. There are three individual-level stress variables: current year drought level, past year drought level, and three-year moving average of drought levels. Each of these three is measured for both initiating state and target state. There are four sets of two dyadic variables to measure shared drought between two neighboring countries. The first shared measure accounts for a situation where both countries have a PDSI measure for the current year below -1, -2, -3, or -4. The second shared measure registers the number of years there has been such a drought between the two neighboring countries. I explain each variable in turn.

The drought values run from negative (drier than usual, or drought) to positive (wetter than usual). As such, positive regression coefficients for the individual-level Palmer Drought Severity Index variable would mean that the wetter the conditions, the greater the expectation of military or violent conflict. Negative regression coefficients for the Palmer Drought Severity Index variable would mean that the wetter the conditions, the lower the expectation of military or violent conflict—and the drier the conditions, the greater the expected likelihood of military or violent conflict.

I also use shared drought values to construct a dichotomous variable measuring the presence of shared drought. The variable is coded as one when *both* states are experiencing a drought of a given PDSI threshold, 0 when they are not. In order to test the sensitivity of countries to shared drought, I use four levels of shared droughts, ranging from mild ($PDSI < -1$) to severe ($PDSI < -4$). For these variables, a positive coefficient means that when both states share a drought of a given level, that the chance of a military or violent event is higher. A negative coefficient means that a shared drought is associated with a decrease in the likelihood of a military or violent event.

Finally, I use four duration variables to examine the number of consecutive years a pair of states have endured a given level of drought. These variables measure the impact of longer duration droughts at or drier than a given level (again, PDSI values at or below -1, -2, -3, or -4). Positive coefficients here mean that for *each year* that both countries experience a drought at or drier than a given level, the chance of a militarized or violent dispute arising increases. Negative coefficients of the duration variables mean that every year sees a corresponding decrease in the likelihood of a dispute.

All of the water stress variables are multiplied by a binary variable, discussed in Chapter 4, indicating whether the states in a given dyad share a river basin or not. If both countries do not share at least one river basin, the chance of water-based conflict will be diminished to near zero, depending on the amount of shared non-river fresh water resources. Some countries share boundaries along a river basin divide such as a mountain range, for example. Other countries have few rivers of any size, such as Libya and Tunisia. While conflict over groundwater is possible, such questions are beyond the scope of currently available data. The world's groundwater is insufficiently mapped for large-scale tests.

The mechanisms by which water stress could lead to violent conflict are discussed in Chapters 2 and 3, but the theoretical underpinnings leave a gap at the *temporal proximity* and *duration* of the drought, and the sensitivity to the drought's *intensity*. It is difficult to theoretically predict the most likely duration and intensity parameters for drought's influence on military conflict. As such, this study uses multiple measures, and for both sides of a dyad.

Table 5.3 of correlation coefficients shows that the non-water variables are definitely not collinear, but that the state-level water variables are unsurprisingly more related. Comparing the water variables for one country, such as current year drought level and one-year-lagged drought level, are related strongly at around $0.62 - 0.66$, and the three-year average PDSI measures, predictably, are nearly collinear with the annual average level and the lagged average level, since these values are components of the three-year average, and since annual average drought

TABLE 5.2: Water Stress Variables

Variable	Explanation
PDSI value, annual average, initiator	Average current-year PDSI value for initiator country
PDSI value, annual average, target	Average current-year PDSI value for target country
PDSI value, lagged annual average, initiator	Average previous-year PDSI value for initiator country
PDSI value, lagged annual average, target	Average previous-year PDSI value for target country
PDSI value, three-year moving average, initiator	Average of current year and two prior years PDSI values for initiator country
PDSI value, three-year moving average, target	Average of current year and two prior years PDSI values for target country
Shared drought (-1, -2, -3, or -4)	This binary variable equals one if both countries are at or below the given PDSI in the current year.
Number of years of shared drought	These four count variables measures the number of consecutive years both countries have a PDSI at or below -1, -2, -3, or -4.

conditions do not change rapidly. The potential collinearity necessitates analyzing them independently of each other. As it is unknown which water scarcity measure might have the greatest impact on the decision to initiate a conflict, I examine multiple measures. It is possible that a sudden shock (the single annual measure) is enough to incite a conquest, or perhaps only a multi-year drought could provide the desperation to encourage a state to seek water sources abroad. As I suggest in Chapter 3, I expect a drought of any duration to cause states to turn inward to address the immediate, pressing problem of a drought. Also, a longer-term drought could wear down the resistance of the home population to cooperative (but restricting) solutions that benefit both parties, and rather than a violent outcome, there would be a cooperative outcome or outcomes.

TABLE 5.3: Independent Variable Correlation Coefficients

Water Variable	PDSI avg. (sender)	PDSI avg., lagged (sender)	3-year PDSI avg., (sender)	PDSI avg. (target)	PDSI avg., lagged (target)	3-year PDSI avg., (target)
PDSI avg. (sender)	1.000					
PDSI avg., lagged (sender)	0.658	1.000				
3-year PDSI avg., (sender)	0.822	0.908	1.000			
PDSI avg. (target)	0.624	0.436	0.534	1.000		
PDSI avg., lagged (target)	0.436	0.621	0.583	0.659	1.000	
3-year PDSI avg., (target)	0.534	0.583	0.645	0.822	0.908	1.000

Independent Variable	Shared Democracy	Natural log of COW capability score (sender)	Natural log of COW capability score (target)	Log of total dyadic trade	Difference of logged real GDP/capita
Shared Democracy	1.000				
Natural log of COW capabilities score (sender)	0.229	1.000			
Natural log of COW capabilities score (target)	0.229	0.336	1.000		
Log of total dyadic trade	0.514	0.526	0.513	1.000	
Difference of logged real GDP/capita	-0.000	0.077	-0.077	-0.002	1.000

5.3.5 Other Independent Variables

As briefly described in Chapter 4, three variables are used to address the logical possibility of conflict over a shared water resource between adjacent countries, and to assess the relative importance of shared water resources between adjacent countries. The first variable is a dichotomous variable indicating the *presence of a shared river basin*. This variable indicates whether or not at least one river receives flow from streams in both countries. Shared river basins more closely tie the fates of neighboring countries: the impact of the natural world and of human activities in one state will potentially affect the water resources of the neighboring state,[5], unlike states that do not share a fresh water resource. While most states in the world do share rivers with their neighbors, in the absence of a shared river, water conflict becomes much less likely since there are fewer options for capturing water resources of a neighboring state, and greater technical and economic impediments to moving captured water across boundaries.

Secondly, two variables account for the *percentage of territory in each state contained within a river basin shared with its dyadic partner*. In this way, the percent of a country's area contained in a shared basin provides a measure of issue salience, although one without precedent in the literature. It is possible that despite containing little of the river basin that a river could still be highly salient to a country, but as the size of the basin within a country grows, there is an increase in the amount of transportation and water use that depend on the river. These two factors increase a state's dependence on the river as a means of economic activity, and thus the size of the shared basin within each country, initiator and target, is a relevant measure of salience.

[5]Where rivers are shared in large basins, upstream states can affect all downstream states, even if they are not adjacent (Lowi 1993, Dinar 2006, e.g.) but a large majority of river basins are shared by only two countries(Wolf et al. 1999), so no attempt is made to address non-adjacent riparians.

For example, among many other rivers, China is a riparian party to both the Salwin and the Mekong rivers but owns a very small territorial percentage of the river basins. This small portion is a *very* small proportion of China's overall land mass. It is therefore unlikely that China views these two basins as important to its well-being compared to the Amur or Huang He rivers. On the other hand, the Ganges-Brahmaputra basin composes a very significant percentage of India's land mass, even not counting its social/religious value to the country. India highly values the Ganges.

Trade: Trade is generally acknowledged to reduce the likelihood of violent conflict (Polachek 1980, Oneal et al. 1996, Oneal and Russett 1997, Bliss and Russett 1998, Russett and Oneal 2001) between countries, with some exceptions (Barbieri 1996, Gowa 1995, Gasiorowski 1986).[6] While the question of the direction of causality has not been answered definitively, the weight of the literature supports the conclusion that bilateral and/or multilateral trade is associated with a decrease in international conflict. Polachek sums up the argument by saying that "the mutual dependence established between two trading partners (dyads) is sufficient to raise the costs of conflict, thereby diminishing levels of dyadic dispute" (1980, 55).

Realists generally expect trade to be easily abandoned during times of crisis, and for differential gains from trade to affect the likelihood and depth of trade between two countries:

> Trade brings economic benefits that states can devote to producing a military advantage. States must be concerned with the distribution of the benefits of trade as well as its profitability. If the benefits of trade accrue disproportionately to one side, the other side has to fear that the first will gain an advantage in military capabilities. The first state could

[6] Gasiorowski finds some evidence supporting both sides of the argument.

use that advantage against its trading partner. (Morrow 1997, 12)

Although not a referendum on the effects of trade, this suite of tests will examine the effects and significant of the trade variables on international military conflict, and international political conflict.

Development: GDP per capita is an imperfect indicator of development. Using the natural log of the GDP per capita, standardized by constant US dollars, provides a better measure of development for an individual country (Kevin Watkins et al. 2006). Countries with great differences in development should have lower levels of conflict and greater levels of cooperation (because of non-trade economic exchange such as technology transfers, labor outsourcing, or foreign direct investment). Country pairs with similar levels of development have smaller gains from technology transfer, labor flows or foreign direct investment, and thus fewer neoliberal ties to improve relations.

COW military capabilities of each country: Neighbors may have widely varying military power. The chance of a very weak country attacking a militarily powerful country to gain access to water corresponds roughly to their chance of success, i.e. very low. On the other hand, powerful states with water-rich but weak neighbors may attempt territorial expansion as a means to remove constraints on further development and growth of power (Choucri and North 1996). Some states may effectively re-allocate or capture water resources from a neighbor by non-violent coercion, but this test specifically addresses international military conflict and overall conflict and would not necessarily detect such actions. I use two logged variables of COW military capabilities, one for the potential attacker and one for the target state. The military data are transformed with a natural logarithm to account for a non-linear impact of military capabilities; that is, for a given logit coefficient, a country with twice the warmaking ability of a reference state will not be twice as likely to initiate a military action, but rather $ln(2)$, or only 0.693, times more likely.

Joint democracy: The democratic peace (Russett 1993, Oneal and Russett 1999, Russett and Oneal 2001) proposes that democracies, because of compatibilities, rational motivations, or internal politics, very rarely engage in military conflicts with each other. This characteristic of the dyad is expressed using the Polity IV (Marshall and Jaggers 2006) democracy and autocracy scores of two countries. A dichotomous (yes/no) variable is created, equal to one if both countries have a democracy $-$ autocracy score of 6 or greater, and zero otherwise. Democractic states (i.e. those with scores above 6) view each other as long-term, compatible partners.

While some authors use population as a substitute for water availability (Gleditsch et al. 2006, Stalley 2003), I do not. As seen in Chapter 4, I have created a variable to examine water availability, relative to local conditions, that does not depend on population to have meaning. Population growth *does* contribute to water scarcity per capita, but extra population makes *all* renewable goods more scarce. As such, $\frac{water}{population}$ cannot be separated from $\frac{land}{population}$ or $\frac{fisheries}{population}$ as a cause of violence; these variable would be collinear. In my analyses, I do not attempt to separate population as a source of military and economic power. Using both population measures and measures of military capabilities introduces collinearity into the equations, and risks destabilizing the statistical model.

Over medium and longer-term time periods, states can adjust to progressive scarcity more easily than acute scarcity (see Figure 2.3). There are no acute shocks in population growth: acute (random, or exogenous) scarcity shocks the socioeconomic system and economies of states, unlike the slow progress of scarcity driven by population growth. As others do not examine these periodic shocks, they are using improper data to determine the causes of conflict and violence.

5.4 Results

A preliminary look at the data suggests that the relationship between drought and years at peace is weak. Figure 5.2 provides a graph showing a scatterplot of the years at peace (that is, the years between military conflict events) versus drought levels of the state that initiated the conflict. If drought had an obvious impact on the overall trend, the shape of the graph would not be uniform, but would either lean to the right, towards greater water availability, or would be sharply truncated towards the left, where peace stopped once a drought was underway, leaving zero years at peace for a drought drier than -1 or -2. Overall, the graph is fairly uniform, with its center around 0 or -1, and shows little evidence of systematic changes to the number of years at peace relative to drought conditions. However, this graph is neither statistically significant or rigorous. It provides a useful baseline condition and little else.

The following tables of statistical results are representative, but many other models were run for completeness and robustness.[7] Tables are grouped by dependent variable and water scarcity type (individual or joint). Each column represents a separate model run using identical covariates but different water stress variables. Because of the potential for spatial autocorrelation between states, especially small states, the individual-level water stress variables are run in separate models. For these models, the water stress variables (PDSI values) are organized by *sender* and *target* state, since political/military events have an initiator and a target assigned to each event.

Tables of numbers can be roughly interpreted thusly: significant (at a likeli-

[7] The complete set of hundreds of model runs are available but not included for brevity's sake.

hood of 95% or higher—that is, $p < 0.05$) positive coefficients for a given variable mean that increases in these values are associated with an increase in the chances of state 'a' initiating a military dispute against state 'b.' In these analyses, both states get the chance to be the initiator in each year. That is, the dyads are directed, not simple pairings of states. Significant negative coefficients mean that increases in the values of that variable are associated with a decrease in the likelihood of a military incident occurring in the given year. On the other hand, strong negative values would strongly reject a hypothesis that expected a positive relationship. For the models considering the effect of individual–level drought, the "water wars" hypothesis predicts negative effects for the water stress variables. That is, as drought conditions worsen (PDSI becomes more negative), the probability of conflict should increase. For the models of shared drought, the "water wars" hypothesis anticipates a positive relationship between the water stress variables and the dependent variable. The presence of shared drought should be associated with an increased probability of conflict.

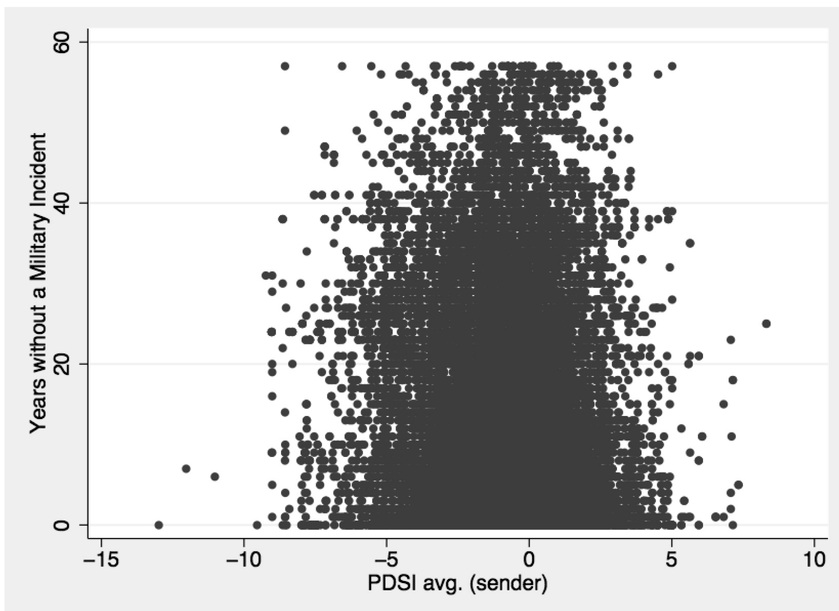

FIGURE 5.2: Graph of years at peace versus drought level. If drought had a significant impact on conflict, the overall shape of the scatterplot would be much lower (or truncated) on the left side, as military conflicts increased with a worsening drought, reducing the peace-years to zero. In this graph, no such relationship is evident.

TABLE 5.4: Logistic Regression, Effect of Individual-Level Drought on Probability of Any Militarized Dispute

Variable	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**
	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	0.019	-0.018	0.011	-0.010	0.010	-0.012
	0.126	0.126	0.127	0.127	0.129	0.129
Log of total dyadic trade	-0.231**	-0.236**	-0.234**	-0.239**	-0.232**	-0.238**
	0.036	0.036	0.036	0.037	0.037	0.037
PDSI avg. (sender) × shared basin	0.050					
	0.026					
PDSI avg. (target) × shared basin		0.055*				
		0.026				
PDSI avg., lagged (sender) × shared basin			0.101**			
			0.028			
PDSI avg., lagged (target) × shared basin				0.089**		
				0.029		
PDSI avg., three year (sender) × shared basin					0.122**	
					0.037	
PDSI avg., three year (target) × shared basin						0.111**
						0.039
Pct of country 1's area shared in dyad	-0.231	-0.222	-0.212	-0.216	-0.173	-0.187
	0.342	0.341	0.344	0.343	0.349	0.348
Pct of country 2's area shared in dyad	-0.230	-0.199	-0.224	-0.183	-0.192	-0.137
	0.346	0.345	0.348	0.347	0.353	0.353
Shared democracy (each score > 6)	-0.325	-0.309	-0.337	-0.319	-0.329	-0.311
	0.264	0.264	0.263	0.262	0.264	0.265
log of COW capabilities score, initiator	0.257**	0.266**	0.252**	0.258**	0.244**	0.248**
	0.070	0.070	0.071	0.070	0.071	0.071
log of COW capabilities score, target	0.178*	0.180*	0.167*	0.175*	0.159*	0.171*
	0.070	0.073	0.070	0.073	0.071	0.074
Intercept	1.677**	1.751**	1.639*	1.723**	1.520*	1.607*
	0.644	0.661	0.650	0.667	0.662	0.679
χ^2	343.068	356.265	360.762	361.917	354.44	356.992
Log-likelihood	-2713.33	-2706.044	-2669.691	-2665.909	-2620.637	-2616.589
N	12893	12893	12762	12762	12590	12590

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 5.5: Logistic Regression, Effect of Individual-Level Drought on Probability of Violent Militarized Dispute

Variable	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**
	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	-0.059	-0.065	-0.065	-0.065	-0.070	-0.065
	0.144	0.145	0.146	0.147	0.149	0.149
Log of total dyadic trade	-0.254**	-0.259**	-0.257**	-0.264**	-0.251**	-0.258**
	0.038	0.039	0.039	0.039	0.039	0.040
PDSI avg. (sender) $\times$ shared basin	0.045					
	0.029					
PDSI avg. (target) $\times$ shared basin		0.049				
		0.029				
PDSI avg., lagged (sender) $\times$ shared basin			0.080*			
			0.031			
PDSI avg., lagged (target) $\times$ shared basin				0.076*		
				0.033		
PDSI avg., three year (sender) $\times$ shared basin					0.101*	
					0.043	
PDSI avg., three year (target) $\times$ shared basin						0.098*
						0.043
Pct of country 1's area shared in dyad	-0.037	-0.040	-0.006	-0.016	0.028	0.006
	0.376	0.378	0.379	0.380	0.384	0.386
Pct of country 2's area shared in dyad	-0.129	-0.076	-0.105	-0.043	-0.076	-0.013
	0.382	0.378	0.385	0.383	0.392	0.388
Shared democracy (each score > 6)	-0.349	-0.328	-0.355	-0.330	-0.353	-0.328
	0.272	0.272	0.267	0.268	0.267	0.269
log of COW capabilities score, initiator	0.287**	0.288**	0.285**	0.285**	0.276**	0.273**
	0.077	0.077	0.077	0.077	0.078	0.079
log of COW capabilities score, target	0.201**	0.213**	0.195*	0.211**	0.183*	0.202*
	0.076	0.079	0.076	0.079	0.078	0.081
Intercept	1.635*	1.714*	1.609*	1.699*	1.442*	1.545*
	0.678	0.704	0.684	0.711	0.699	0.727
χ^2	269.407	283.24	280.92	290.26	270.907	285.212
Log-likelihood	-2205.28	-2197.386	-2161.489	-2154.749	-2123.098	-2118.567
N	12893	12893	12762	12762	12590	12590

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 5.6: Logistic Regression, Effect of Shared Drought on Probability of Any Militarized Dispute

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
Log of total dyadic trade	-0.234**	-0.233**	-0.233**	-0.234**	-0.234**	-0.233**	-0.235**	-0.235**
	0.035	0.035	0.035	0.035	0.036	0.036	0.035	0.035
PDSI, both states below -1 × shared basin	-0.165							
	0.115							
PDSI, both states below -2 × shared basin		-0.338*						
		0.169						
PDSI, both states below -3 × shared basin			-0.653*					
			0.257					
PDSI, both states below -4 × shared basin				-0.954**				
				0.329				
PDSI, years both states below -1 × shared basin					-0.076**			
					0.024			
PDSI, years both states below -2 × shared basin						-0.206**		
						0.068		
PDSI, years both states below -3 × shared basin							-0.318*	
							0.128	
PDSI, years both states below -4 × shared basin								-0.464**
								0.161
Pct of country 1's area shared in dyad	-0.239	-0.234	-0.241	-0.246	-0.193	-0.210	-0.243	-0.250
	0.336	0.336	0.335	0.336	0.333	0.334	0.335	0.335
Pct of country 2's area shared in dyad	-0.230	-0.227	-0.234	-0.237	-0.185	-0.204	-0.235	-0.240
	0.339	0.338	0.338	0.339	0.337	0.337	0.338	0.338
Shared democracy (each score $>$ 6)	-0.314	-0.320	-0.323	-0.322	-0.339	-0.341	-0.317	-0.320
	0.256	0.256	0.256	0.257	0.257	0.254	0.255	0.256
log of COW capabilities score, initiator	0.261**	0.257**	0.257**	0.260**	0.251**	0.252**	0.257**	0.260**
	0.070	0.070	0.070	0.070	0.069	0.069	0.070	0.070
log of COW capabilities score, target	0.182*	0.179*	0.178*	0.181*	0.174*	0.173*	0.178*	0.182*
	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
Intercept	1.791**	1.741**	1.736**	1.767**	1.686*	1.689*	1.747**	1.777**
	0.660	0.660	0.661	0.661	0.660	0.661	0.660	0.660
χ^2	350.799	362.687	348.499	350.884	355.64	356.667	349.74	350.492
Log-likelihood	-2787.348	-2785.53	-2782.846	-2782.855	-2755.784	-2762.226	-2771.346	-2781.274
N	13088	13088	13088	13088	12974	13026	13066	13088

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 5.7: Logistic Regression, Effect of Shared Drought on Probability of Violent Militarized Dispute

Variable	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
	SE	SE	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	-0.054	-0.054	-0.055	-0.055	-0.055	-0.055	-0.055	-0.055
	0.141	0.140	0.140	0.140	0.140	0.140	0.140	0.140
Log of total dyadic trade	-0.260**	-0.259**	-0.258**	-0.259**	-0.258**	-0.259**	-0.261**	-0.260**
	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
PDSI, both states below -1 × shared basin	-0.070							
	0.122							
PDSI, both states below -2 × shared basin		-0.269						
		0.188						
PDSI, both states below -3 × shared basin			-0.827*					
			0.341					
PDSI, both states below -4 × shared basin				-1.721**				
				0.512				
PDSI, years both states below -1 × shared basin					-0.051*			
					0.025			
PDSI, years both states below -2 × shared basin						-0.178*		
						0.074		
PDSI, years both states below -3 × shared basin							-0.308	
							0.160	
PDSI, years both states below -4 × shared basin								-0.661*
								0.310
Pct of country 1's area shared in dyad	-0.034	-0.026	-0.029	-0.035	0.019	0.002	-0.032	-0.040
	0.371	0.371	0.370	0.371	0.368	0.369	0.371	0.371
Pct of country 2's area shared in dyad	-0.100	-0.090	-0.091	-0.092	-0.049	-0.062	-0.095	-0.097
	0.373	0.373	0.373	0.374	0.372	0.372	0.373	0.373
Shared democracy (each score > 6)	-0.343	-0.348	-0.355	-0.354	-0.360	-0.373	-0.344	-0.351
	0.265	0.265	0.265	0.266	0.262	0.261	0.265	0.265
log of COW capabilities score, initiator	0.294**	0.288**	0.284**	0.286**	0.286**	0.284**	0.287**	0.288**
	0.076	0.076	0.077	0.076	0.076	0.076	0.076	0.076
log of COW capabilities score, target	0.217**	0.212**	0.208**	0.211**	0.209**	0.207**	0.210**	0.212**
	0.078	0.079	0.078	0.078	0.078	0.078	0.078	0.078
Intercept	1.785**	1.730*	1.690*	1.718*	1.680*	1.682*	1.728*	1.738*
	0.689	0.690	0.693	0.692	0.690	0.690	0.690	0.691
χ^2	277.363	282.65	280.833	286.887	281.339	282.836	280.383	280.771
Log-likelihood	-2252.106	-2250.606	-2245.419	-2242.052	-2227.629	-2229.796	-2237.122	-2244.174
N	13088	13088	13088	13088	12974	13026	13066	13088

Significance levels: $*: < 5\%$ $**: < 1\%$

In sum, the models presented below reveal that lower levels of rainfall appear to be a restrictive condition for the incidence of military conflict—worse drought is associated with a reduction in the likelihood of either a violent military event, or any military event between adjacent countries. Greater rainfall appears to be a permissive condition for military conflict, as better soil moisture conditions are associated with a rise in the likelihood of a militarized dispute. This result is counter to the expectations or findings of several authors (Stalley 2003, Klare 2002, among others) and these different findings may be attributable to the higher quality, time-varying drought data. The results of my initial tests are consistent with the expectations of the neo-cornucopians. Both initiator and target states become more likely to experience a MID (either all types, or only violent clashes) as the country-wide rainfall exceeds annual expected levels. This effect strengthens as a country experiences successive years of above-average soil moisture conditions, and strengthens again if the three-year average is above normal.

I review the findings for the various models in detail below. First, I discuss the effects of individual-level drought. Next, I consider the effects of shared drought. Finally, I consider the effect of multi-year shared drought on the probability of conflict. Among non-water covariates, three variables are universally significant: dyadic trade, military power for the initiator state, and military power for the target state. Trade significantly reduces the likelihood of any militarized dispute, violent or not. Higher military capabilities of either the potential attacker or target state are significantly associated with an increased likelihood of the dyad experiencing a violent or non-violent militarized dispute.

5.4.1 Individual-level Drought, Any Militarized Dispute

Recall that the "water wars" hypothesis predicts a negative relationship between the water scarcity variables and the probability of conflict for the models of individual-level drought effects. Water variable coefficients for Table 5.4 show no association between the current year drought level of the potential dispute initiator and the likelihood of a militarized dispute, in cases where both countries are adjacent and share at least one river basin. There is a marginal but significant positive effect on likelihood of conflict when the potential target state has more water than average—or a reduction in the likelihood of conflict when the potential target has *less* water than average—in dyads where the states share one or more river basins. This suggests a failure of the "water wars" hypothesis. For the lagged water variables, both the size of the coefficient and the strength of the significance rise, and for the three-year drought variables, grow larger still.

Further analysis reveals that in addition to being statistically significant, the negative relationship between water scarcity and conflict is substantively meaningful. Table 5.8 reports the predicted change in the probability of a militarized dispute that accompanies a five–unit change (from $+3$ to -2) in the alternative independent variables. A five–unit decrease in the lagged value of the sender's PDSI measure results in a 39% decrease in the likelihood of a militarized dispute in the dyad, all else equal. The model employing the lagged value of the target country's PDSI measure predicts a 35% decrease in the likelihood of a militarized dispute for the same shift in drought conditions. Lastly, the three year drought average levels for states that share a river basin were stronger than either the current-year or lagged-year PDSI levels. The same 5-unit worsening of a drought results in a 46% decrease in the likelihood of a dispute initiated by one state, and a 44% decrease in the likelihood of a much drier state being targeted for a dispute.

Higher levels of trade seem to consistently reduce the likelihood of either state being involved in a military dispute, and the impact is more than double the size of the impact of drought. So while drought is significantly associated with a low likelihood of any military incidents, trade is associated with a stronger suppression of MIDs. In contrast, military capabilities for either state have no significant impact on the initiation of a militarized dispute. The amount of a state's land mass contained in a shared river basin (a potential measure of issue salience) also has no significant impact on the outcome.

5.4.2 Individual-level Drought, Violent Militarized Dispute

The results considering only *violent* militarized disputes are similar to those from the analysis of all militarized disputes. Table 5.5 reveals that current-year drought levels have no significant impact on the likelihood of a violent militarized dispute between adjacent riparians, but that lagged and three-year average PDSI levels are significant and have modest positive effects on the likelihood of a violent clash between states that share a river basin. These findings indicate (again) that the probability of conflict is negatively related to scarcity. Substantive effects are presented in Table 5.8 The influence of drought on initiating states is about the same as for target states, with a PDSI shift of 5 units drier resulting in a 44% decrease in the likelihood of a violent event for initiator or target state. An identical change in the three-year average variable results in a 42% decrease in the likelihood of a violent conflict for the same 5-unit drop in PDSI for either initiator or target.

The impact of individual level drought on the expected likelihood of violent events can be seen graphically in Figure 5.3. The upward trend from left to right shows the increasing chances of violence as the water availability increases from severe drought (large negative numbers) to average levels, and upward into wetter-than-normal conditions. The three-year average, with the largest coefficient, shows a very low chance of violent conflict under severe drought and the highest chance of violence during a very wet year.

Here again, trade provides a statistically significant impact on the expected likelihood of a violent dispute, military capabilities have no impact, and neither does the percent of a state's territory contained in a shared river basin. The analysis of individual-level drought offers no support for H_{1a}.

TABLE 5.8: Changes to Dispute Likelihood Under Individual Drought Conditions

	Violent Militarized Disputes	**All Militarized Disputes**
Drought Variable	**Impact of 5 units drier (e.g., PDSI $+3$ to -2) on the likelihood of conflict**	
lagged PDSI (sender)	44% decrease	39% decrease
lagged PDSI (target)	44% decrease	35% decrease
3-yr. avg. PDSI (sender)	42% decrease	46% decrease
3-yr. avg. PDSI (target)	42% decrease	44% decrease

Percentages come from King, Tomz and Wittenberg's (2000) Clarify package for Stata.

5.4.3 Shared Drought, Any Militarized Dispute

I turn next to the models that consider the effect of shared drought on the probability of militarized conflict. Here, the "water wars" hypothesis predicts a positive relationship between my scarcity measure (the presence of shared drought) and the probability of conflict. As for the models of individual-level drought, the "water wars" hypothesis is not supported by the data. Shared drought variables (all for the current year) in Table 5.6 show significant and strong *negative* effects for shared drought at moderate to severe intensity. These findings again suggest that

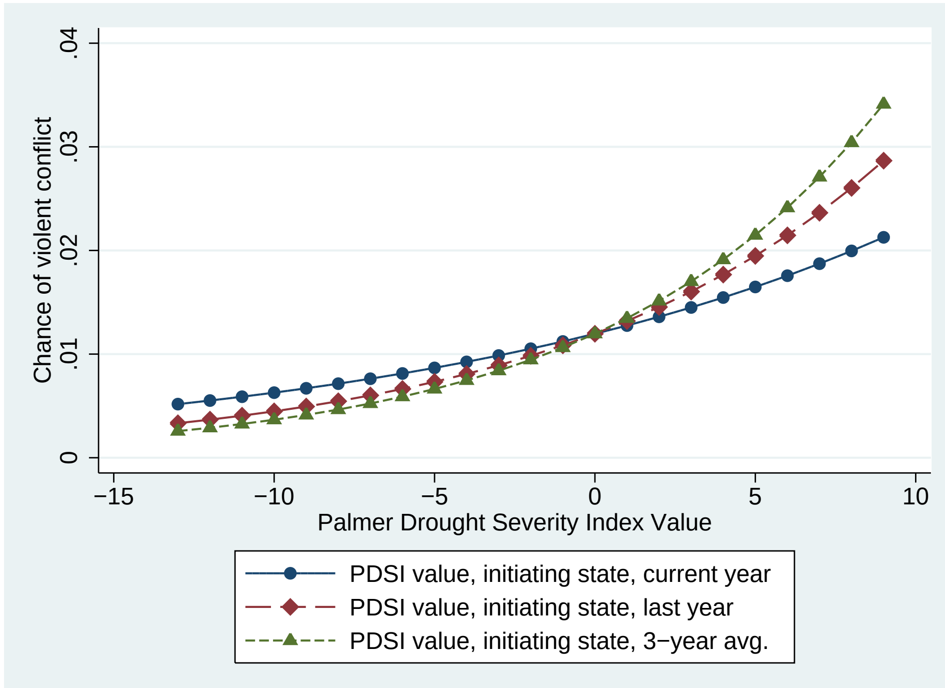

FIGURE 5.3: Effects of drought on the likelihood of military violence. As drought conditions ease (i.e., more rain falls), the likelihood of a state initiating a violent MID increases. This effect is stronger for lagged drought conditions and for the three-year average drought conditions.

conflict is less likely under drought conditions.

Table 5.9 presents substantive effects, reporting the predicted change in the probability of conflict that accompanies a change from a scenario in which a dyad is not experiencing shared drought to one in which they are. For mild shared droughts of PDSI less than -1 for adjacent states that share a river basin, there is no significant change in the likelihood of a militarized dispute. But for increasingly severe shared droughts, *ceteris paribus*, there is a 28% decrease (PDSI < -2), 46% decrease (PDSI < -3) and a 60% decrease (PDSI < -4) in the likelihood of military conflict in the dyad. These increasingly intense associations of shared drought and a *decreased* likelihood of military conflict strongly reject Hypothesis H_{1a} and provide strong support for Hypothesis H_{1b}, showing that states involved in a drought are less likely to initiate military conflict.

5.4.4 Shared Drought, Violent Militarized Dispute

Similar to the impact on all militarized disputes (violent and non-violent), shared drought produces a significant decrease in the likelihood of a militarized violent dispute. Mild and moderate shared drought produces no significant association, but shared PDSI levels of -3 and -4 produce a 54% and 80% decrease, respectively, in the likelihood that two states will clash violently. As shown in Tables 5.7 and 5.9, the large coefficients (-0.827 and -1.721) provide a notable association with the suppression of interstate violence in states sharing a river basin.

TABLE 5.9: Changes to Dispute Likelihood Under Shared Drought Conditions

	Violent Militarized Disputes	**All Militarized Disputes**
Dichotomous Shared Drought Variable	**Impact of shared scarcity at a given level on the likelihood of conflict**	
PDSI < -1	no change	no change
PDSI < -2	no change	28% decrease
PDSI < -3	54% decrease	46% decrease
PDSI < -4	80% decrease	60% decrease

Percentages come from King, Tomz and Wittenberg's (2000) Clarify package for Stata.

5.4.5 Shared, Consecutive Multi-year Drought, Any Militarized Dispute

Shared droughts that persist for more than one consecutive year in a contiguous dyad also produce significant negative results, increasing in magnitude as the shared droughts become more severe. Also from Tables 5.6 and 5.10, one can see that there is a significant coefficient for a mild shared multi-year drought of PDSI < -1, but with a negligible substantive impact. As before in the single-year shared drought variables, greater intensity of drought follows increasingly large substantive associations with the likelihood of a military dispute: each year of shared drought at -2 yields a 12% decrease in the likelihood of a militarized dispute, a 22% decrease at -3, and at -4, a 34% decrease. Consecutive years of drought are associated with a very strong negative impact on the likelihood of militarized conflict.

5.4.6 Shared, Consecutive Multi-year Drought, Violent Militarized Dispute

As before, the relation of a drought's duration to the associated reduction in the likelihood of either kind of MID is also related to the strength of the drought: stronger droughts are associated with a stronger suppression of military conflict, and the effect is cumulative for each additional year of drought. All else being equal, a mild shared drought produces only a very small decrease in the expected likelihood of a violent event, but each year of shared drought at -2 produces a 12% decrease, each year at -3 sees a 22% decrease, and each year at a PDSI of -4 or less produces a 34% decrease in the expected likelihood of a violent military dispute. These results are shown graphically in figure 5.4. The small, nearly negligible effects of a mild shared multi-year drought are the top line (with circles as the line marker). The stronger droughts are also shown, with a shared drought at -2 or lower resulting in the chance of a violent event dropping to about half by the third year, and drop below 0.005 at the fifth consecutive year of drought. For a worse drought (PDSI less than < -3), the impact is more dramatic. The chance of violence drops to about half by the second year, and drops below 0.005 by the third year. As with the other tests in this chapter, Hypothesis H_{1a} has no support: instead, the results show a strong, opposite outcome from the outcomes predicted by H_{1a}. Water scarcity is significantly associated with less military conflict.

As the democratic peace literature suggests, an increase in trade (or rather, an increase in the log of dyadic trade) is again associated with a decrease in the incidence of conflict. As before, greater military capabilities in either country increase the likelihood of a militarized dispute.

TABLE 5.10: Changes to Dispute Likelihood Under Shared Multi-Year Drought Conditions

	Violent Militarized Disputes	**All Militarized Disputes**
Years of Shared Drought Variable	**Impact of shared scarcity for each year at a given level on the likelihood of conflict**	
PDSI < -1	negligible decrease	negligible decrease
PDSI < -2	10% decrease	12% decrease
PDSI < -3	22% decrease	22% decrease
PDSI < -4	43% decrease	34% decrease

Percentages come from King, Tomz and Wittenberg's (2000) Clarify package for Stata.

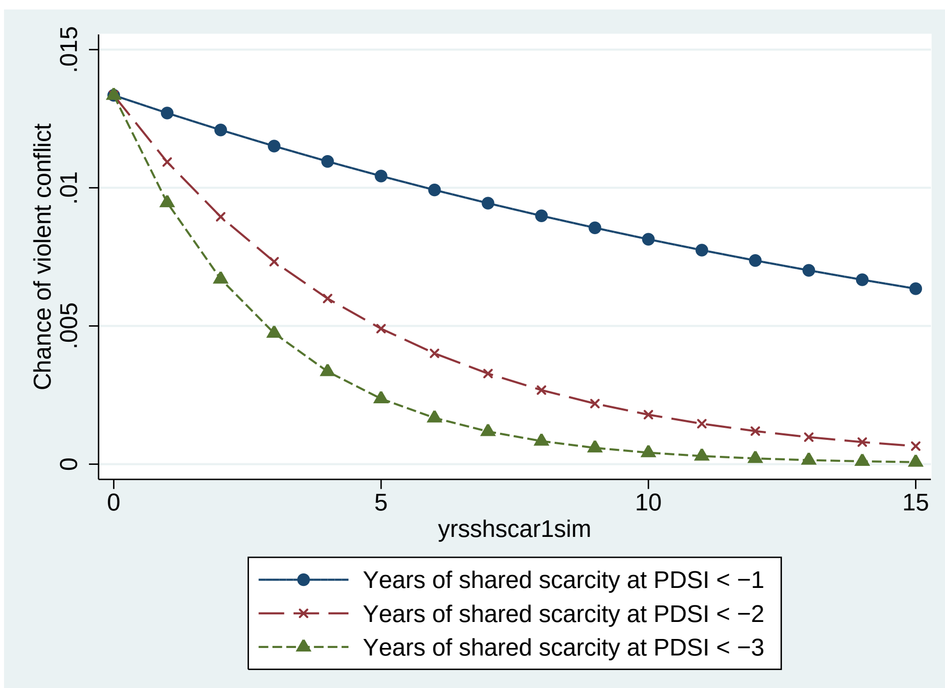

FIGURE 5.4: Effects of shared drought on the likelihood of military violence. The likelihood of a violent MID decreases for each year the pair of states share a given level of drought. This effect increases as the shared drought becomes more severe.

5.5 Discussion

Drought is associated with a significant decline in the likelihood of all types of militarized conflict between states, and shared drought is associated with an even stronger reduction in the likelihood of all kinds of militarized interstate disputes. The analysis here suggests that even short-term shared droughts are strongly associated with a steep decline in the likelihood of military conflict between adjacent states. States therefore appear to 'retire to their corners' during drought years, perhaps because of changing internal priorities brought on by the drought. During years that both riparian partners have significant drought, the chance of a MID drops sharply, including violent MIDs. Additionally, multiple years of drought are significantly associated with a reduction in the chance of violent MIDs. After three or four years of a shared drought at $PDSI = -2$ or drier, the chance of a violent military conflict is cut in half. Similarly, the chance of a violent military conflict falls to half its initial level after only *two* years of both countries experiencing a PDSI level of -3 or drier.

The tests in this chapter reveal a marked lack of support for the water-wars hypothesis, H_{1a}, as I and others have defined them. The results are consistent with the opposite of the realist / lateral pressure / malthusian expectations, showing support for water scarcity leading to *less* conflict, violent or otherwise, among neighbors from 1948–2001. Using multiple data sets and methods of analysis, I find that drought is associated with a strong reduction in the likelihood of violent conflict, and a reduction in the amount and/or intensity of conflict. In a very limited fashion, some of the individual-level results could, taken by themselves, provide support for the neomalthusian predictions: since a higher level of soil moisture (lower level of drought) increases the chance of militarized disputes for the *target* state, this could be taken as evidence that more water makes a state more likely to be targeted for attack. However, because the connection between drought and conflict initiation are stronger for initiating states, and because shared drought is associated with a reduction in the likelihood of a militarized dispute, the aggregate results more consistently support the cornucopian predictions.

Because the initiating state tends away from military conflict during droughts, it therefore tends towards conflict and/or violence during wetter times. But this is also true for the target states. The data show that under shared drought, the two contiguous states are far less likely to experience a violent or military event. Perhaps the initiator does not want to provoke a target state when it is obvious that both states have drought conditions and domestic issues are pressing more urgently on the government. Perhaps when both countries have wetter conditions (within reason), the economies improve, and adventurism becomes more likely.

On the other hand, when an initiating state has totally normal precipitation and soil moisture conditions, and its neighbor has a wetter-than-normal weather pattern, the coefficients indicate that a relatively dry state is still more likely to initiate a violent event against its neighbor. This situation could be seen, in isolation, as evidence in favor of the malthusian argument. However, the reverse of this situation—a relatively wet state invading a state that has average moisture conditions—is equally possible, and provides evidence exactly the opposite of the malthusian argument: a state, wetter than normal, has no impetus to incite a conflict with a neighboring state *just because* the potential target has less water than normal. Recall from Chapter 3 that a state that has any excess water under normal conditions is likely to have that water in use. But a state experiencing wetter than normal weather *did not plan* to have that water. This surplus would provide a windfall to the water-using industries and alleviate the pressure to look across the border for more water. So while some specific situations could appear to support the malthusians, the opposite of that situation seems implausible.

Among non-water covariates, dyadic trade reduces the likelihood of conflicts, and more strongly reduces the likelihood of violent events. This finding reinforces numerous studies linking trade to the liberal peace. Trade is also important in terms of water because it allows states to trade for 'virtual water' such as grain or steel, instead of using local water resources to produce these goods. Military power covariates consistently show statistically significant association with an increased likelihood of involvement in a militarized or violent dispute, whether the state is sender or target in the dispute. Without claiming either state is more belligerent *because* of its military capabilities, it is clear that having military power increases the likelihood that it will use it. Because the COW military capabilities index uses both total and urban population as portions of the overall composite measure, it is possible that military power is a potential proxy for "the need for additional resources coupled with the ability to take it." Population measures are fairly strongly correlated with the COW military capabilities index, producing multicollinarity issues when regressed together, and so I do not separately include them here.[8]

My findings complement those of Wolf, Yoffe and Giordano (2003), who find that "most of the parameters commonly identified as indicators of water conflict are actually only weakly linked to dispute," and Yoffe, Wolf and Giordano (2003), who find that, for water-specific events, "most of the commonly cited indicators linking freshwater to conflict proved unsupported by the data. Spatial proximity, government type, climate, basin water stress, dams and infrastructure develop-

[8]The natural log of a country's population is correlated with the natural log of its COW military capabilities index at around 0.8.

ment, and dependence on freshwater resources for agricultural or energy needs showed no significant association with conflict over freshwater resources." Some of their results are inconsistent with more general analyses in political science like Vasquez (1995), who examines the empirical regularity that spatial proximity *does* lead to a greater instance of conflict. Violent water conflict is not unheard of (Wolf and Hamner 2000, Yoffe et al. 2004), and Yoffe et al. (2004) find some support for an increase in international conflict as "the average precipitation within a basin decreases or the variability of precipitation or [river] discharge increases" but my results show that the influence of exogenous water scarcity on the incidence of conflict is probably suppressive rather than permissive or sufficient. This finding is new, and previously unseen in the literature.

The results in this chapter suggest that violence is not used to divide or establish the provision of water resources between states, although nonviolent coercion, economic pressure, or threats could be used and yet would not show up in these results. These results directly contradict some of the existing literature using other data sets to codify water stress. The results in my analyses generally support the expectations of the neoliberal scholars and explicitly contradict the expectations of the realists/malthusians. These results draw on a broad set of dependent variables and independent variables, unlike the current state of resource conflict research. Using these new data I find robust results that do more than fail to support the realist theories—these results actively contradict the "water wars" hypotheses. Overall, it appears that extra water in the country's water budget allow a free hand for expansionist/revisionist behavior, whereas drought at least encourages countries to look inward and become less belligerent, and, at the limits, is strongly associated with a suppression of interstate military and/or violent conflict.

In Chapters 6, 7 and 8, I will examine the possibility that conflict and cooperation outcomes occur independently of each other: in other words, can water scarcity have independent effects on violence, conflict and cooperation? The next chapter examines conflict using events data instead of the military disputes data from the Correlates of War, and different statistical models. The possibility exists that even absent military coercion or violence, conflict arises as a result of water scarcity, or that conflicts fester or become more numerous during droughts.

Chapter 6

Drought and Costly International Conflict

> Any water war could spark a general war, with a heavy price in blood, as well as billions of dollars of expense—which might have been used to construct desalination plants. The conclusion is clear: For economic, social, and political reasons, it is not worthwhile launching such a water war.
>
> *Arnon Soffer, 1999*

In this chapter, I continue my examination of the effect of freshwater scarcity on the probability of international conflict. Rather than looking exclusively at military conflicts (as in the last chapter), I now expand the scope of conflict to include political conflict events and the aggregate levels of conflict between adjacent countries in a given dyad. This chapter tests Hypothesis H_2, which proposes that drought may affect the probability of costly international conflict that does not rise to the level of military action or violence (although the conflict could include such actions). Rather than looking at the military and violent interstate events alone, it is possible that interstate relations between countries are improved or worsened in the grip of a water crisis, even if the relations fall short of violence or all-out military confrontation. So, while violence over water may be rare, conflict short of violence may increase or decrease in response to freshwater scarcity. This scarcity may the *number* of conflictual acts between countries or the average *intensity* of conflictual acts. If water shortages (here, expressed as drought) cause a decrease in the level of costly conflict, the tests in this chapter will reveal support for the second set of hypotheses in the dissertation:

> H_2: *A state experiencing a period of acute scarcity involving a shared water resource experiences a* **decrease in the level of conflict** *it initiates, compared to a state sharing a water resource that is not experiencing scarcity.*
>
> > H_{2a}: *A state experiencing a period of acute scarcity involving a shared water resource initiates* **fewer conflictual events** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*
> >
> > H_{2b}: *A state experiencing a period of acute scarcity involving a shared water resource initiates* **a lower overall intensity of conflict** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*

These hypotheses are theoretically very similar to the hypotheses in Chapter 5, in that the mechanisms that may cause the violence or conflict remain the same. The difference is that the level of conflict need not reach an interstate military encounter to still establish the power of water scarcity to cause, worsen, or catalyze interstate conflict that might escalate to war. If water scarcity is associated with lower levels of conflict, interstate relations might worsen such that a more violent conflict erupts. Or, water scarcity might cause greater demands and threats between states such that the threats escalate into violence. However, my theoretical expectations suggest that scarce water and conflict are, as before, *less* likely to be associated with each other, or *negatively* associated, meaning that scarce water would be linked to a reduction of violent or conflictual acts, and/or the intensity of those acts.

I use two methods to test Hypothesis H_2. First, I use a negative binomial count model to examine the overall count of costly conflictual events. Second, I examine the relative *intensity* of conflict in a given pair of adjacent countries. Each event may be nearly meaningless, or may be very costly and intense for the state initiating that action. Whether the number of conflictual events rises or falls, the relative intensity of those conflictual events may offer a different story than merely examining the number of events. In two of the three data sets, I find that the number of conflict events is unchanged by drought levels. Where water is associated with conflict, I find that a rise in the number of conflictual events is linked to *greater* water availability, rather than *lower* water availability.

6.1 Events Data

To examine Hypotheses H_2, H_{2a}, and H_{2b}, I use three sets of *events* data. The events data come from the Conflict and Peace Data Bank (COPDAB) project (Azar 1980), the Project to Assess Nonviolent Direct Action (PANDA) (Bond and Bond 1995, Bond et al. 1997) and the Integrated Data for Events Analysis (IDEA) project (King and Lowe 2003, Bond et al. 2003). Events data (COPDAB, PANDA and IDEA) provide a different type of conflict data than the data on militarized interstate disputes employed in the Chapter 5 analyses. They provide militarized and non-militarized conflict data that allow observers to detect smaller variations in interstate conflict. Not all conflict occurs at the military level; some conflict remains the domain of diplomacy and economics. MID does not report economic conflict; an increase in insults, condemnation, and (e.g.) expulsion of diplomats, while notable and even costly, are also unavailable as a measure of 'conflict' in the MID data. Events data offer a finer-grained measure of how states get along. These data sets are summarized in Table 6.1 and 6.2.

Goldstein (1992) produced a weighting scheme for events following McClelland's (1972) World Events Interaction Survey format. This weighting scheme makes it possible to assign greater and lesser impacts to specific events, such as economic or political union (a large positive number) and all-out war (a large negative number). Later events data collection efforts such as PANDA and its successor, IDEA, have adopted and extended the WEIS coding scheme. The COPDAB data scale is only positive, unlike the WEIS scale, and I follow the Basins at Risk project (Wolf, Yoffe and Giordano 2003, Yoffe, Wolf and Giordano 2003) in re-centering the scale with positive numbers representing cooperative events, neutral events at zero, and conflictual events represented as negative numbers.

TABLE 6.1: Conflict Events Data Sets

Data Set	**Acronym**	**Time Period**	**Observation**
Conflict and Peace Data Bank	COPDAB	1948–1978	political or military events at the interstate level
Political And Nonviolent Direct Action	PANDA	1984–1994	political or military events at the interstate level
Integrated Data Event Analysis	IDEA	1990–2001	political or military events at the interstate level

Note: these data sets also include intrastate observations, but these observations are not included in the interstate-only data used for this chapter's analyses.

6.1.1 Dependent Variables

I use events data to make several dependent variables, split into two types: first, the *count* of the events of a given type; second, the *weight*, or *average intensity* of those events. Event counts relate the number of specific, discrete interactions—

the number of specifically conflictual, or violent, or cooperative acts. Event weights or averages allow me to examine the tone and intensity of overall relations, or of groups of specifically conflictual, or violent, or cooperative relations. Breaking the event types into several categories provides greater resolution on interstate relations, since (as seen in Chapter 5) the absence of a violent interaction does not mean that interstate relations are good or even neutral, only that they are non-violent. Further, conflict may exist without great costs being incurred by either side. Similarly, cooperation may not exist in great amounts, but it may be concurrent with conflict in the same dyad, under the same conditions. In this chapter, only conflictual events are examined. Cooperative events and overall averages of events are examined in Chapters 7 and 8.

One potentially confusing issue with these events data lies in the interpretation of the coefficients. For event count models, a negative coefficient indicates that an increase in an independent variable is associated with a decline in conflict events. Conversely, a positive coefficient for a given independent variable means that as that variable is positive and grows larger, the number of expected conflict events will increase. For the models predicting the frequency of conflict events below, Hypothesis 2 predicts that the coefficients for the individual-level drought variables will be positive, while the coefficients for the shared drought variables will be negative. Recall that the individual-level water scarcity variables (Palmer Drought Severity Index measures increase as drought conditions become *less* severe. Increasing values of these variables, then, should be associated with increased numbers of conflict events. Conversely, the shared drought measure takes on a value of 0 in the absence of a shared drought and a value of 1 when the countries in a dyad are experiencing a shared drought. If shared drought leads to a decrease in the number of conflict events, the coefficients for the shared drought variables in the event count models will be negative.

The predicted signs on the coefficients are reversed for the models predicting conflict intensity. Because conflict is generally considered negative, the Goldstein weights place a negative weight on conflict events. The more intense the conflict, the larger the negative value. Coefficients with a negative value indicate that as the independent variable is positive and grows larger, conflict will become more intense. A negative value does not indicate that a variable is associated with a *decline* in conflict. Hypothesis 2 predicts that as the value of the individual-level drought variables increase (drought becomes less severe) the intensity of conflict should increase. That is, the dependent variable should become more negative. Accordingly, I expect the individual-level drought variables to be signed negatively in the models of conflict intensity below. Conversely, the shared drought variables should have positive coefficients.

TABLE 6.2: Conflict Events and Intensity Variables

Dataset	**Variable**	**Obs.**	μ	σ	**Min.**	**Max.**
COPDAB[1] 1948–1978	Conflict events	7989	0.928	8.121	0	450
	Weighted conflict sum	7989	-7.106	75.68	-4323	0
	Violent events	7989	0.614	7.785	0	450
	Weighted violence sum	7989	-4.395	72.474	-4322	0
PANDA 1984–1994	Conflict events	1957	3.75	10.304	0	146
	Weighted conflict sum	1957	-13.322	47.338	-716	0
	Violent events	1957	0.789	3.801	0	65
	Weighted violence sum	1957	-7.549	36.979	-640	0
IDEA 1990–2004	Conflict events	5476	0.551	2.499	0	60
	Weighted conflict sum	5476	-10.234	30.843	-844	0
	Violent events	5476	0.464	2.045	0	56
	Weighted violence sum	5476	-4.267	19.458	-539	0

[1]Note that the COPDAB event intensity scale is not directly comparable to the WEIS coding scheme used by the IDEA and PANDA data.

6.2 Unit of Analysis

The data are again in directed dyads—adjacent country pairs with each state listed once as the initiator, and once as the target, for each year. Outside observers record the events taking place within the two-country pair. These events are aggregated two ways: a *count* of events of a given type, without consideration for the event's level of intensity; and a *weighted sum* of event intensities–each event is multiplied by an intensity weight describing the intensity of interaction the event represents; the weighted number is then added to the whole. Large negative numbers indicate intense conflict (or an enormous number of minor conflicts), whereas small negative numbers (i.e. close to zero) indicate minor conflicts, small disputes, or even diplomatic gaffes. Very small conflicts are not included in the weighted term; only significant conflictual events are included in the weighted average term.

6.3 Methodology

Two methods were used to analyze the conflictual events data. For the event counts, a negative binomial (event-count) regression is used to estimate the change in the expected *number of events* associated with changing covariates. For the *event intensity averages*, a form of ordinary least squares (OLS) linear regression is used to estimate the intensity of dyadic hostility associated with variation in the data.

6.3.1 Methodology, Count Models

A standard count model analysis tool, Poisson regression, is unusable for these count models because I expect the occurrence of one event to influence the expected number of subsequent events (King 1989, 48–49, 51), a process known as *contagion*. I expect countries that have multiple cooperative or conflictual events are likely to experience contagion, yielding more of either type of events—and possibly more of *any* type of event. Further, because of the negative binomial's ability to handle overdispersion in the model (where the dispersion is greater than the mean), it is a more robust choice for analyzing count models.

6.3.2 Methodology, Linear Models

Each directed dyadic event's intensity was averaged, then summed by year. As mentioned before, these dyads are directional, meaning state 'a' is the initiator and the target in the dyad once per time period, and so also with state 'b.' Analyzing continuous variables with expected values away from the maximum or minimum value of the dependent variable is fairly robust with ordinary least squares (OLS) linear regression and its variants.

It is possible and even likely that the dependent variables are influenced by the levels of the previous year or years. Instead of using a series of time dummy variables, as in Chapter 5, I use cross-sectional time-series OLS, with an autoregressive component of AR(1). An autoregressive component means that I expect the activities of the previous year's dependent variable to influence the current year's interaction. Because I choose AR(1), I therefore do not expect the dependent variable from *two* previous years or earlier to have a statistically significant impact on the relations for the current year. In the dependent variable, the levels of hostility are linear and continuous. The event weighting schemes avoid the need for logarithmic scaling to account for more-intense events. Examining the graph of event conflict intensities versus drought levels (Figure 6.1) reveals that the events are approximately normally distributed and not skewed. This further suggests the appropriateness of the linear model.

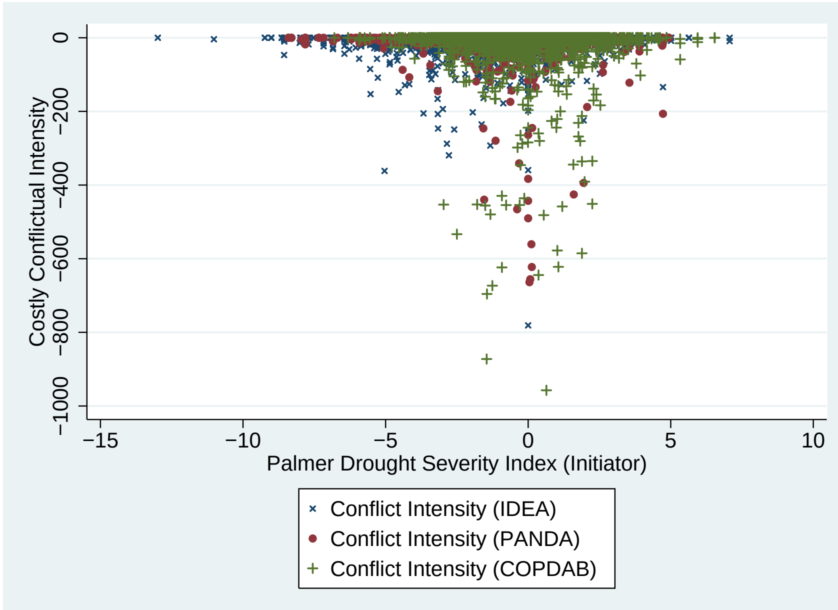

FIGURE 6.1: Graph of conflict intensity versus drought level. If drought had an obvious positive impact on international conflict, the overall shape of the scatterplot would tend to the left, as conflict became more intense with a worsening drought. In this graph, no such relationship is evident.

6.4 Water Variables and Covariates

All tests in this dissertation use similar covariates and water variables. This consistency avoids concerns of using preferred data to achieve results one way or another. As before, I use individual-level drought measures, both for the event's source and target, and shared drought dummy measures if both states are below a numeric threshold for drought in a given year. Lastly, I again use duration variables, reflecting how long a given state pair has experienced a given level of drought. The non-water covariates from Chapter 5 are shown in Table 6.3.

6.5 Results

Visual observation of Figures 6.1 and 6.2 (which show the distributions of the dependent variables) reveals no obvious tendencies or association with regard to

TABLE 6.3: Non-water Covariates Used in Statistical Models

Variable	**Description**
Difference in development	Difference in the logged real (constant value) GDP per capita of each state
Trade	Log of the sum of all trade between the two states in the dyad
Military capabilities (initiator)	Logged COW military capabilities score for the initiating state
Military capabilities (target)	Logged COW military capabilities score for the target state
Shared Democracy	Dummy variable, equal to one if both states have a Polity IV $democracy - autocracy$ score of 6 or higher, zero otherwise

the level of drought. If drought were consistently associated with a more severe conflict or a larger number of conflictual events in the dyad, these graphs would look less like bell curves and more observations under drought conditions would appear more often to the left of PDSI = 0. The analyses below identify a negative relationship between scarcity and the frequency of conflict events for the COPDAB data, but this association does not extend to the other two data sets. None of the analyses identify a significant relationship between freshwater scarcity and the intensity of conflict. I review the findings in detail below, by data source. The effects of military power and trade are consistent across all models. Trade is universally associated with a reduction in conflict (events or aggregate intensity), whereas military capabilities of either the sender or target are significantly linked to more conflict events or a greater intensity of those events.

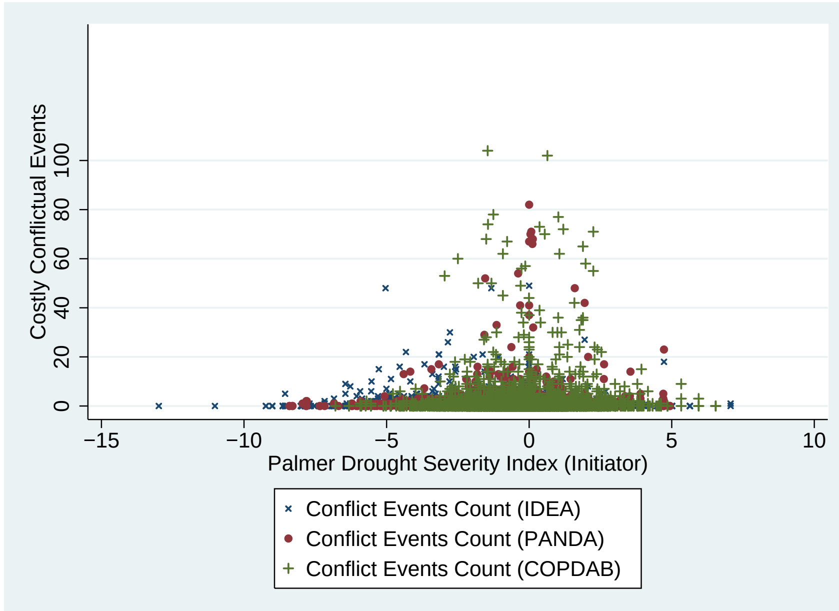

FIGURE 6.2: Graph of costly conflictual events versus drought level. If drought had a significant impact on international conflict, the overall shape of the scatterplot would tend to the left, as conflict became more common with a worsening drought. In this graph, no such relationship is evident.

6.5.1 COPDAB data

The results of COPDAB analyses are found in Tables 6.4, 6.5, 6.6, and 6.7. Table 6.4 presents the analysis of the effects of the individual-level drought variables on the frequency of conflict events. Table 6.5 reports the analysis of shared drought on the frequency of conflict events. Tables 6.6 and 6.7 report the analyses of the effects of individual and shared drought variables (respectively) on the intensity of conflict. Consistent with the results from the MID data, the events data for adjacent countries from 1948–1978 show a strong association with a *lessening* of violent and nonviolent conflict during periods of individual-level drought, as evidenced by the positive and statistically significant coefficients for the water variables in Table 6.4. The effect is the same for either sender or target for each individual-level drought variable Figure 6.3 graphically illustrates this effect—more severe drought conditions are associated with a decrease in the number of conflict events experienced in a dyad.

The analysis of shared droughts conditions (presented in Table 6.5) reveals a similar pattern. As predicted by Hypothesis 2, the coefficient for shared drought at PDSI levels of -1 is negative and significant indicating that for mild shared droughts there is a decrease in the expected number of conflict events. A change from conditions of no shared drought to a current-year shared drought results in a drop in the number of predicted conflict events from 0.314 to 0.203 per year, a drop of about one-third. For consecutive years of drought at PDSI < -1, there is also a drop of about one-third per year: at zero years of consecutive drought (the reference condition), the expected number of conflict events is 0.308; after three years of drought, it drops to 0.099, and after six years, to 0.032 expected costly conflictual events per year. These findings support Hypotheses H_2, and H_{2a}.

In the event count models, the non-water variables perform as expected. Trade is associated with a reduction in the number of conflictual events and violent events. Joint democracy is associated with a significant reduction in the number of conflict events in the dyad. Greater military capabilities of either the initiator or the target are associated with an increase in the expected count of conflict events in the COPDAB data.

The linear regression results for COPDAB's intensity of conflict measures (presented in Tables 6.6 and 6.7) show no significant association with the water scarcity variables. But as in the event count models, dyadic trade is associated with a significant decrease in the intensity of conflict—conflict events have a negative weight, so the positive coefficients for trade (between 0.95 and 1.6) means that trade works to increase the negative aggregate values of conflict back towards zero. The negative, significant coefficients of the COW capabilities scores (ranging from -1.04 to -1.94 on either Table 6.6 or 6.7) indicate that an increase in military capabilities for either the sender or target state *does* contribute to an increase in the aggregate intensity of conflict.

TABLE 6.4: Negative Binomial Regression, Effect of Individual-Level Drought on Number of Conflict Events, COPDAB

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	0.070	0.090	0.066	0.106	0.054	0.098
	0.113	0.114	0.119	0.120	0.121	0.122
Log of total dyadic trade	-0.164**	-0.168**	-0.128**	-0.111**	-0.127**	-0.105*
	0.041	0.044	0.046	0.041	0.048	0.043
PDSI avg. (sender) $\times$ shared basin	0.110*					
	0.049					
PDSI avg. (target) $\times$ shared basin		0.111*				
		0.049				
PDSI avg., lagged (sender) $\times$ shared basin			0.095*			
			0.044			
PDSI avg., lagged (target) $\times$ shared basin				0.097*		
				0.043		
PDSI avg., three year (sender) $\times$ shared basin					0.161*	
					0.068	
PDSI avg., three year (target) $\times$ shared basin						0.163**
						0.063
Pct of country 1's area shared in dyad	-0.245	-0.281	-0.246	-0.131	-0.148	-0.011
	0.391	0.407	0.398	0.400	0.409	0.409
Pct of country 2's area shared in dyad	-0.842*	-0.854*	-0.667	-0.692	-0.516	-0.560
	0.400	0.388	0.385	0.367	0.396	0.376
Shared democracy (each score $>$ 6)	-0.632*	-0.588*	-0.980**	-1.041**	-0.957**	-1.062**
	0.253	0.282	0.243	0.239	0.253	0.241
log of COW capabilities score, initiator	0.292**	0.258**	0.301**	0.197**	0.286**	0.164*
	0.097	0.076	0.101	0.075	0.104	0.075
log of COW capabilities score, target	0.182**	0.209*	0.161*	0.237**	0.174*	0.261**
	0.070	0.084	0.067	0.088	0.068	0.089
Intercept	2.174**	2.169**	2.136**	2.109**	2.111**	2.077**
	0.100	0.101	0.105	0.103	0.111	0.108
χ^2	53.428	58.877	75.728	77.156	75.687	84.488
Log-likelihood	-2632.676	-2634.764	-2565.325	-2560.422	-2494.93	-2487.569
N	4037	4037	4006	4006	3970	3970

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.5: Negative Binomial Regression, Effect of Shared Drought on Number of Conflict Events, COPDAB

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	0.072	0.076	0.078	0.078	0.087	0.085	0.078	0.078
	0.117	0.118	0.117	0.118	0.118	0.118	0.118	0.118
Log of total dyadic trade	-0.158**	-0.156**	-0.158**	-0.157**	-0.150**	-0.146**	-0.157**	-0.157**
	0.040	0.040	0.040	0.040	0.041	0.041	0.040	0.040
PDSI, both states below -1 × shared basin	-0.435*							
	0.189							
PDSI, both states below -2 × shared basin		-0.588						
		0.348						
PDSI, both states below -3 × shared basin			-0.657					
			0.383					
PDSI, both states below -4 × shared basin				-0.501				
				0.478				
PDSI, years both states below -1 × shared basin					-0.380**			
					0.102			
PDSI, years both states below -2 × shared basin						-0.334		
						0.196		
PDSI, years both states below -3 × shared basin							-0.130	
							0.224	
PDSI, years both states below -4 × shared basin								-0.268
								0.464
Pct of country 1's area shared in dyad	-0.227	-0.217	-0.228	-0.229	-0.079	-0.125	-0.228	-0.229
	0.387	0.391	0.394	0.396	0.380	0.389	0.395	0.396
Pct of country 2's area shared in dyad	-0.774*	-0.785*	-0.793*	-0.797*	-0.586	-0.671	-0.796*	-0.797*
	0.379	0.385	0.388	0.389	0.364	0.373	0.389	0.390
Shared democracy (each score > 6)	-0.713**	-0.706**	-0.706**	-0.710**	-0.877**	-0.914**	-0.709**	-0.710**
	0.227	0.227	0.228	0.229	0.205	0.206	0.229	0.229
log of COW capabilities score, initiator	0.288**	0.288**	0.292**	0.295**	0.274**	0.292**	0.295**	0.295**
	0.093	0.095	0.095	0.095	0.099	0.098	0.095	0.095
log of COW capabilities score, target	0.201*	0.204*	0.206*	0.207*	0.220**	0.226**	0.208*	0.208*
	0.083	0.084	0.084	0.085	0.082	0.083	0.085	0.085
Intercept	2.183**	2.187**	2.190**	2.192**	2.140**	2.167**	2.192**	2.192**
	0.097	0.097	0.098	0.098	0.097	0.098	0.098	0.098
χ^2	70.022	60.798	65.044	61.036	93.960	79.371	60.323	58.873
Log-likelihood	-2715.624	-2717.481	-2718.704	-2719.364	-2674.885	-2697.917	-2719.469	-2719.481
N	4085	4085	4085	4085	4072	4083	4085	4085

Significance levels: $* : < 5\%$ $** : < 1\%$

TABLE 6.6: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Individual-Level Drought on Conflict Intensity, COPDAB

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	-0.060	-0.085	-0.092	-0.228	-0.039	-0.196
	0.687	0.708	0.631	0.517	0.630	0.512
Log of total dyadic trade	1.608**	1.589**	1.281**	0.954**	1.279**	0.946**
	0.248	0.244	0.228	0.183	0.227	0.181
PDSI avg. (sender) × shared basin	-0.329					
	0.264					
PDSI avg. (target) × shared basin		-0.166				
		0.249				
PDSI avg., lagged (sender) × shared basin			-0.332			
			0.241			
PDSI avg., lagged (target) × shared basin				-0.285		
				0.188		
PDSI avg., three year (sender) × shared basin					-0.425	
					0.315	
PDSI avg., three year (target) × shared basin						-0.363
						0.246
Pct of country 1's area shared in dyad	-0.472	-0.440	0.005	-0.050	-0.182	-0.310
	1.855	1.933	1.706	1.404	1.708	1.397
Pct of country 2's area shared in dyad	3.504	3.514	2.569	1.738	2.219	1.429
	1.855	1.930	1.706	1.401	1.706	1.394
Shared democracy (each score > 6)	-2.710	-3.222*	-0.782	0.429	-0.912	0.351
	1.543	1.554	1.427	1.158	1.426	1.147
log of COW capabilities score, initiator	-1.936**	-1.936**	-1.713**	-1.109**	-1.664**	-1.044**
	0.407	0.427	0.375	0.312	0.375	0.310
log of COW capabilities score, target	-1.211**	-1.235**	-1.061**	-1.248**	-1.082**	-1.285**
	0.411	0.424	0.379	0.308	0.380	0.307
Intercept	-28.527**	-28.603**	-25.100**	-21.228**	-24.564**	-20.669**
	3.430	3.521	3.156	2.577	3.155	2.558
χ^2	65.714	64.767	55.468	56.802	53.919	56.077
N	4037	4037	4006	4006	3970	3970

Significance levels: $*$: < 5% $**$: < 1%

TABLE 6.7: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Shared Drought on Conflict Intensity, COPDAB

Variable	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
	SE	SE	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	-0.088	-0.088	-0.088	-0.088	-0.170	-0.148	-0.088	-0.088
	0.704	0.704	0.704	0.705	0.694	0.694	0.705	0.705
Log of total dyadic trade	1.545**	1.529**	1.528**	1.528**	1.506**	1.486**	1.529**	1.528**
	0.249	0.249	0.249	0.249	0.246	0.246	0.249	0.249
PDSI, both states below -1 × shared basin	1.304							
	1.081							
PDSI, both states below -2 × shared basin		0.515						
		1.828						
PDSI, both states below -3 × shared basin			0.107					
			2.958					
PDSI, both states below -4 × shared basin				-0.348				
				4.723				
PDSI, years both states below -1 × shared basin					0.599			
					0.503			
PDSI, years both states below -2 × shared basin						0.138		
						1.046		
PDSI, years both states below -3 × shared basin							-0.292	
							2.076	
PDSI, years both states below -4 × shared basin								-0.163
								3.997
Pct of country 1's area shared in dyad	-0.516	-0.472	-0.472	-0.471	-0.743	-0.581	-0.471	-0.472
	1.919	1.920	1.920	1.921	1.895	1.891	1.921	1.921
Pct of country 2's area shared in dyad	3.114	3.169	3.172	3.174	2.442	2.639	3.175	3.173
	1.918	1.918	1.919	1.919	1.894	1.889	1.919	1.919
Shared democracy (each score > 6)	-2.398	-2.347	-2.332	-2.333	-1.836	-1.636	-2.331	-2.332
	1.569	1.570	1.569	1.569	1.553	1.552	1.569	1.569
log of COW capabilities score, initiator	-1.901**	-1.922**	-1.929**	-1.930**	-1.812**	-1.855**	-1.932**	-1.930**
	0.421	0.421	0.421	0.421	0.416	0.415	0.421	0.421
log of COW capabilities score, target	-1.256**	-1.278**	-1.285**	-1.286**	-1.383**	-1.406**	-1.288**	-1.286**
	0.421	0.421	0.421	0.421	0.417	0.416	0.421	0.421
Intercept	-28.488**	-28.552**	-28.611**	-28.625**	-28.147**	-28.560**	-28.646**	-28.620**
	3.470	3.478	3.475	3.473	3.426	3.428	3.478	3.472
χ^2	63.188	61.779	61.66	61.649	62.935	62.019	61.659	61.647
N	4085	4085	4085	4085	4072	4083	4085	4085

Significance levels: $*: < 5\%$ $**: < 1\%$

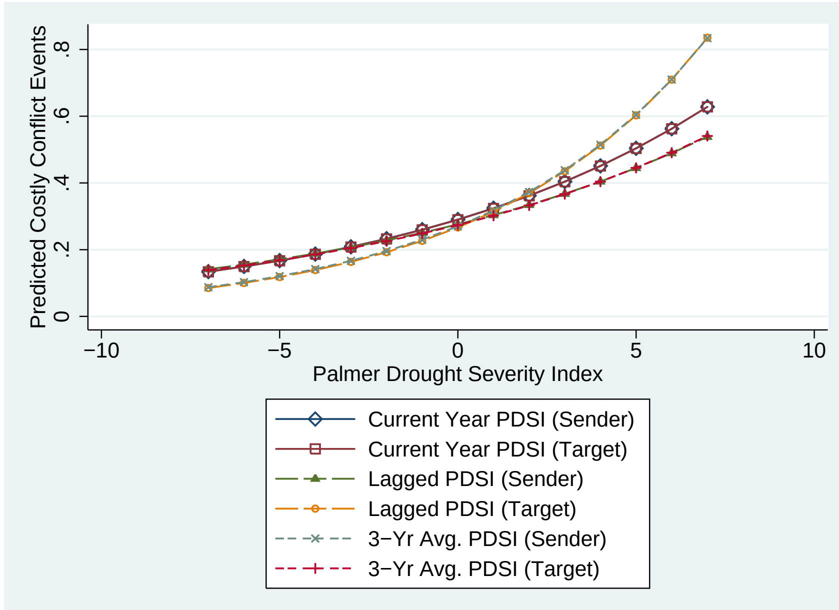

FIGURE 6.3: Graph of expected conflict events (COPDAB) versus drought level. With less water available, the level of expected conflictual events is lower. This relationship does not exist in either the PANDA or IDEA data.

6.5.2 PANDA data

PANDA events data, seen in Tables 6.8 and 6.9, appear to be independent of association with the drought variables, including shared drought and consecutive-year shared drought data. These findings fail to support Hypotheses H_2 and H_{2a}. The short time period of observation (1984–1994) and relatively small number of observations (about 1200) may account for the lack of significant variables, but three of the non-water covariates are significant and in the expected direction. The log of dyadic trade is associated with a significant decrease in the number of conflict events, while the logged military capabilities index of both the initiator and target as associated with an increase in the count of conflict events.

The linear regression on PANDA conflict intensity data (Tables 6.10 and 6.11) show similar results to the conflict events data analyses. Water scarcity or abundance is again not associated with any change in the level of dyadic conflict intensity, whether the water scarcity is individual, shared, or shared and longer-term. Dyadic trade is associated with a reduction in the aggregate intensity of dyadic conflict. Greater military capabilities of both the sender and target states significantly increase the expected levels of conflict intensity. The results of the PANDA analyses also show that the difference in GDP per capita is associated with a reduction in the intensity of conflict in the dyad, with a coefficient of around 1.58. Both the events analyses and the least-squares analyses show no relation between water scarcity and conflict, and thus the results fail to support H_2, H_{2a}, or H_{2b}.

TABLE 6.8: Negative Binomial Regression, Effect of Individual-Level Drought on Number of Conflict Events, PANDA

Variable	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**
	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	-0.045	-0.039	-0.049	-0.044	-0.050	-0.037
	0.096	0.097	0.096	0.097	0.096	0.097
Log of total dyadic trade	-0.080*	-0.080*	-0.079*	-0.079*	-0.079*	-0.078*
	0.036	0.036	0.036	0.036	0.036	0.036
PDSI avg. (sender) × shared basin	-0.005					
	0.026					
PDSI avg. (target) × shared basin		-0.002				
		0.027				
PDSI avg., lagged (sender) × shared basin			0.013			
			0.026			
PDSI avg., lagged (target) × shared basin				0.008		
				0.030		
PDSI avg., three year (sender) × shared basin					0.016	
					0.035	
PDSI avg., three year (target) × shared basin						0.023
						0.036
Pct of country 1's area shared in dyad	-0.348	-0.341	-0.310	-0.318	-0.314	-0.315
	0.281	0.271	0.279	0.271	0.283	0.271
Pct of country 2's area shared in dyad	0.002	0.012	0.023	0.019	0.005	0.011
	0.308	0.317	0.307	0.317	0.310	0.322
Shared democracy (each score > 6)	-0.007	-0.008	-0.007	-0.010	-0.014	-0.020
	0.155	0.155	0.155	0.154	0.156	0.155
log of COW capabilities score, initiator	0.185**	0.186**	0.183**	0.181**	0.185**	0.182**
	0.063	0.065	0.063	0.065	0.063	0.065
log of COW capabilities score, target	0.184**	0.186**	0.182**	0.184**	0.180**	0.181**
	0.066	0.065	0.067	0.064	0.068	0.064
Intercept	0.362**	0.361**	0.362**	0.365**	0.373**	0.370**
	0.131	0.132	0.131	0.132	0.131	0.132
χ^2	28.506	28.568	28.196	27.86	28.993	29.6
Log-likelihood	-1565.363	-1558.059	-1561.806	-1556.607	-1549.558	-1544.271
N	1193	1188	1190	1185	1180	1175

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.9: Negative Binomial Regression, Effect of Shared Drought on Number of Conflict Events, PANDA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	-0.042	-0.043	-0.042	-0.042	-0.044	-0.043	-0.043	-0.043
	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
Log of total dyadic trade	-0.083*	-0.082*	-0.082*	-0.082*	-0.082*	-0.081*	-0.082*	-0.082*
	0.036	0.036	0.036	0.035	0.036	0.036	0.035	0.035
PDSI, both states below -1 $\times$ shared basin	0.070							
	0.114							
PDSI, both states below -2 $\times$ shared basin		-0.092						
		0.162						
PDSI, both states below -3 $\times$ shared basin			-0.015					
			0.195					
PDSI, both states below -4 $\times$ shared basin				-0.087				
				0.243				
PDSI, years both states below -1 $\times$ shared basin					-0.010			
					0.033			
PDSI, years both states below -2 $\times$ shared basin						-0.012		
						0.054		
PDSI, years both states below -3 $\times$ shared basin							0.004	
							0.067	
PDSI, years both states below -4 $\times$ shared basin								-0.045
								0.071
Pct of country 1's area shared in dyad	-0.344	-0.324	-0.333	-0.329	-0.311	-0.323	-0.331	-0.331
	0.276	0.278	0.277	0.277	0.281	0.280	0.277	0.276
Pct of country 2's area shared in dyad	0.007	0.031	0.022	0.024	0.008	0.020	0.017	0.025
	0.315	0.311	0.311	0.309	0.323	0.314	0.311	0.308
Shared democracy (each score $>$ 6)	0.006	0.002	0.003	0.001	-0.003	-0.005	0.001	0.001
	0.156	0.155	0.155	0.156	0.161	0.157	0.156	0.155
log of COW capabilities score, initiator	0.189**	0.183**	0.186**	0.185**	0.187**	0.184**	0.187**	0.185**
	0.064	0.064	0.064	0.063	0.065	0.064	0.064	0.063
log of COW capabilities score, target	0.192**	0.185**	0.188**	0.187**	0.184**	0.186**	0.189**	0.186**
	0.065	0.066	0.066	0.066	0.066	0.066	0.066	0.066
Intercept	0.356**	0.355**	0.356**	0.356**	0.365**	0.362**	0.361**	0.356**
	0.132	0.130	0.131	0.131	0.131	0.131	0.131	0.131
χ^2	28.805	31.464	29.803	30.384	28.819	29.476	29.811	32.885
Log-likelihood	-1577.405	-1577.427	-1577.58	-1577.534	-1566.843	-1571.443	-1574.027	-1577.479
N	1206	1206	1206	1206	1196	1199	1203	1206

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.10: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Individual-Level Drought on Conflict Intensity, PANDA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	1.546*	1.590*	1.570*	1.601*	1.583*	1.574*
	0.704	0.709	0.702	0.708	0.709	0.715
Log of total dyadic trade	1.326**	1.339**	1.328**	1.336**	1.336**	1.345**
	0.248	0.249	0.250	0.250	0.251	0.252
PDSI avg. (sender) $\times$ shared basin	0.071					
	0.265					
PDSI avg. (target) $\times$ shared basin		0.082				
		0.270				
PDSI avg., lagged (sender) $\times$ shared basin			-0.049			
			0.266			
PDSI avg., lagged (target) $\times$ shared basin				0.076		
				0.264		
PDSI avg., three year (sender) $\times$ shared basin					-0.085	
					0.348	
PDSI avg., three year (target) $\times$ shared basin						-0.006
						0.339
Pct of country 1's area shared in dyad	3.368	3.340	3.102	3.241	3.075	3.275
	2.019	2.008	2.026	2.016	2.059	2.046
Pct of country 2's area shared in dyad	1.031	1.014	0.899	0.963	1.087	1.095
	2.036	2.053	2.030	2.049	2.063	2.090
Shared democracy (each score > 6)	-1.307	-1.349	-1.305	-1.373	-1.305	-1.351
	1.258	1.260	1.264	1.266	1.275	1.277
log of COW capabilities score, initiator	-1.487**	-1.495**	-1.497**	-1.502**	-1.517**	-1.501**
	0.401	0.405	0.404	0.406	0.406	0.411
log of COW capabilities score, target	-1.424**	-1.445**	-1.416**	-1.449**	-1.395**	-1.432**
	0.399	0.396	0.401	0.399	0.405	0.401
Intercept	-29.630**	-29.788**	-29.577**	-29.760**	-29.685**	-29.838**
	3.768	3.775	3.800	3.808	3.819	3.831
χ^2	47.681	48.197	46.965	47.314	46.981	46.946
N	1193	1188	1190	1185	1180	1175

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.11: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Shared Drought on Conflict Intensity, PANDA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	1.525*	1.525*	1.528*	1.524*	1.534*	1.531*	1.531*	1.529*
	0.693	0.694	0.694	0.694	0.697	0.697	0.695	0.694
Log of total dyadic trade	1.339**	1.335**	1.338**	1.336**	1.362**	1.345**	1.335**	1.344**
	0.246	0.246	0.246	0.246	0.249	0.249	0.246	0.247
PDSI, both states below -1 × shared basin	-0.591							
	1.107							
PDSI, both states below -2 × shared basin		0.130						
		1.501						
PDSI, both states below -3 × shared basin			-0.575					
			1.807					
PDSI, both states below -4 × shared basin				-0.029				
				2.367				
PDSI, years both states below -1 × shared basin					-0.012			
					0.276			
PDSI, years both states below -2 × shared basin						0.038		
						0.495		
PDSI, years both states below -3 × shared basin							-0.091	
							0.705	
PDSI, years both states below -4 × shared basin								0.412
								0.865
Pct of country 1's area shared in dyad	3.333	3.202	3.262	3.222	3.182	3.232	3.200	3.206
	1.986	1.989	1.981	1.982	2.023	2.011	1.987	1.977
Pct of country 2's area shared in dyad	1.063	0.909	0.994	0.930	1.236	0.974	0.984	0.876
	2.019	2.017	2.014	2.008	2.054	2.037	2.022	2.007
Shared democracy (each score > 6)	-1.352	-1.315	-1.345	-1.321	-1.411	-1.316	-1.334	-1.287
	1.248	1.249	1.250	1.252	1.269	1.263	1.257	1.249
log of COW capabilities score, initiator	-1.514**	-1.486**	-1.506**	-1.491**	-1.540**	-1.491**	-1.496**	-1.474**
	0.401	0.402	0.402	0.400	0.406	0.403	0.402	0.400
log of COW capabilities score, target	-1.456**	-1.425**	-1.445**	-1.431**	-1.436**	-1.435**	-1.437**	-1.412**
	0.395	0.397	0.395	0.395	0.401	0.399	0.397	0.395
Intercept	-29.890**	-29.628**	-29.842**	-29.682**	-30.129**	-29.779**	-29.736**	-29.559**
	3.759	3.783	3.774	3.754	3.829	3.804	3.773	3.748
χ^2	48.857	48.552	48.65	48.544	48.628	47.978	48.37	48.778
N	1206	1206	1206	1206	1196	1199	1203	1206

Significance levels: $*: < 5\%$ $**: < 1\%$

6.5.3 IDEA data

As with the PANDA data, IDEA conflict data (Tables 6.12, 6.13, 6.14, and 6.15) show no significant association with the drought variables of any form. Also similar to the PANDA data, the log of dyadic trade and the log of COW military capabilities for sender and target are significantly associated with a change in the number of conflict events in the dyad. Of note, the percentage of the initiator's land area that is contained in a shared basin is associated with a significant drop in the expected number of conflict events. Because the variable is a percentage, the impact of the coefficient (ranging from -0.89 to -1.125) will be diluted unless all of the state is contained within a river basin shared with its dyadic partner.

Cross-sectional time-series linear regression return no association between any water variable and the intensity of conflict in the dyad, as in the other data sets. Neither the events data nor the conflict intensity data provide any support for Hypothesis H_2. The military capabilities of each state are again significant, and greater military power contributes to a more intensely conflictual environment. And as in the IDEA events data, the amount of the country that lies in a shared basin with its dyadic partner significantly correlates with a decrease in the intensity of conflict in the dyad.

TABLE 6.12: Negative Binomial Regression, Effect of Individual-Level Drought on Number of Conflict Events, IDEA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.084	-0.026	0.076	-0.006	0.066	-0.008
	0.104	0.103	0.102	0.101	0.104	0.102
Log of total dyadic trade	-0.173**	-0.183**	-0.168**	-0.175**	-0.165**	-0.171**
	0.041	0.042	0.040	0.042	0.041	0.043
PDSI avg. (sender) $\times$ shared basin	-0.061					
	0.033					
PDSI avg. (target) $\times$ shared basin		-0.034				
		0.033				
PDSI avg., lagged (sender) $\times$ shared basin			-0.052			
			0.033			
PDSI avg., lagged (target) $\times$ shared basin				-0.036		
				0.039		
PDSI avg., three year (sender) $\times$ shared basin					-0.085	
					0.049	
PDSI avg., three year (target) $\times$ shared basin						-0.043
						0.056
Pct of country 1's area shared in dyad	-1.025**	-0.985**	-0.992**	-0.952**	-0.972**	-0.891**
	0.328	0.320	0.334	0.324	0.342	0.333
Pct of country 2's area shared in dyad	-0.385	-0.645	-0.358	-0.608	-0.343	-0.599
	0.325	0.372	0.327	0.382	0.336	0.396
Shared democracy (each score $>$ 6)	0.322	0.300	0.310	0.291	0.314	0.296
	0.185	0.182	0.184	0.180	0.187	0.184
log of COW capabilities score, initiator	0.278**	0.339**	0.281**	0.337**	0.287**	0.344**
	0.073	0.069	0.074	0.069	0.076	0.070
log of COW capabilities score, target	0.398**	0.304**	0.395**	0.305**	0.399**	0.304**
	0.072	0.083	0.072	0.085	0.073	0.088
Intercept	1.620**	1.686**	1.607**	1.671**	1.618**	1.672**
	0.115	0.130	0.115	0.134	0.118	0.140
χ^2	70.901	69.892	68.236	67.461	68.382	65.931
Log-likelihood	-2248.04	-2280.546	-2240.587	-2267.565	-2200.801	-2229.453
N	3501	3498	3477	3474	3428	3425

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.13: Negative Binomial Regression, Effect of Shared Drought on Number of Conflict Events, IDEA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.020	0.018	0.020	0.020	0.016	0.020	0.020	0.023
	0.103	0.104	0.104	0.103	0.104	0.105	0.105	0.104
Log of total dyadic trade	-0.210**	-0.211**	-0.209**	-0.208**	-0.207**	-0.204**	-0.206**	-0.207**
	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.041
PDSI, both states below -1 $\times$ shared basin	0.086							
	0.134							
PDSI, both states below -2 $\times$ shared basin		0.198						
		0.172						
PDSI, both states below -3 $\times$ shared basin			0.146					
			0.192					
PDSI, both states below -4 $\times$ shared basin				0.127				
				0.272				
PDSI, years both states below -1 $\times$ shared basin					0.013			
					0.029			
PDSI, years both states below -2 $\times$ shared basin						-0.052		
						0.056		
PDSI, years both states below -3 $\times$ shared basin							-0.022	
							0.085	
PDSI, years both states below -4 $\times$ shared basin								-0.058
								0.134
Pct of country 1's area shared in dyad	-1.125**	-1.125**	-1.111**	-1.106**	-1.099**	-1.060**	-1.089**	-1.102**
	0.310	0.316	0.317	0.318	0.321	0.319	0.319	0.317
Pct of country 2's area shared in dyad	-0.684*	-0.691*	-0.670	-0.669	-0.688	-0.661	-0.675	-0.665
	0.347	0.349	0.349	0.348	0.353	0.349	0.349	0.347
Shared democracy (each score > 6)	0.337	0.340	0.326	0.325	0.331	0.307	0.310	0.322
	0.179	0.179	0.177	0.177	0.181	0.181	0.180	0.178
log of COW capabilities score, initiator	0.311**	0.316**	0.312**	0.310**	0.316**	0.308**	0.311**	0.307**
	0.073	0.073	0.073	0.073	0.074	0.073	0.073	0.072
log of COW capabilities score, target	0.333**	0.336**	0.334**	0.332**	0.331**	0.325**	0.329**	0.330**
	0.083	0.083	0.083	0.083	0.084	0.084	0.083	0.083
Intercept	1.738**	1.734**	1.737**	1.737**	1.755**	1.752**	1.753**	1.738**
	0.118	0.119	0.119	0.118	0.119	0.118	0.118	0.118
χ^2	75.336	75.097	74.159	74.308	72.944	76.290	74.455	75.14
Log-likelihood	-2357.054	-2356.451	-2357.035	-2357.202	-2318.023	-2331.825	-2336.972	-2357.255
N	3581	3581	3581	3581	3505	3536	3561	3581

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.14: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Individual-Level Drought on Conflict Intensity, IDEA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.020	1.013	0.094	0.884	0.131	0.910
	0.561	0.565	0.552	0.554	0.549	0.554
Log of total dyadic trade	0.227	0.253	0.218	0.230	0.196	0.203
	0.201	0.205	0.199	0.202	0.198	0.201
PDSI avg. (sender) × shared basin	0.012					
	0.121					
PDSI avg. (target) × shared basin		0.102				
		0.126				
PDSI avg., lagged (sender) × shared basin			0.025			
			0.130			
PDSI avg., lagged (target) × shared basin				0.156		
				0.133		
PDSI avg., three year (sender) × shared basin					0.099	
					0.192	
PDSI avg., three year (target) × shared basin						0.264
						0.196
Pct of country 1's area shared in dyad	4.220*	3.055	4.101*	3.115	3.872*	2.590
	1.663	1.693	1.639	1.648	1.629	1.661
Pct of country 2's area shared in dyad	0.822	1.425	0.842	1.282	0.526	1.141
	1.678	1.663	1.638	1.633	1.642	1.633
Shared democracy (each score > 6)	-0.156	-0.241	-0.195	-0.273	-0.219	-0.308
	0.846	0.871	0.842	0.861	0.841	0.861
log of COW capabilities score, initiator	-0.904**	-1.328**	-0.935**	-1.309**	-0.960**	-1.364**
	0.350	0.355	0.345	0.348	0.343	0.348
log of COW capabilities score, target	-1.661**	-1.356**	-1.652**	-1.391**	-1.679**	-1.404**
	0.352	0.350	0.346	0.344	0.344	0.343
Intercept	-23.327**	-23.723**	-23.321**	-23.570**	-23.122**	-23.315**
	3.436	3.468	3.396	3.411	3.368	3.401
χ^2	54.419	55.307	56.491	57.941	57.172	58.005
N	3501	3498	3477	3474	3428	3425

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 6.15: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Shared Drought on Conflict Intensity, IDEA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.433	0.432	0.432	0.434	0.451	0.445	0.435	0.434
	0.588	0.588	0.588	0.588	0.593	0.591	0.589	0.588
Log of total dyadic trade	0.380	0.379	0.375	0.374	0.365	0.358	0.358	0.380
	0.215	0.215	0.215	0.215	0.217	0.216	0.215	0.215
PDSI, both states below -1 $\times$ shared basin	-0.127							
	0.526							
PDSI, both states below -2 $\times$ shared basin		0.079						
		0.695						
PDSI, both states below -3 $\times$ shared basin			0.587					
			0.890					
PDSI, both states below -4 $\times$ shared basin				0.963				
				1.133				
PDSI, years both states below -1 $\times$ shared basin					-0.054			
					0.123			
PDSI, years both states below -2 $\times$ shared basin						0.112		
						0.248		
PDSI, years both states below -3 $\times$ shared basin							0.379	
							0.404	
PDSI, years both states below -4 $\times$ shared basin								0.385
								0.575
Pct of country 1's area shared in dyad	4.484*	4.453*	4.420*	4.431*	4.405*	4.311*	4.351*	4.450*
	1.746	1.746	1.745	1.744	1.764	1.756	1.749	1.745
Pct of country 2's area shared in dyad	1.944	1.914	1.879	1.883	1.971	1.908	1.916	1.904
	1.737	1.737	1.736	1.736	1.755	1.747	1.740	1.736
Shared democracy (each score > 6)	-0.364	-0.349	-0.325	-0.312	-0.387	-0.277	-0.243	-0.335
	0.920	0.921	0.920	0.920	0.937	0.928	0.922	0.919
log of COW capabilities score, initiator	-1.072**	-1.066**	-1.055**	-1.055**	-1.092**	-1.058**	-1.044**	-1.058**
	0.369	0.370	0.369	0.369	0.374	0.372	0.370	0.369
log of COW capabilities score, target	-1.466**	-1.459**	-1.450**	-1.450**	-1.477**	-1.439**	-1.433**	-1.453**
	0.368	0.368	0.368	0.368	0.372	0.370	0.369	0.368
Intercept	-24.602**	-24.564**	-24.454**	-24.451**	-24.644**	-24.280**	-24.205**	-24.508**
	3.639	3.649	3.643	3.641	3.683	3.670	3.652	3.640
χ^2	49.297	49.349	49.74	49.997	48.704	48.771	49.848	49.694
N	3581	3581	3581	3581	3505	3536	3561	3581

Significance levels: $*: < 5\%$ $**: < 1\%$

6.6 Discussion

In sum, the evidence supporting Hypothesis 2 is weak. Although I identify a significant negative relationship between freshwater scarcity and the frequency of conflict in the COPDAB data, this relationship is not evident in either the PANDA or the IDEA data. Further, in none of the analyses presented here is there a significant relationship between freshwater scarcity and the intensity of conflict. These results do not offer convincing evidence that supports H_2, H_{2a}, or H_{2b}. They do, however, generally reinforce Hypotheses H_1 and H_{1b}: it appears that water scarcity *does not* contribute to a higher intensity or amount of dyadic conflict.

The remainder of the political covariates perform as expected; greater levels of military capability increase the intensity of conflicts, while trade decreases the intensity of conflict as domestic interests pressure the government to avoid conflict that might be economically costly.

In the most recent data (IDEA), it appears that the amount of shared basin area in the initiator's country is associated with a lessening of conflict intensity, but this result is not found in the earlier data sets. Because the PANDA data are nearly as recent as the IDEA data but have about one-third the number of observations, it is possible that this result does not appear in the PANDA data because of an insufficiently large number of observations.

Chapter 5 reveals that military conflict and war are negatively associated with droughts, either shared or individual. That is, drought appears to reduce the likelihood of military conflict. In this chapter, however, examining more general conflict reveals that water availability has little (if any) impact on the expected number of conflict events, or the expected intensity of a conflict between two adjacent countries in a given year. These results, taken in conjunction with the results from

Chapter 5, could be interpreted to mean that while states shy away from military and violent conflict during droughts and have a “free hand” to engage more freely in military activity during wetter periods, that aggregate conflict is largely unaffected by water issues. Any drought-related conflict is lost in the aggregate measures of conflict between each pair of countries. This finding indicates that, on the whole, lower level conflicts that might eventually escalate are unrelated to water scarcity issues. While there is limited support for Hypothesis H_2 (droughts lead to less conflict), there is no change in the rejection of Hypothesis H_{1a}—there is no evidence that droughts lead to higher levels of conflict.

Having thoroughly examined the first two hypotheses about conflict and violence over scarce water, the next chapter addresses the presence of costly cooperation between states during periods of water stress. While I have found that conflict is not associated with water stress, and indeed military conflict falls off during droughts, these results do not mean that cooperation must therefore increase during droughts.

Chapter 7

Drought and International Cooperation

> We never know the value of water 'till the well is dry.
>
> *Russian Proverb*

Earlier sections of this dissertation have examined the effects of drought on international military and violent conflict, and second, on nonviolent conflict and conflict intensity. These tests have not utilized the cooperation information also contained within the events data sets. Throughout the year, a pair of states (particularly adjacent ones) have some spectrum of interaction, ranging from economic cooperation and goodwill to conflictual events of varying intensities. Chapter 5 used only military and violent conflict to examine the effects of drought. Chapter 6 introduced the events data, whereby one can examine a broader scope of interaction, asking how *many* conflict events were there, and how *intense* were these conflictual events? In this chapter, I examine costly cooperative events data to test Hypothesis H_3 (how drought affects costly cooperation, if at all):

H_3: *A state experiencing a period of acute scarcity involving a shared water resource* *experiences a* **change in the level of cooperation** *with an adjacent state, compared to a state sharing a water resource that is not experiencing scarcity.*

> H_{3a}: *A state experiencing a period of acute scarcity involving a shared water resource will initiate* **more cooperative events** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
> H_{3b}: *A state experiencing a period of acute scarcity involving a shared water resource will initiate a* **higher aggregate intensity of cooperation** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*

As with Chapter 6, I use the *number of events* and the *summed intensity of those events* as separate measures of dyadic interaction—here, measures of costly cooperation. Tests reveal that costly cooperation, like conflict, declines significantly during droughts. The results are not entirely consistent, but are consistent between the two most recent data sets. Because cooperation decreases during a drought, one possible inference is that natural disasters like a drought reduce the activity of a country's foreign policy apparatus while the domestic problems are addressed; these findings are different from the mechanism I proposed in Chapter 3.

7.1 Cooperation

Broadly speaking, cooperation, like power, is aimed at increasing a country's ability to provide fundamental services for its citizens and for the state. These benefits include military defense or infrastructure, and possibly more specific benefits for an electorate or selectorate. Cooperation is somewhat incompatible with military conflict: cooperation during wartime is less likely, and cooperative events may be few compared to conflictual events. Though a lack of conflict does not indicate the presence of cooperation, Chapters 5 and 6, reveal a decrease in military conflict and conflict overall during droughts. This drop in conflict leaves the way open for countries to cooperate during droughts.

Remember that "cooperation," as I define it, follows Keohane's (1984, 51) definition, rather than a more general definition such as "working together on a jointly-relevant project." Here, I choose to examine those events that appear to have costs associated with them, as a proxy for Keohane's archetypal cooperative event. A list of actions classified as "costly cooperation" is found in Table 7.1. While these events could be motivated by realist concerns or alliance obligations, they do reflect a costly policy coordination that would probably not otherwise occur. It would be impossible to examine each event for the necessary features to make it "cooperation" instead of "harmony," and so this list is an approximation of actual policy coordination where there are previously divergent preferences.

TABLE 7.1: Cooperative Events using WEIS coding and Goldstein (1992) weighting

Action	**Weight**
Promise economic support	5
Promise humanitarian support	5.2
Promise military support	5.2
Promise material support	5.2
Improve relations	5.2
Agree	6
Collaborate	6
Extend humanitarian aid	6.5
Make agreement	6.5
Reward	7
Extend economic aid	7.4
Extend military aid	8.3
Merge, Integrate	10

The neoliberal institutionalists suggest that once a way to overcome coordination difficulties and find a positive-sum outcome has been found, an unpleasant situation such as a drought would reinforce the value of that institution and the benefits it provides. Institutions, not just those addressing natural resources, presumably are created with a means to improve the welfare of both countries. The existence of a cooperative event or institution could potentially lead to a future increase in cooperation, that is, an increase in *positive* conflict behavior and attempts at policy coordination instead of a resort to threats or force. The cooperative institution may contribute to an increase in the number of cooperative events between the two countries despite any difficulties created by a drought. A cooperative event or institution could, however, lead to more, but less intense, conflict, since an institution might be responsible for addressing grievances. Countries that perceive their partners as unlikely to initiate a violent conflict are more able to express grievances and other low-level conflicts since these conflicts are unlikely to escalate to violence.

The realist paradigm proposes that cooperation is epiphenomenal, and that any cooperation will be abandoned if security issues or national interests require it (Strange 1983, 345). Because this situation is known to all actors, no one has expectations of durable or costly cooperation over the long term, since each state in an alliance or trade agreement will evaluate its compliance with that agreement when significant costs will be incurred by taking actions specified by the agreement. Cooperation, for the realists, is a temporary device of subordinate significance to national security.

I propose instead that costly cooperative events—*new*, costly, cooperative events, as opposed to honoring commitments from previous years—will increase during drought periods. Economic necessity drives states to pursue gains from cooperation during drought, and the economic downturn in one state may increase the likelihood that another state offers aid or agrees to cooperate where it might not have otherwise: if the two states are trading partners, then the drought and the attendant economic downturn may have effects across state boundaries, encouraging neighboring countries to have a favorable disposition towards new trade negotiations or other near-term gains from cooperation.

There is a plausible alternative and opposing explanation to my theoretical expectations: rather than look outward for assistance in coping with a drought, a government might pay attention to its domestic population and pressure groups (Olson 1965, 128) to the exclusion of its foreign policy. Both unilateral and international action has the potential to produce quick results, but usually treaty negotiations take years or decades to conclude. States may then rationally choose to deal with the drought themselves and only pursue international cooperation where it is very important, focusing their efforts on the domestic situation. The malthusian/realist expectations, rejected by earlier chapters, expect a state to look inward or go to war: whether the state is tending to domestic issues and ignoring most international ones, or whether it is abandoning costly cooperation because the drought is affecting its military capability and it must maintain the military power or risk the loss of independence, the level of cooperation could drop during a drought.

7.2 Dependent Variables

I use events-based cooperation data to examine Hypothesis H_3 in two ways. First, I use a *count* of cooperative events in a dyad in a given year as a dependent variable to asses the impact of water scarcity on the *frequency* of cooperation. Second, I use *aggregate intensity of cooperation* as another dependent variable to explore the relationship between scarcity and the *intensity* of cooperation. To express the intensity variable as a numeric value, I use a modified Goldstein (1992) weight for each recorded event in the dyad. The average of these weights from initiator to target comprises the dependent variable. In the COPDAB data, which precede the Goldstein scale, I again follow Wolf, Yoffe and Giordano (2003) and re-center the scale with zero as the middle, "neutral" event type. In this way the scale approximates the Goldstein scale. However, I make no claim that these data are *exchangeable*[1] and thus test each data set separately. To further approximate Goldstein's scale, I multiply the re-centered Azar (COPDAB) scale by 0.1, so the coefficients do not vary so widely among statistical tests. See Table 7.2 for a summary of these cooperation data.

7.3 International Cooperation Data

Data about cooperative events are less common than conflict data, but these data provide one of the only reliable ways to measure cooperation between countries. The COPDAB, PANDA and IDEA project data sets, seen in the previous chapter, allow the measurement of interstate relations of a positive sort. Previous tests (both in this dissertation and most of the literature in general) have not done more than test the presence or absence of conflict, usually military conflict. These measures do more than show a lack of conflict. They make it possible to show the presence of cooperation, or lack of cooperation, *independent* from conflict. These data sets follow the organization of the previous chapter. Adjacent states are paired twice in each year (directed dyads), with each state the potential initiator of cooperation and the potential recipient of a request for cooperation.

[1]Howell (1983) has shown COPDAB and WEIS scales and data to be incompatible, and their results inconsistent during their years of overlap. However, see Reuveny and Kang (1996), who in a more recent test have shown that the COPDAB and WEIS scales and data may indeed be compatible.

TABLE 7.2: Cooperative Events and Intensity Variables

Dataset	Variable	Obs.	μ	σ	Min.	Max.
COPDAB[2] 1948–1978	Weighted events sum	7989	-0.515	76.1	-4323.1	70.5[3]
	Coop. event count	7989	1	1.605	0	18[4]
	Weighted coop. sum	7989	5.282	6.557	0	61.4[5]
PANDA 1984–1994	Weighted events sum	1957	-3.079	21.434	-343.2	56.55[6]
	Coop. event count	1957	2.245	4.303	0	62[7]
	Weighted coop. sum	1957	7.164	14.614	0	192.4[8]
IDEA 1990–2004	Weighted events sum	5476	4.850	31.416	-670.7[9]	349.6[10]
	Coop. event count	5476	0.484	1.396	0	22[11]
	Weighted coop. sum	5476	15.085	30.572	0	456.9[12]

7.4 Methodology

I use two separate methods of analyzing the three data sets: count models and linear models. For count models, I use a negative binomial regression to examine the annual numbers of cooperative events in a directed dyad. For the linear models, I use an autoregressive cross-sectional time-series linear regression to measure the overall dyadic cooperation. In all models, the independent variables are the same as seen in the previous two chapters. Because I use three sets of data for the dependent variables, each with two separate dependent variables, it is important to keep the analyses as exchangeable as possible, so all independent variables

[2]Note that the COPDAB event intensity scale is not directly comparable to the WEIS coding scheme used by the IDEA and PANDA data.
[3]Poland – USSR, 1958.
[4]Syria – Jordan, 1956.
[5]Syria – Jordan, 1956; Syria – Lebanon, 1976.
[6]East and West Germany, 1990.
[7]Iraq – Iran, 1988.
[8]Iraq – Iran, 1988.
[9]Iraq – Kuwait, 1990.
[10]Canada – USA, 1994.
[11]Canada – USA, 2001.
[12]Canada – USA, 1993.

remain and are not changed, listed in Table 7.3.

TABLE 7.3: Non-water Covariates Used in Statistical Models

Variable	**Description**
Difference in development	Difference in the logged real (constant value) GDP per capita of each state
Trade	Log of the sum of all trade between the two states in the dyad
Military capabilities (initiator)	Logged COW military capabilities score for the initiating state
Military capabilities (target)	Logged COW military capabilities score for the target state
Shared Democracy	Dummy variable, equal to one if both states have a Polity IV $democracy - autocracy$ score of 6 or higher, zero otherwise

7.4.1 Methodology, Count Models

To analyze the event-count data, I use a negative binomial regression. This method allows the user to appropriately examine the impact of water scarcity and other covariates on the expected number of events of a given type, such as cooperation, over a given time period. Negative binomial regressions are a better choice than a simpler Poisson regression because the Poisson regression requires the conditional variance and conditional mean be the same. Negative binomial analysis, a more general model, handles the variance being larger than the mean (such data are said to be "overdispersed"). In addition, Poisson regressions assumes that event occurrences are independent, and among neighboring states, I expect the opposite—events of any sort often occur as reactions to earlier events. Therefore, the negative binomial model is more appropriate than a Poisson regression.

7.4.2 Methodology, Linear Models

Measuring the impact of water scarcity and other covariates on the aggregate level of cooperation between two countries requires that the method be able to handle a continuous dependent variable. Because the dependent variables used to test Hypothesis H_{3b} are continuous, a least squares linear model is useful, and because the expected values stay away from the maximum and minimum scores on each scale, the linear model introduces no problems associated with out-of-range predictions. Finally, the large number of observations in the three data sets increases the performance of the linear model. These models use two-tailed tests, since they test for results that could be significant for an increase or decrease in the level/intensity of cooperation. Because a basic linear model does not account for autoregression or time-series data, and is therefore prone to incorrect standard errors and variable coefficients, I run cross-sectional time-series linear regressions with an autoregressive component for each model, expecting the amount of cooperation from the previous year to influence the cooperation for the current year. That is, the autoregressive component is AR(1) for these models. Years prior to the previous year are not expected to have a significant impact on the cooperation levels for the current year.

7.5 Results

Interpreting the results in this chapter are more straightforward than in Chapter 6, because the direction of coefficients for either type of analysis can be interpreted similarly, i.e. positive coefficients indicate that an increase in the value of an independent variable is associated with an increase in cooperation regardless of which model produces the result. The coding of the scarcity variables is the same as in previous chapters—individual-level drought measures are based on Palmer

Drought Severity Index measures, where higher values are associated with *less* scarcity. Accordingly, Hypothesis 3 predicts negative relationships between the individual-level drought variables and both dependent variables (cooperation frequency and cooperation intensity). Conversely, the measure of shared drought is a dichotomous measure that is equal to 0 in the absence of a shared drought and 1 in the presence of a shared drought. This variable should be positively associated with both dependent variables. (As drought increases, cooperation should increase.) Just as in the previous chapters, I provide summary tables and substantive graphs to assist in the interpretation of the results.

7.5.1 COPDAB data

The COPDAB data spans the years 1948–1978, before many modern states had gained independence from their colonial powers. In addition, as noted previously, the COPDAB coefficients are at least nominally different from those of PANDA and IDEA.

The analysis of the effects of individual-level drought on the frequency of cooperation is presented in Table 7.4. These models offer no support for Hypothesis H_3 or H_{3a}. None of the water scarcity variables attains significant significance in any of the models. Table 7.5 reports the results of the analyses of the relationship between shared drought and the frequency of cooperative events. There is a decrease in cooperation under specific conditions of shared drought (PDSI of -3 or drier over multiple years). This finding is reinforced by the analyses in the other data sets (discussed below), but not by the other results within the COPDAB data. That is, of the eight shared drought models, the relationship between scarcity and frequency of cooperation is only significant in one. The evidence from the COPDAB data offers minor evidence against Hypothesis H_{3a}, but there is no consistent correlation between water scarcity and cooperation in this data set.

The event count models for both individual-level and shared drought reveal that trade is associated with an increase the number of costly (significant) cooperative events. Though, it is possible that the increase in trade *is* the cooperative event, stemming from a trade barrier's removal or a cooperative production agreement. The military strength of either country is also significantly associated with an increase in cooperation. Note that in previous chapters, military power is significantly associated with an increase in the intensity of, or instance of, dyadic conflict. These coefficients show the value of using events data instead of aggregated or conflict-only data; these results support the idea that states with greater military power both conflict *and* cooperate more than weaker states.

I next consider the impact of scarcity on the intensity of cooperation. Tables 7.6 and 7.7 report the effects of individual-level and shared drought on cooperation intensity, respectively. Evidence disconfirming H_{3b} (drought leads to an increased intensity of cooperation) is found in two models, with the rest showing no association with water scarcity. One of the six individual-level drought models finds a significant effect for water scarcity. The lagged value of the sender state's PDSI is (as expected) positive and significant. None of the other individual-level scarcity variables attains statistical significance, however. All but one of the scarcity variables in the shared drought models offer support for H_{3b}: A positive and significant effect is identified when both states in a dyad experience an extreme drought (PDSI < -4) indicating that strong shared droughts may be associated with an increase in the intensity of cooperation.

Overall, the COPDAB data presents a mixed picture. For all models, trade is significantly related to an increase in cooperation intensity. I similarly find that strong shared drought is correlated with an increase in cooperation (a finding that is consistent with H_{3b}). However, there is conflicting evidence that individual-level drought is associated with a decrease in cooperation, providing evidence against H_{3b}.

TABLE 7.4: Negative Binomial Regression, Effect of Individual-Level Drought on Number of Cooperative Events, COPDAB

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	-0.001	0.004	-0.002	0.002	-0.001	0.006
	0.052	0.052	0.052	0.052	0.053	0.053
Log of total dyadic trade	0.164**	0.164**	0.164**	0.165**	0.168**	0.168**
	0.021	0.020	0.021	0.021	0.022	0.021
PDSI avg. (sender) × shared basin	0.008					
	0.015					
PDSI avg. (target) × shared basin		0.002				
		0.014				
PDSI avg., lagged (sender) × shared basin			0.004			
			0.015			
PDSI avg., lagged (target) × shared basin				-0.003		
				0.015		
PDSI avg., three year (sender) × shared basin					0.022	
					0.023	
PDSI avg., three year (target) × shared basin						0.010
						0.023
Pct of country 1's area shared in dyad	0.048	0.056	0.043	0.052	0.045	0.052
	0.177	0.177	0.178	0.178	0.181	0.181
Pct of country 2's area shared in dyad	-0.087	-0.100	-0.089	-0.101	-0.069	-0.081
	0.169	0.170	0.170	0.171	0.172	0.173
Shared democracy (each score > 6)	0.123	0.122	0.109	0.108	0.098	0.098
	0.160	0.160	0.165	0.165	0.168	0.168
log of COW capabilities score, initiator	0.069*	0.063	0.067*	0.061	0.063*	0.058
	0.032	0.033	0.032	0.033	0.032	0.033
log of COW capabilities score, target	0.026	0.031	0.026	0.031	0.029	0.035
	0.034	0.033	0.034	0.033	0.034	0.033
Intercept	-0.034	-0.038	-0.047	-0.051	-0.061	-0.066
	0.068	0.068	0.068	0.068	0.068	0.068
χ^2	189.638	186.346	182.286	185.075	185.918	184.64
Log-likelihood	-5426.039	-5425.356	-5382.771	-5381.883	-5311.134	-5311.6
N	4037	4037	4006	4006	3970	3970

Significance levels: $* : < 5\%$ $** : < 1\%$

TABLE 7.5: Negative Binomial Regression, Effect of Shared Drought on Number of Cooperative Events, COPDAB

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
Log of total dyadic trade	0.161**	0.161**	0.161**	0.161**	0.163**	0.161**	0.161**	0.161**
	0.020	0.020	0.020	0.020	0.021	0.020	0.020	0.020
PDSI, both states below -1 $\times$ shared basin	-0.016							
	0.061							
PDSI, both states below -2 $\times$ shared basin		0.070						
		0.087						
PDSI, both states below -3 $\times$ shared basin			-0.124					
			0.126					
PDSI, both states below -4 $\times$ shared basin				0.022				
				0.167				
PDSI, years both states below -1 $\times$ shared basin					-0.025			
					0.028			
PDSI, years both states below -2 $\times$ shared basin						-0.013		
						0.049		
PDSI, years both states below -3 $\times$ shared basin							-0.149*	
							0.074	
PDSI, years both states below -4 $\times$ shared basin								-0.051
								0.132
Pct of country 1's area shared in dyad	0.052	0.050	0.052	0.051	0.052	0.049	0.052	0.051
	0.176	0.177	0.176	0.177	0.177	0.176	0.176	0.176
Pct of country 2's area shared in dyad	-0.089	-0.092	-0.089	-0.090	-0.092	-0.089	-0.089	-0.090
	0.169	0.169	0.169	0.169	0.170	0.169	0.169	0.169
Shared democracy (each score $>$ 6)	0.105	0.100	0.104	0.104	0.090	0.106	0.105	0.104
	0.157	0.157	0.157	0.157	0.159	0.158	0.157	0.157
log of COW capabilities score, initiator	0.073*	0.074*	0.072*	0.073*	0.070*	0.072*	0.072*	0.073*
	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
log of COW capabilities score, target	0.035	0.036	0.035	0.035	0.031	0.035	0.034	0.035
	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Intercept	-0.042	-0.042	-0.043	-0.042	-0.054	-0.041	-0.043	-0.042
	0.068	0.068	0.068	0.068	0.067	0.068	0.068	0.068
χ^2	189.919	189.156	187.875	188.138	198.455	193.364	188.602	188.934
Log-likelihood	-5517.674	-5517.49	-5517.501	-5517.706	-5497.978	-5515.744	-5517.144	-5517.689
N	4085	4085	4085	4085	4072	4083	4085	4085

Significance levels: $*$: $<5\%$ $**$: $<1\%$

TABLE 7.6: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Individual-Level Drought on Intensity of Cooperation, COPDAB

Variable	Coeff. / SE	Coeff. / SE	Coeff. / SE	Coeff. / SE	Coeff. / SE	Coeff. / SE
Difference of log RGDP/capita	0.022	0.029	-0.004	0.031	0.005	0.017
	0.241	0.242	0.241	0.241	0.238	0.239
Log of total dyadic trade	0.560**	0.551**	0.541**	0.537**	0.568**	0.556**
	0.077	0.077	0.076	0.076	0.076	0.076
PDSI avg. (sender) × shared basin	-0.095					
	0.062					
PDSI avg. (target) × shared basin		-0.092				
		0.063				
PDSI avg., lagged (sender) × shared basin			0.130*			
			0.062			
PDSI avg., lagged (target) × shared basin				0.119		
				0.062		
PDSI avg., three year (sender) × shared basin					-0.055	
					0.099	
PDSI avg., three year (target) × shared basin						-0.072
						0.100
Pct of country 1's area shared in dyad	0.687	0.689	0.666	0.617	0.643	0.663
	0.665	0.667	0.665	0.665	0.655	0.657
Pct of country 2's area shared in dyad	0.588	0.529	0.470	0.438	0.598	0.522
	0.664	0.665	0.664	0.664	0.654	0.656
Shared democracy (each score > 6)	0.747	0.784	0.696	0.719	0.510	0.573
	0.487	0.488	0.487	0.487	0.485	0.487
log of COW capabilities score, initiator	0.085	0.078	0.070	0.062	0.052	0.050
	0.144	0.146	0.144	0.146	0.142	0.144
log of COW capabilities score, target	-0.012	0.005	-0.038	-0.025	-0.021	0.000
	0.146	0.145	0.146	0.145	0.144	0.143
Intercept	3.753**	3.868**	3.674**	3.746**	3.488**	3.667**
	1.167	1.169	1.165	1.166	1.151	1.154
χ^2	102.112	100.832	99.075	97.437	98.430	97.137
N	4037	4037	4006	4006	3970	3970

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.7: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Shared Drought on Intensity of Cooperation, COPDAB

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.027	0.027	0.027	0.028	0.026	0.029	0.027	0.028
	0.240	0.241	0.241	0.241	0.238	0.241	0.241	0.241
Log of total dyadic trade	0.544**	0.540**	0.540**	0.539**	0.555**	0.540**	0.541**	0.540**
	0.076	0.076	0.076	0.076	0.075	0.076	0.076	0.076
PDSI, both states below -1 × shared basin	0.448							
	0.233							
PDSI, both states below -2 × shared basin		0.530						
		0.402						
PDSI, both states below -3 × shared basin			0.615					
			0.644					
PDSI, both states below -4 × shared basin				1.927*				
				0.979				
PDSI, years both states below -1 × shared basin					0.152			
					0.122			
PDSI, years both states below -2 × shared basin						-0.017		
						0.249		
PDSI, years both states below -3 × shared basin							0.002	
							0.475	
PDSI, years both states below -4 × shared basin								1.118
								0.839
Pct of country 1's area shared in dyad	0.672	0.684	0.685	0.684	0.630	0.672	0.687	0.686
	0.664	0.666	0.666	0.666	0.657	0.667	0.667	0.667
Pct of country 2's area shared in dyad	0.544	0.561	0.560	0.559	0.491	0.555	0.563	0.562
	0.663	0.664	0.665	0.665	0.657	0.666	0.666	0.666
Shared democracy (each score > 6)	0.695	0.696	0.710	0.715	0.546	0.731	0.708	0.713
	0.483	0.483	0.483	0.484	0.479	0.484	0.484	0.484
log of COW capabilities score, initiator	0.106	0.103	0.099	0.100	0.085	0.091	0.095	0.098
	0.144	0.144	0.144	0.144	0.143	0.145	0.144	0.144
log of COW capabilities score, target	0.023	0.021	0.016	0.016	-0.005	0.012	0.012	0.014
	0.144	0.144	0.144	0.145	0.143	0.145	0.145	0.145
Intercept	4.154**	4.177**	4.134**	4.140**	3.899**	4.083**	4.094**	4.114**
	1.148	1.152	1.151	1.152	1.137	1.153	1.153	1.152
χ^2	102.777	100.649	99.639	102.375	99.376	98.868	98.761	100.323
N	4085	4085	4085	4085	4072	4083	4085	4085

Significance levels: $*: < 5\%$ $**: < 1\%$

7.5.2 PANDA data

The PANDA data cover the years 1984–1994. This time period has a small overlap with the IDEA data, below. The results for this dataset are reported in Tables 7.8 (individual-level drought, cooperation frequency), 7.9 (shared drought, cooperation frequency), 7.10 (individual-level drought, cooperation intensity), and 7.11 (shared drought, cooperation intensity). The PANDA data return significant results that show water scarcity, both individual and shared, is associated with a *decrease* in the number of cooperative events between countries, rejecting Hypothesis H_{3a}. Individual-level water scarcity depresses the frequency of cooperation. Five of the six individual-level water scarcity variables are positive and statistically significant (opposite of results predicted by Hypothesis H_{3a}). Figure 7.1 illustrates the substantive effects of these variables.

Mild levels of shared water scarcity (Table 7.9) are associated with a drop in the number of cooperative events under drought conditions. Substantively speaking, more rain is associated with more cooperation between countries. However, this relationship does not extend to more extreme levels of drought or to multi-year droughts at any intensity. These findings provide some support for the idea that drought focuses governments on domestic issues and shuts down foreign policy activities, a result opposing Hypothesis H_{3a}.

As before in the COPDAB data, the COW capabilities of each state are associated with an increase the amount of cooperative events in each state, with larger military power being correlated with a rise in the amount of cooperation. The coefficients are slightly larger for the initiator state (about 0.245, whereas the coefficients for the target state are about 0.196).

Linear regression results of weighted sums of cooperation in Tables 7.10 and

7.11 show no change in the intensity of cooperation with variation in water availability. None of the individual-level or group water scarcity variables is significantly linked to the intensity of cooperation. Put another way, drought has no measurable effect on the intensity of dyadic cooperation. The only significant variables in the models predicting intensity of cooperation are, as before, the COW military capabilities indices. In all, the cross-sectional time-series OLS provides no support for Hypothesis H_{3b} (drought is associated with higher levels of cooperation).

TABLE 7.8: Negative Binomial Regression, Effect of Individual-Level Drought on Number of Cooperative Events, PANDA

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	0.033	0.049	0.032	0.053	0.033	0.055
	0.130	0.130	0.128	0.128	0.129	0.129
Log of total dyadic trade	-0.049	-0.048	-0.048	-0.048	-0.049	-0.050
	0.047	0.047	0.047	0.047	0.047	0.047
PDSI avg. (sender) $\times$ shared basin	0.060*					
	0.031					
PDSI avg. (target) $\times$ shared basin		0.059*				
		0.029				
PDSI avg., lagged (sender) $\times$ shared basin			0.063*			
			0.031			
PDSI avg., lagged (target) $\times$ shared basin				0.069*		
				0.029		
PDSI avg., three year (sender) $\times$ shared basin					0.077	
					0.042	
PDSI avg., three year (target) $\times$ shared basin						0.082*
						0.039
Pct of country 1's area shared in dyad	-0.078	-0.123	-0.108	-0.122	-0.095	-0.132
	0.315	0.303	0.314	0.302	0.319	0.304
Pct of country 2's area shared in dyad	-0.117	-0.114	-0.120	-0.115	-0.107	-0.101
	0.319	0.333	0.319	0.330	0.319	0.336
Shared democracy (each score $>$ 6)	0.043	0.040	0.034	0.034	0.037	0.035
	0.171	0.171	0.171	0.171	0.173	0.173
log of COW capabilities score, initiator	0.247**	0.246**	0.245**	0.244**	0.247**	0.244**
	0.072	0.073	0.072	0.073	0.073	0.074
log of COW capabilities score, target	0.196**	0.196**	0.196**	0.196**	0.196**	0.196**
	0.075	0.072	0.074	0.072	0.075	0.073
Intercept	0.235*	0.239*	0.239*	0.235*	0.257*	0.252*
	0.119	0.117	0.115	0.115	0.116	0.114
χ^2	36.896	38.094	35.802	36.913	35.904	37.136
Log-likelihood	-1535.143	-1531.16	-1531.778	-1526.069	-1517.856	-1514.044
N	1193	1188	1190	1185	1180	1175

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.9: Negative Binomial Regression, Effect of Shared Drought on Number of Cooperative Events, PANDA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.041	0.038	0.040	0.040	0.043	0.042	0.041	0.040
	0.129	0.130	0.130	0.130	0.129	0.130	0.130	0.130
Log of total dyadic trade	-0.045	-0.047	-0.046	-0.047	-0.046	-0.048	-0.047	-0.048
	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
PDSI, both states below -1 $\times$ shared basin	-0.314**							
	0.121							
PDSI, both states below -2 $\times$ shared basin		-0.266						
		0.165						
PDSI, both states below -3 $\times$ shared basin			-0.275					
			0.226					
PDSI, both states below -4 $\times$ shared basin				-0.206				
				0.326				
PDSI, years both states below -1 $\times$ shared basin					-0.052			
					0.037			
PDSI, years both states below -2 $\times$ shared basin						-0.056		
						0.075		
PDSI, years both states below -3 $\times$ shared basin							-0.075	
							0.106	
PDSI, years both states below -4 $\times$ shared basin								0.035
								0.109
Pct of country 1's area shared in dyad	-0.083	-0.102	-0.116	-0.126	-0.115	-0.130	-0.132	-0.140
	0.305	0.308	0.307	0.308	0.309	0.309	0.308	0.306
Pct of country 2's area shared in dyad	-0.078	-0.119	-0.130	-0.142	-0.088	-0.113	-0.132	-0.156
	0.324	0.326	0.325	0.324	0.327	0.326	0.326	0.324
Shared democracy (each score $>$ 6)	0.044	0.049	0.051	0.051	0.031	0.042	0.041	0.059
	0.172	0.173	0.172	0.174	0.177	0.176	0.174	0.173
log of COW capabilities score, initiator	0.240**	0.246**	0.248**	0.251**	0.245**	0.250**	0.251**	0.254**
	0.073	0.074	0.073	0.073	0.074	0.073	0.073	0.073
log of COW capabilities score, target	0.192**	0.198**	0.199**	0.202**	0.198**	0.203**	0.202**	0.206**
	0.073	0.075	0.074	0.074	0.075	0.075	0.075	0.074
Intercept	0.230*	0.242*	0.243*	0.246*	0.253*	0.255*	0.252*	0.248*
	0.115	0.118	0.117	0.117	0.115	0.116	0.116	0.116
χ^2	40.186	43.408	38.359	35.456	36.104	34.916	36.253	34.641
Log-likelihood	-1546.574	-1548.661	-1549.071	-1549.567	-1536.167	-1540.461	-1544.559	-1549.733
N	1206	1206	1206	1206	1196	1199	1203	1206

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.10: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Individual-Level Drought on Intensity of Cooperation, PANDA

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	0.290	0.360	0.266	0.365	0.300	0.366
	0.478	0.483	0.478	0.483	0.484	0.490
Log of total dyadic trade	-0.111	-0.110	-0.115	-0.117	-0.119	-0.118
	0.167	0.168	0.169	0.170	0.171	0.172
PDSI avg. (sender) × shared basin	0.128					
	0.157					
PDSI avg. (target) × shared basin		0.051				
		0.158				
PDSI avg., lagged (sender) × shared basin			0.096			
			0.159			
PDSI avg., lagged (target) × shared basin				0.154		
				0.158		
PDSI avg., three year (sender) × shared basin					0.114	
					0.211	
PDSI avg., three year (target) × shared basin						0.121
						0.205
Pct of country 1's area shared in dyad	0.519	0.379	0.370	0.358	0.359	0.287
	1.403	1.407	1.416	1.416	1.445	1.449
Pct of country 2's area shared in dyad	-0.488	-0.625	-0.585	-0.525	-0.399	-0.454
	1.408	1.414	1.404	1.416	1.436	1.450
Shared democracy (each score > 6)	-0.004	0.001	-0.028	-0.049	-0.020	-0.047
	0.790	0.792	0.796	0.797	0.803	0.805
log of COW capabilities score, initiator	0.949**	0.960**	0.951**	0.941**	0.951**	0.948**
	0.280	0.283	0.283	0.285	0.285	0.289
log of COW capabilities score, target	0.772**	0.784**	0.791**	0.787**	0.801**	0.801**
	0.281	0.279	0.283	0.282	0.288	0.286
Intercept	14.434**	14.598**	14.635**	14.618**	14.623**	14.692**
	2.624	2.634	2.654	2.663	2.677	2.691
χ^2	31.065	30.815	30.872	31.707	30.445	30.636
N	1193	1188	1190	1185	1180	1175

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.11: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Shared Drought on Intensity of Cooperation, PANDA

Variable	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**
	SE	SE	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	0.315	0.300	0.311	0.310	0.318	0.317	0.314	0.310
	0.469	0.470	0.470	0.470	0.475	0.473	0.471	0.470
Log of total dyadic trade	-0.096	-0.105	-0.109	-0.114	-0.117	-0.123	-0.114	-0.108
	0.166	0.166	0.166	0.166	0.169	0.168	0.166	0.166
PDSI, both states below -1 $\times$ shared basin	-1.182							
	0.645							
PDSI, both states below -2 $\times$ shared basin		-1.172						
		0.879						
PDSI, both states below -3 $\times$ shared basin			-0.565					
			1.064					
PDSI, both states below -4 $\times$ shared basin				-0.659				
				1.406				
PDSI, years both states below -1 $\times$ shared basin					-0.152			
					0.168			
PDSI, years both states below -2 $\times$ shared basin						-0.215		
						0.294		
PDSI, years both states below -3 $\times$ shared basin							-0.184	
							0.422	
PDSI, years both states below -4 $\times$ shared basin								0.148
								0.521
Pct of country 1's area shared in dyad	0.616	0.554	0.407	0.404	0.394	0.405	0.356	0.362
	1.379	1.383	1.378	1.378	1.419	1.405	1.383	1.375
Pct of country 2's area shared in dyad	-0.264	-0.382	-0.498	-0.530	-0.283	-0.382	-0.492	-0.597
	1.387	1.388	1.387	1.383	1.422	1.407	1.395	1.382
Shared democracy (each score $>$ 6)	-0.022	0.015	0.023	0.019	-0.053	-0.022	-0.034	0.058
	0.783	0.784	0.785	0.786	0.798	0.793	0.789	0.784
log of COW capabilities score, initiator	0.914**	0.921**	0.950**	0.959**	0.933**	0.952**	0.961**	0.976**
	0.278	0.280	0.280	0.278	0.284	0.281	0.280	0.279
log of COW capabilities score, target	0.744**	0.755**	0.789**	0.792**	0.792**	0.796**	0.797**	0.811**
	0.277	0.279	0.278	0.277	0.284	0.281	0.279	0.277
Intercept	14.090**	14.129**	14.471**	14.557**	14.450**	14.577**	14.603**	14.704**
	2.611	2.628	2.621	2.607	2.680	2.650	2.622	2.603
χ^2	34.951	33.086	31.654	31.61	31.936	32.001	31.928	31.5
N	1206	1206	1206	1206	1196	1199	1203	1206

Significance levels: $*: < 5\%$ $**: < 1\%$

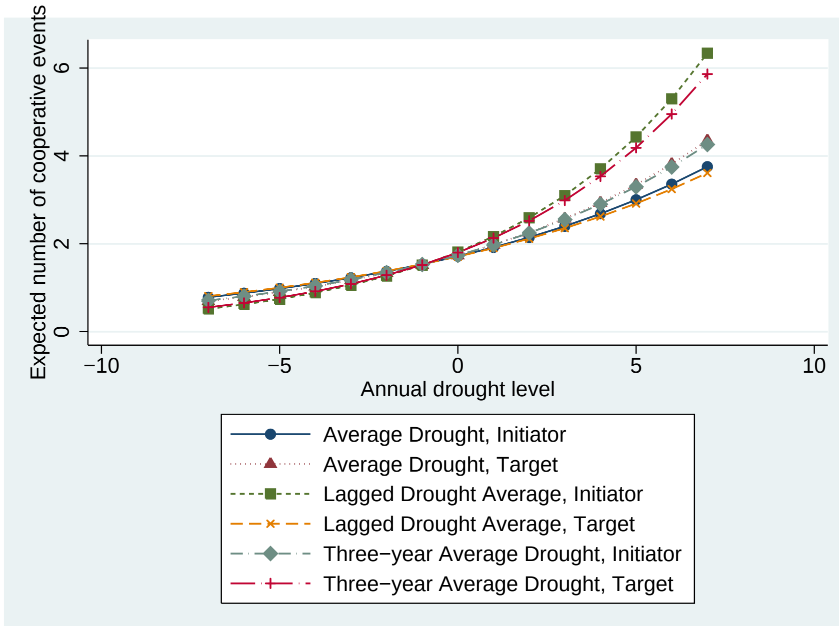

FIGURE 7.1: Graph of expected cooperative events (PANDA) versus individual drought level.

7.5.3 IDEA data

The IDEA data, covering the years 1990–2004,[13] contain a very large number of observations, and probably has fewer problems associated with attention bias compared to the earlier, smaller COPDAB and PANDA data sets. Tables 7.12 and 7.13 (which report the event count models considering the effect of individual-level and shared drought, respectively) offer the strongest evidence against H_{3a}. The water variables are nearly uniformly significant. As in the PANDA data, individual-level drought is associated with a decrease in the count of cooperative events in the dyad, initiated by state 'a.' All of the individual-level drought variables are statistically significant and in the predicted direction. Whether scarcity is operationalized by availability in the target or sender state, as a contemporaneous, lagged, or three-year average, the presence of scarcity is associated with a decrease in the

[13]Because of some missing covariates, only 1990–2001 are used for statistical analysis here.

number of cooperative events.

The shared and duration drought variables are less-uniformly significant, but a one-year shared drought is associated with a drop in the number of cooperative events, and consecutive years of drought reduce the number of expected cooperative events as well. The expected impact of these variables becomes stronger as the drought worsens. See Figures 7.2 and 7.3 for a graphical representation of drought effects on cooperative events, holding all other variables at their means or medians.

As in other data sets, above, the larger the COW military capabilities of either state, the greater the number of cooperative events can be expected. As seen in earlier chapters but not in the COPDAB or PANDA data results, dyadic trade is associated with an increase in cooperation. A larger difference between the sender and target countries real GDP per capita increases the expected number of cooperative events.

The results for the intensity of cooperation analyses using the IDEA data show a limited increase in cooperation as there is more water in the 'sender' country (with a corresponding decrease in cooperation during droughts). This coefficient is significant for the current-year level of drought, but not for the lagged measure of the three-year average measure. The one-year lagged value of scarcity in the 'target' state is also statistically significant and related to a decrease in the intensity of cooperation. The relationship is not significant for the current-year or three-year average measures, however. Among the shared drought variables only one of the eight measures, the shared, current-year drought of PDSI < -3 is significant. Its effect is in the predicted direction. Although not overwhelming, these findings suggest that if scarcity influences the intensity of cooperation, its effect is to depress the level of cooperation.

These models of cooperation intensity, again show that military power and trade are associated with increases in the intensity of cooperation. Additionally, shared democracy is significant, indicating that pairs of democratic states are more likely to engage in costly cooperation than dyads in which one or both states are non-democracies.

TABLE 7.12: Negative Binomial Regression, Effect of Individual-Level Drought on Number of Cooperative Events, IDEA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.295*	0.263	0.301*	0.269	0.293*	0.273
	0.136	0.140	0.137	0.141	0.138	0.142
Log of total dyadic trade	0.140**	0.141*	0.140*	0.144*	0.141*	0.145*
	0.054	0.056	0.055	0.057	0.055	0.057
PDSI avg. (sender) × shared basin	0.059*					
	0.024					
PDSI avg. (target) × shared basin		0.052*				
		0.021				
PDSI avg., lagged (sender) × shared basin			0.077**			
			0.025			
PDSI avg., lagged (target) × shared basin				0.095**		
				0.025		
PDSI avg., three year (sender) × shared basin					0.095**	
					0.036	
PDSI avg., three year (target) × shared basin						0.114**
						0.034
Pct of country 1's area shared in dyad	-0.266	-0.157	-0.267	-0.122	-0.259	-0.116
	0.306	0.293	0.310	0.296	0.313	0.298
Pct of country 2's area shared in dyad	-0.383	-0.405	-0.349	-0.387	-0.338	-0.382
	0.295	0.310	0.297	0.313	0.298	0.314
Shared democracy (each score > 6)	0.215	0.172	0.220	0.168	0.226	0.175
	0.138	0.134	0.141	0.136	0.140	0.134
log of COW capabilities score, initiator	0.260**	0.283**	0.262**	0.284**	0.262**	0.283**
	0.069	0.070	0.069	0.070	0.070	0.070
log of COW capabilities score, target	0.238**	0.221**	0.247**	0.228**	0.246**	0.228**
	0.068	0.068	0.069	0.068	0.069	0.068
Intercept	0.533**	0.528**	0.534**	0.519**	0.533**	0.519**
	0.176	0.185	0.179	0.186	0.180	0.187
χ^2	212.785	185.736	216.648	190.68	218.303	187.837
Log-likelihood	-2748.771	-2726.048	-2722.397	-2697.429	-2691.655	-2666.842
N	3501	3498	3477	3474	3428	3425

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.13: Negative Binomial Regression, Effect of Shared Drought on Number of Cooperative Events, IDEA

Variable	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE	**Coeff.** SE
Difference of log RGDP/capita	0.283*	0.285*	0.285*	0.284*	0.283*	0.284*	0.287*	0.284*
	0.130	0.132	0.132	0.132	0.131	0.132	0.132	0.132
Log of total dyadic trade	0.130*	0.129*	0.129*	0.128*	0.128*	0.128*	0.129*	0.128*
	0.051	0.053	0.053	0.053	0.052	0.053	0.053	0.053
PDSI, both states below -1 × shared basin	-0.203*							
	0.093							
PDSI, both states below -2 × shared basin		-0.164						
		0.112						
PDSI, both states below -3 × shared basin			-0.269					
			0.152					
PDSI, both states below -4 × shared basin				-0.243				
				0.212				
PDSI, years both states below -1 × shared basin					-0.054*			
					0.024			
PDSI, years both states below -2 × shared basin						-0.094		
						0.051		
PDSI, years both states below -3 × shared basin							-0.167*	
							0.079	
PDSI, years both states below -4 × shared basin								-0.133
								0.142
Pct of country 1's area shared in dyad	-0.276	-0.282	-0.288	-0.297	-0.284	-0.293	-0.279	-0.297
	0.297	0.296	0.298	0.298	0.303	0.301	0.299	0.298
Pct of country 2's area shared in dyad	-0.440	-0.453	-0.458	-0.463	-0.429	-0.447	-0.459	-0.464
	0.295	0.300	0.301	0.301	0.301	0.303	0.302	0.301
Shared democracy (each score > 6)	0.237	0.246	0.246	0.247	0.243	0.239	0.249	0.248
	0.133	0.136	0.136	0.136	0.136	0.137	0.137	0.136
log of COW capabilities score, initiator	0.264**	0.263**	0.264**	0.266**	0.259**	0.264**	0.266**	0.266**
	0.066	0.068	0.068	0.068	0.067	0.068	0.068	0.068
log of COW capabilities score, target	0.220**	0.219**	0.220**	0.222**	0.225**	0.225**	0.223**	0.222**
	0.066	0.067	0.067	0.067	0.067	0.068	0.067	0.068
Intercept	0.588**	0.594**	0.592**	0.595**	0.590**	0.593**	0.582**	0.596**
	0.168	0.171	0.171	0.170	0.171	0.172	0.172	0.170
χ^2	184.587	185.42	181.937	181.826	182.945	185.81	182.048	181.655
Log-likelihood	-2814.288	-2816.27	-2815.814	-2816.618	-2760.634	-2778.942	-2800.624	-2816.805
N	3581	3581	3581	3581	3505	3536	3561	3581

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.14: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Individual-Level Drought on Intensity of Cooperation, IDEA

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	1.252	0.747	1.255	0.709	1.242	0.765
	0.754	0.751	0.755	0.752	0.760	0.757
Log of total dyadic trade	1.015**	1.016**	1.004**	1.011**	1.012**	1.022**
	0.242	0.241	0.243	0.241	0.244	0.243
PDSI avg. (sender) × shared basin	0.244*					
	0.119					
PDSI avg. (target) × shared basin		0.179				
		0.117				
PDSI avg., lagged (sender) × shared basin			0.236			
			0.127			
PDSI avg., lagged (target) × shared basin				0.265*		
				0.124		
PDSI avg., three year (sender) × shared basin					0.358	
					0.199	
PDSI avg., three year (target) × shared basin						0.337
						0.197
Pct of country 1's area shared in dyad	-1.045	-0.598	-1.202	-0.794	-0.974	-0.545
	2.351	2.452	2.353	2.371	2.370	2.469
Pct of country 2's area shared in dyad	-1.556	-0.631	-0.754	-0.508	-1.555	-0.476
	2.421	2.322	2.349	2.321	2.440	2.340
Shared democracy (each score > 6)	2.380*	1.691	2.340*	1.633	2.362*	1.654
	0.926	0.923	0.929	0.926	0.934	0.931
log of COW capabilities score, initiator	1.575**	1.683**	1.543**	1.655**	1.578**	1.666**
	0.495	0.499	0.497	0.498	0.499	0.504
log of COW capabilities score, target	1.654**	1.633**	1.731**	1.636**	1.646**	1.632**
	0.497	0.492	0.497	0.493	0.502	0.496
Intercept	21.725**	21.751**	21.716**	21.734**	21.833**	21.737**
	4.592	4.579	4.610	4.590	4.630	4.615
χ^2	115.866	106.395	113.352	107.739	114.539	107.084
N	3501	3498	3477	3474	3428	3425

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 7.15: Autoregressive Cross-Sectional Time-Series Linear Regression, Effect of Shared Drought on Intensity of Cooperation, IDEA

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	1.037	1.041	1.040	1.034	1.030	1.030	1.037	1.034
	0.741	0.741	0.741	0.741	0.746	0.744	0.742	0.741
Log of total dyadic trade	0.982**	0.991**	0.991**	0.989**	0.981**	0.985**	0.983**	0.983**
	0.239	0.239	0.239	0.239	0.241	0.240	0.240	0.239
PDSI, both states below -1 × shared basin	-0.091							
	0.452							
PDSI, both states below -2 × shared basin		-0.749						
		0.602						
PDSI, both states below -3 × shared basin			-1.731*					
			0.772					
PDSI, both states below -4 × shared basin				-1.001				
				0.975				
PDSI, years both states below -1 × shared basin					0.090			
					0.120			
PDSI, years both states below -2 × shared basin						-0.248		
						0.226		
PDSI, years both states below -3 × shared basin							-0.547	
							0.360	
PDSI, years both states below -4 × shared basin								-0.320
								0.505
Pct of country 1's area shared in dyad	-1.384	-1.255	-1.156	-1.331	-1.473	-1.273	-1.250	-1.378
	2.328	2.330	2.329	2.327	2.342	2.338	2.330	2.325
Pct of country 2's area shared in dyad	-1.190	-1.065	-0.957	-1.128	-1.305	-1.057	-1.068	-1.179
	2.303	2.304	2.304	2.302	2.316	2.313	2.305	2.300
Shared democracy (each score > 6)	2.433**	2.388**	2.375**	2.408**	2.533**	2.380**	2.419**	2.431**
	0.917	0.917	0.916	0.917	0.931	0.922	0.918	0.917
log of COW capabilities score, initiator	1.597**	1.576**	1.576**	1.590**	1.644**	1.588**	1.589**	1.593**
	0.492	0.492	0.492	0.492	0.496	0.494	0.492	0.491
log of COW capabilities score, target	1.627**	1.604**	1.610**	1.621**	1.678**	1.619**	1.622**	1.623**
	0.490	0.490	0.490	0.490	0.494	0.492	0.490	0.489
Intercept	21.549**	21.270**	21.265**	21.423**	22.048**	21.441**	21.469**	21.491**
	4.554	4.560	4.555	4.555	4.596	4.583	4.563	4.552
χ^2	107.327	108.846	112.35	108.373	108.11	108.317	110.113	107.893
N	3581	3581	3581	3581	3505	3536	3561	3581

Significance levels: $*: < 5\%$ $**: < 1\%$

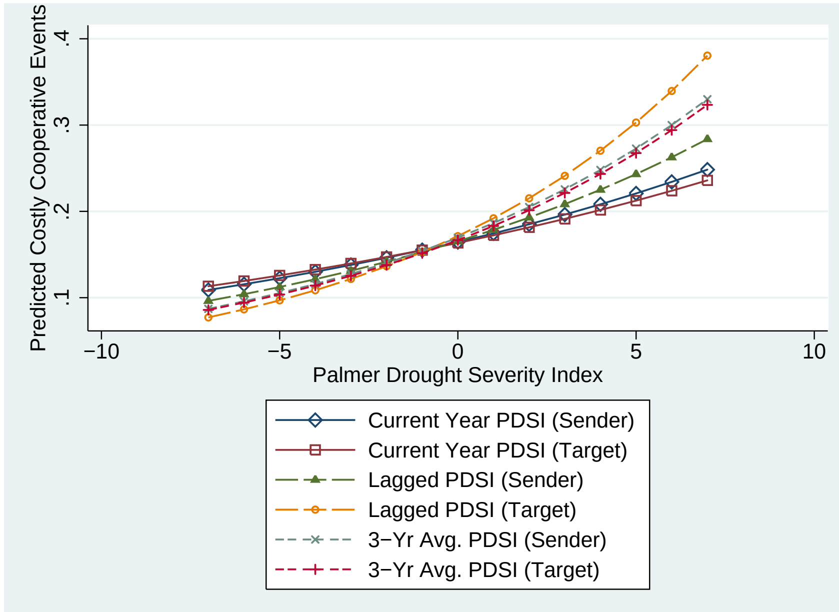

FIGURE 7.2: Graph of expected cooperative events (IDEA) versus individual drought level.

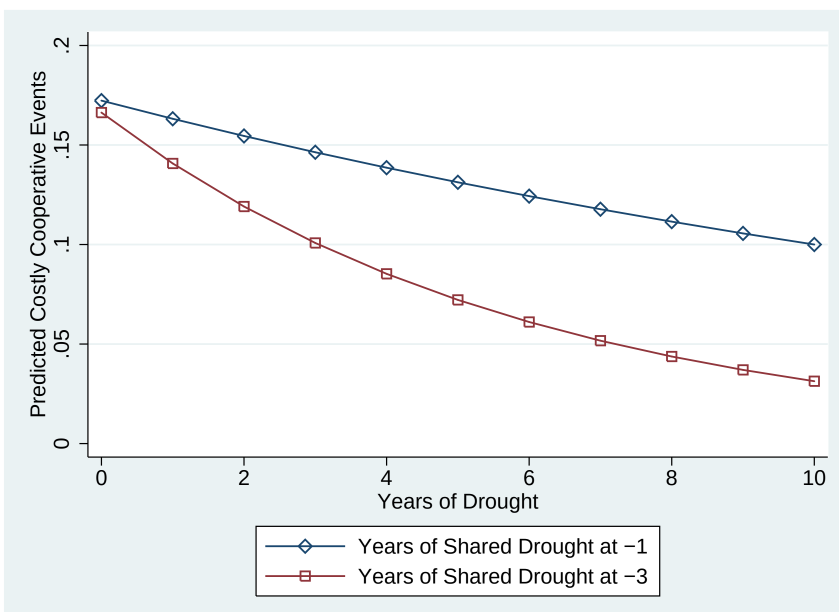

FIGURE 7.3: Graph of expected cooperative events (IDEA) versus years of shared drought.

7.6 Discussion

The effects of drought on the *number* of cooperative events are significant for shared and individual-level droughts. This pattern could mean that states reduce the activity of their foreign policy, save very important international events or obligations. Tests in the last two chapters show that conflict either does not increase during droughts, or in the case of military conflict, drops off. These findings support the more optimistic expectations of the cornucopian thinkers and the rational idea that war should not happen because it is not cost effective given the expected outcomes.

Results from this chapter show that while the chances of war and violent interstate conflict drop off, there is no corresponding increase in cooperation. Rather, cooperation *also* drops off during droughts, and sharply so during shared droughts. These findings are fairly robust across several tests, datasets, and dependent variables. These findings undercut the ideas of some of the more optimistic theorists, who propose that water is so precious that rather than fight, drought-stricken countries prefer cooperation rather than risk harming the resource in an armed conflict. These results reject Hypotheses H_3 (scarce water has an impact on cooperation), H_{3a} (drought increases the number of cooperative events, and H_{3b} (drought increases the intensity of cooperation between countries).

It appears that countries avoid cooperation along with conflict during times of water stress. I propose therefore, that similar to the explanation offered in Chapters 5 and 6, countries cannot gain immediate relief from the drought by either making war or by merely increasing the level of dyadic cooperation. Drought gives countries little *reason* to go to war, or to sign a trade agreement, or to have cultural exchanges. Countries, despite internal pressures to deal with the drought, apparently do not look increase their external commitments and entanglements, because of cooperative gains that will abate or minimize the effects of the drought. Avoiding cooperation prevents obligations that might be undesirable for a country that prefers self-reliance, but do nothing to relieve a drought's effects.

As stated in Chapters 2 and 3, importing grain or iron and steel can greatly offset crop losses and water shortages for countries that can afford it. Those countries that cannot afford or do not wish to import grain or iron and steel have even greater impetus to immediately and internally address the drought's effects. Without trade or other profitable activity, the drought may undercut both the social stability and the government's ability to stay relevant or effective as the crisis worsens. This instability from drought will be worse in primarily agricultural economies, and worse among poorer states with a less-diverse economy. These states are least able to offset the impact of drought with trade or subsidy.[14] However, cooperation, including trade, produces dependencies and commitments that may not be easily abandoned. These obligations may not be preferable for states over the long term, despite their positive-sum outcomes. States may prefer present pain to unknown future difficulties stemming from a new institution, agreement, or trade relationship. However, I expect the need for relief, whether from the effects of the drought or from an angry electorate, will push states to seek out gains from cooperation during a drought.

These results are potentially similar to Yoffe, Wolf and Giordano (2003), who find that "countries that cooperate in general also cooperate over water, and countries with overall unfriendly relations are also unfriendly over water issues." I find that external droughts reduce the overall level of, and intensity of, cooperation be-

[14]It is also possible that these states have little cooperation with neighbors because of their small economies and lack of exportable goods, but that topic is external to this, more general, analysis.

tween countries. This effect is not the same as expecting overall cooperation to lead to water cooperation, but in the next chapter, I find that water-specific cooperation is not affected by the decline in cooperation that accompanies a drought.

In Chapter 8, I examine the potential for water-specific cooperation under drought conditions. While an increase in international cooperation may not necessarily bring substantive, immediate relief to a country under drought conditions, in some cases "hydro-cooperation" can improve water conditions within days, and even if large projects must be undertaken, will bring relief on a shorter, and more reliable, time scale than either conquest or broadly increasing economic activity.

Chapter 8

Drought and "Hydro-Cooperation"

> Forever and evermore, I shall not transgress the territory of Ningirsu! I shall not shift its irrigation channels and canals! I shall not smash its monuments! Whenever I do transgress, may the great battle net of Enlil, king of heaven and earth, by which I have sworn, descend upon Umma!
>
> *From the treaty ending the Lagash–Umma water conflict, 2500 BCE*

This chapter tests the hypothesis that states are more likely to enter into water treaties during times of water stress. If states choose a diplomatic path and enter into negotiations with each other, they may successfully create a treaty. These treaties normally take years to negotiate and implement before the benefits of the treaty are realized, though some situations may facilitate more immediate relief. Any given treaty may have no substantive obligations, but some treaties measurably divide water resources and/or create costly cooperative ventures such as dams or pollution control. These specific provisions make it possible to identify water-specific, costly cooperation between or among countries. This water-specific cooperation is important because it may take place despite ongoing conflicts that overshadow water-specific cooperation, or it may take place despite a difficult water scarcity episode, contrary to the expectations of some realists and others (Klare 2002, e.g.). If *general* cooperation exists in great amounts, it would be unsurprising to see *water-specific* cooperation; if cooperation is unchanged, dwindling and/or conflict is on the rise, it is counter-intuitive to expect an increase in any specific type of cooperation, barring external influences. The results from Chapters 5 and 6 on conflict and water stress show that conflict does not rise during droughts. Chapter 7 shows that overall cooperation shrinks or does not change during water scarcity events. If cooperation declines, even in the absence of military conflict, how might the likelihood of water-specific treaties rise?

International treaties that deal with water as a natural resource often provide explicit obligations on each side. These obligations reflect concrete cooperation over water and related resource issues in an anarchic environment. Because these obligations are specific to hydraulic resources, it is more likely that the climatic and drought conditions will have an impact on the occurrence of these treaty-signing events. Rather than trace overall cooperation like events data usually do, these events are specific and should help differentiate between the causes of more general events or averages of those events. The water treaty data are taken from the *Transboundary Freshwater Dispute Database* (Beach et al. 2000, Wolf and Hamner 2000).[1] This project contains over 300 interstate water treaties and contains great detail about each agreement. These treaties sometimes explicitly provide actual proportions of benefits assigned to each signatory.

[1]The database collection effort was begun in 1995 and continues, now titled the "Basins at Risk" project (Wolf, Yoffe and Giordano 2003). I collected the first 250 and located 150 other missing treaties of potential use. The FAO collections of water treaties number over 3600, but nearly all do not treat water as a specific resource. Most of the treaties address navigation, taxes and commerce, boundary demarcation, or other issues that do not address water as a natural resource.

8.1 Theoretical Summary of Treaty Formation

A fuller discussion of the underpinnings of water treaties and their formation can be found in Chapter 3. However, a summary re-statement follows.

8.1.1 Unilateral Development and Endogenous Scarcity

States have a general desire for self-reliance; this desire means that states in the realist paradigm may prioritize cooperation below autarky under normal conditions, preferring the ability to abandon trade and other mutually beneficial forms of cooperation at a moment's notice. A state with access to some water resource, even if it is shared, will develop local resources unilaterally. The returns on water resources development are generally decreasing with respect to cost. That is, self-reliance on water becomes increasingly expensive. States at some point will become less willing to spend money on "water autarky" and will begin importing water via trade and other forms of substitution or efficiency gains. States will also look to cooperative ventures with neighbors. The costs of these cooperative ventures (and the subsequent reduction in self-reliance) makes such ventures costly for leaders to propose despite the potential gains from cooperation.

8.1.2 Water Crisis Behavior

If states eschew violent conquest in the face of exogenous (periodic) water scarcity, they have several options to offset the effects of that scarcity. First, they may make internal changes. These changes are painful and costly, and may upset large portions of the selectorate or empower opposition parties against those in power. However, these changes may reflect pareto improvements or encourage efficiency improvements that might otherwise be ignored. Internal changes include supply augmentation via dams or desalination; efficiency improvements via technology upgrades and rationing; shifting water to higher-value industries or crops; and importing 'virtual' water via substitutes such as grain and finished steel. Internal options such as these may be the only path open to some states, with unwilling or hegemonic river basin partners; strong states may deter or evade attempts to negotiate sharing agreements or other mechanisms.

8.1.3 Domestic Treaty Approval

Domestic (within-country) pain that results from a drought may increase the public's willingness to accept water supply outcomes that would be unacceptable in non-drought years. The up-front costs of an agreement result in greater future stability of water supply. Prospect theory (Kahneman and Tversky 1979) highlights two important facts about uncertainty: first, that leaders prefer certain outcomes to uncertain ones, even uncertain ones that would result in greater benefits; and second, that even a small number of positive outcomes quickly reset the zero-point for comparison. Thus during a drought, people compare the situation to the usual average. But after a few years of above-average rainfall, even a "normal" year of rainfall would be viewed as a drought. Using Kahneman and Tversky's ideas, it is possible to infer that the annual variability of rainfall and soil moisture is less preferable to a guaranteed constant water supply—*even if it is a smaller amount than the average*. Reducing the uncertainty of water supplies makes economies, leaders, and populations more content (Lodgaard 1992).[2]

The selectorate in a country pays closer attention to the activities of the government during crises, economic or otherwise (Downs 1957, 36–52). For instance, in the United States, voter participation rises during economic downturns or other

[2] Note that prospect theory could cut both ways; a public's sensitivity to drought may make them less willing to accept losses in future water supplies, especially given their current conditions. I assume that half a loaf is better than none.

nationally divisive or troubling situations (Abramowitz and Saunders 2008). Therefore, audience costs of bad decisions or outcomes will be elevated during crises. During these crises, if a government avoids violence, a policy change can offer governments a chance to change the [s]electorate's negative expectations of future performance (thus keeping the incumbents in office or avoiding violent uprisings). The polity might normally reject agreements with neighbors that reduce the availability of water (say, building a dam or specifying quantities of water allocated to each country), but the reduction in uncertainty will allow countries to accommodate and adapt to these changes. Treaties can make situations more stable, and that benefit may be worth more than the cost of making and maintaining a treaty's provisions. Drought, plus the potential benefits from cooperation, may offer leaders the opportunity to make significant policy changes that will benefit the entire country rather than either continuing to suffer under a drought.

8.1.4 Interstate Treaty Negotiation

A treaty might just codify the status quo[3] (Downs, Rocke and Barsoom 1996, Powell 1999); merely codifying the status quo is a less compelling argument if both target states are suffering from a water shortage, but remains possible. A treaty could also reflect the desire of a hegemon to keep the system stable (e.g. the USA and Mexico in 1973), at some cost to itself. But if cooperation is possible, and provides some benefit to both sides, an otherwise unwilling partner might agree to a water supply treaty during a drought. States may find that they have a linked fate with regard to water supplies, improving the chances for a new agreement. The promise of efficiency improvements or side payments might also raise the likelihood that states will engage in new cooperation.

[3] Mearsheimer (2001, 138,152) calls this "blackmail."

8.1.5 Hypotheses

Because droughts create uncertainty and economic disruption but apparently do not lead to war, countries obviously find ways to cope. One mechanism they may use to cope with water stress is a cooperative treaty. This chapter tests whether states are more likely to enter into water treaties of various kinds, including specific water-sharing agreements, during times of water stress. I codify this idea in Hypotheses H_4 and H_{4a}.

> H_4: *A state experiencing a period of acute scarcity experiences an* **increase in the likelihood of the formation of a treaty addressing water issues** *with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.*
>
> H_{4a}: *Acute water scarcity* **increases** *the likelihood of water treaty formation; this impact intensifies as the* **intensity of the acute scarcity increases.**

8.2 Treaty Data

8.2.1 Dependent Variables

The dependent variable in this series of tests is the *formation of a treaty specifically addressing fresh water as a resource*, rather than as a boundary. Treaties addressing the oceans are not considered since ocean water is not currently a scarce commodity and is unusable for most economic activities for which fresh water is used. These freshwater treaties are relatively rare as international events. Their rarity does not detract from their impact: several institutions that address international basins such as the Mekong Commission and the Permanent Indus Commission have performed their duties and maintained their commitments through wars among signatories. Others, like the US–Mexico International Boundary Commission, have given leverage to weaker countries that lie outside of the realist expectations, though not all treaties create international organizations.

The Transboundary Freshwater Dispute Database covers the time period from the early 1800s through the present, but because of the great social and economic changes in the international state system following the Second World War, I limit the time period of analysis to 1948–2001, like the previous two chapters. The treaties to be examined are grouped into three types of agreements.

I classified the treaties in the Transboundary Freshwater Dispute Database into three groups for testing. There is some overlap between some of the groups. Not all of the treaties in the database are included in these categories.

First, I model the adoption of treaties specifically addressing hydropower and navigational situations. These activities involve dams, river bank maintenance and who pays for it, and the distribution of benefits from electricity generation by the dams. Second, there are treaties that deal with water supplies, water quality, and irrigation. These treaties may have an environmental protection component or create an environmental institution that specifically addresses water issues. They may also include treaties that explicitly divide shared water resources into quantities or percentages of available flow that are allocated to each party of the treaty. Irrigation treaties may do both. Lastly, the third group of treaties under examination are treaties that explicitly divide up fresh water resources among the signatory countries. Treaties in this third category are the most restrictively specific: they only deal with water supply; they clearly and explicitly divide up water resources. Not all treaties that address hydropower also discuss or divide up storage of water behind those dams, and thus these treaties cannot be viewed as relevant to international water supply and/or storage; sometimes these treaties are separate from water supply treaties (that may be tougher to negotiate), and thus hydropower and water supply are kept separate. Treaty types are summarized in Table 8.1.

TABLE 8.1: Water Treaty Types Used to Test Hypothesis H_4

Treaty Type	**Description**
Hydropower & navigation	Dam building and management, reparations for displaced people, channel dredging, canal building
Water supply, irrigation & water quality	Environmental concerns, pollution, dumping, waste, fertilizer/effluent concerns (especially from agricultural activity), and water supply treaties.
Water supply only	Only treaties that specifically divide fresh water among riparians with specific allocated amounts

8.2.2 Independent Variables

The water stress variables are identical to those in the previous chapters; they are broken into two types: individual country-level water stress, and shared water stress of varying intensities. Unlike previous chapters, I do not include the length of duration of a given shared water stress level because of problems with using covariates that measure duration in a duration model analysis. Recall that the individual-level and shared drought variables are coded differently. For the individual-level measure, higher values are associated with wetter conditions. For the shared drought measure, higher values are associated with drier conditions. Accordingly, H_4 predicts that the coefficients for the water variables will be negative in the individual-level models and positive in the shared drought models.

As with previous chapters, the other independent variables are a small, empirically established set of variables common to many studies in international relations, intended to avoid omitted variable bias and provide baselines for comparison with the water stress variables as they are correlated with changes in the likelihood of two countries signing a treaty dealing with water issues. The non-water covariates include measures of dyadic trade, differences in RGDP per capita, an indicator of shared democracy, and measures of military capabilities.

There are two important differences in the data set used for the analysis of the water treaties, compared to the data sets used elsewhere in this project. First, rather than use directed dyads, I use non-directed dyads; in this series of tests, each state pair appears only once in the data. The states are no longer given the opportunity to be both 'sender' (previously state *a*) and 'target' (previously state *b*). Diplomatic machinations make it difficult to determine who made the initial move towards a treaty, and both states must agree to the treaty regardless of who makes the first move. Second, the state labels 'a' and 'b' are re-assigned. The PDSI of state 'a' is lower (drier, 'worse') than the PDSI of state 'b'. In other words, state 'a' will always be the more water-stressed state, and the state-level covariates (here, the COW military capabilities) are re-computed based on the new definition of states 'a' and 'b' where necessary. So, in this test, I examine each state pair only once, and state 'a' will always be drier than state 'b'.

8.3 Methodology

Because the occurrence of a treaty is relatively rare and less likely to occur in groups, I analyze them using an event-history model. The coefficients of this statistical model reflect the increase or decrease in the likelihood that an event will occur during a given time period, as a result of changes in the covariates. Because I have no expectations for the shape of the likelihood (hazard) curve as time changes, I choose to use Cox's (1972, 1975) semi-parametric model. The relatively small number of treaty outcomes is still large enough to allow a Cox model to discern some relation between changes in a small set of covariates and the increased or decreased likelihood of a "failure" (event occurrence) in a given time period.

In addition to statistical tests, I also tested the models themselves to see if any model overall, or any variables within the model, violate assumptions of the Cox model (thus rendering its results suspect or invalid). For the variables and time periods tested here, I found no violation of the proportionality assumptions; that is, the shape of the hazard does not change with a change in one or more variables (Table 8.2). Rather, the position of the hazard shifts upward or downward from the established baseline. As a result, these Cox model results are nominally robust and unbiased.

Results from the proportional hazard testing for one of the models for the water supply treaties is presented in Table 8.2. The test provides no suggestion of non-proportional hazards. Other tests for proportional hazards were similar. As such, I have confidence that the Cox model is an appropriate means to analyze the data, and that although I do not have a preliminary expectation of the shape of the hazard, the data can be reliably tested by the Cox survival model.

TABLE 8.2: Proportional Hazard Test Results

Variable	ρ	χ^2	**df**	**Prob.** $> \chi^2$
Shared drought at PDSI < -2	-0.062	0.09	1	0.760
Shared Democracy	-0.090	0.33	1	0.568
Difference of logged RGDP per capita	-0.021	0.02	1	0.889
Log of total dyadic trade	-0.000	0.00	1	0.999
Log of COW military capabilities (lower PDSI)	0.027	0.03	1	0.870
Log of COW military capabilities (higher PDSI)	0.065	0.14	1	0.705
Global test		0.59	6	0.997

Though Cox models do not theoretically allow simultaneous events, and though the water scarcity data described in Chapter 4 is monthly, not annual, the remainder of the covariates are stored as annual data. As a result, I aggregate the water scarcity data up to the annual level and use the Efron method for deciding ties where simultaneous events occur (Efron 1977).

8.4 Results

Model results for three types of treaties are listed here: hydropower & navigation, water supply & water quality, and water supply only.

8.4.1 Hydropower and Navigation Treaties

Tables 8.3 and 8.4 show the results of the Cox models for the tests of influences on the relative changes in time between hydropower and navigation treaties for the individual-level (Table 8.3) and shared (Table 8.4) drought variables.

States with lower levels of water stress (that is, higher average PDSI values) have a greater hazard of signing a treaty over a given time span. This effect is significant and consistent across the individual-level and shared drought models. Also unsurprising is that greater availability of water makes hydropower and navigation more prominent or possible. Put another way, if there is not any water available, it is less important to build hydropower projects and less useful to agree upon navigation regimens when there is no water in the river channel or canal. See Figure 8.1 to see the decrease in the hazard as both countries share a drought of PDSI< -2 or worse: the baseline hazard (the solid line) reflects about a 20% cumulative chance of a hydropower or navigation treaty after twenty years of normal water conditions, all else being equal. When the two countries share a moderate drought, the cumulative chance of a treaty is a little greater than half that of the unstressed model over the same duration.

The impact of individual-level water variables (Table 8.3) on the hazard of the hydropower and navigation treaties is quite strong under conditions of greater water availability for a state, though less strong or insignificant for the country with the lesser level of water availability. It appears that the country with more water is therefore more likely to (i.e. the hazard is greater) enter into a water treaty

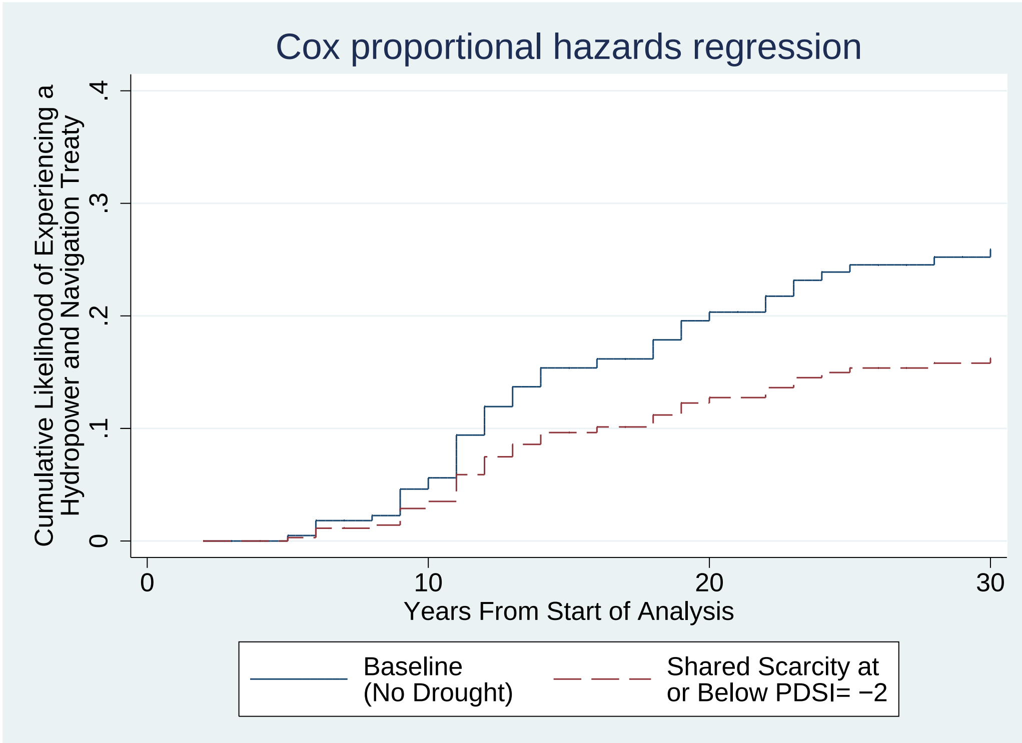

FIGURE 8.1: Water Stress and Navigation or Hydropower Treaties. Shared drought reduces the hazard that a treaty is signed at a given moment.

than the country with less water. Or, the country with less water is a constraint on the treaty making process. Similarly, shared scarcity is associated with a significant and strong lengthening of the time between treaties (see Table 8.4). These results do not support Hypotheses H_4 or H_{4a}. There is a change in the likelihood of a treaty addressing water issues, but drought reduces that likelihood.

Both the individual-level and shared drought analyses indicate that as levels of trade increase, the time between expected hydropower and navigation treaties shrinks. This makes intuitive sense, as countries that share a water resource probably use it for navigation and thus, commerce. Shared democracy significantly lengthens the time between treaties. As the military power of the wetter state rises, the time between treaties lengthens. There is some evidence that as the military power of the drier state rises, the time between treaties lengthens. The measures of COW capabilities of the drier state are significant and negative in two of the six individual-level drought models and in two of the three shared drought models. The military power of the wetter state has no effect.

TABLE 8.3: Cox Survival-Time Regression, Effect of Individual-Level Drought on Probability of Adoption of Hydropower and Navigation Treaties

Variable	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	-0.460	-0.416	0.157	0.214	0.030	-0.003
	0.399	0.406	0.346	0.384	0.336	0.361
Log of total dyadic trade	0.287*	0.311**	0.193	0.177	0.229*	0.272*
	0.120	0.119	0.123	0.120	0.112	0.107
PDSI avg. (drier) × shared basin	0.284*					
	0.135					
PDSI avg. (wetter) × shared basin		0.413**				
		0.139				
PDSI avg., lagged (drier) × shared basin			0.238*			
			0.100			
PDSI avg., lagged (wetter) × shared basin				0.476**		
				0.117		
PDSI avg., three year (drier) × shared basin					0.332*	
					0.132	
PDSI avg., three year (wetter) × shared basin						0.528**
						0.127
Shared democracy (each score > 6)	-1.711**	-1.785**	-1.678**	-1.631**	-1.582**	-1.769**
	0.467	0.415	0.564	0.512	0.442	0.435
log of COW capabilities score (drier)	-0.363*	-0.371*	0.062	0.086	-0.196	-0.212
	0.159	0.158	0.139	0.154	0.150	0.169
log of COW capabilities score (wetter)	-0.185	-0.243	-0.333	-0.361	-0.228	-0.270
	0.142	0.129	0.180	0.187	0.149	0.145
χ^2	29.834	47.955	18.001	37.976	24.778	31.958
Log-likelihood	-79.535	-77.482	-76.382	-72.467	-78.814	-75.89
N	6282	6282	6208	6208	6092	6092

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 8.4: Cox Survival-Time Regression, Effect of Shared Drought on Probability of Adoption of Hydropower and Navigation Treaties

Variable	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	-0.453	-0.280	-0.426
	0.430	0.412	0.396
Log of total dyadic trade	0.280*	0.332**	0.296*
	0.130	0.126	0.120
PDSI, both states below -1 × shared basin	-1.514**		
	0.584		
PDSI, both states below -2 × shared basin		-1.637*	
		0.746	
PDSI, both states below -3 × shared basin			-0.343
			1.176
Shared democracy (each score > 6)	-1.662**	-1.651**	-1.547**
	0.427	0.472	0.485
log of COW capabilities score (drier PDSI)	-0.350*	-0.350*	-0.271
	0.153	0.145	0.151
log of COW capabilities score (wetter PDSI)	-0.195	-0.194	-0.141
	0.139	0.148	0.153
χ^2	36.379	32.54	23.196
Log-likelihood	-77.592	-78.877	-81.618
N	6282	6282	6282

Significance levels: $*: < 5\%$ $**: < 1\%$

8.4.2 Water Supply and Water Quality Treaties

The results for the analysis of water supply, water quality, and irrigation treaties are found in Tables 8.5 (individual-level drought) and 8.6 (shared drought).

The performance of the individual-level drought variables is inconsistent. The variables are not consistently statistically significant, or consistently in the same direction. One individual-level drought variable significantly shrinks the expected time between treaties: as the drier state's three-year average PDSI values rise, the hazard of a treaty on water supply or quality rises in a given time period (the time between treaties grows shorter). Opposing the shrinking times between treaties for the three-year average PDSI of the drier state is the three-year average PDSI for the *wetter* state, which is significant and has a larger negative coefficient (lengthening the time between treaties).

The findings for the shared drought variables are more consistent and are consistent with the predictions of H_4. Mild and moderate drought are strongly associated with an increase in the hazard of a new treaty (i.e. a new treaty is more likely to occur sooner rather than later under these conditions). And a moderate drought is associated with a larger hazard than a mild drought, offering some support for H_{4a}, that treaty adoption becomes more likely as drought severity increases. H_{4a} is not wholly supported, however, as the significant effect does not extend to the most severe droughts. Figure 8.2 graphically displays the expected changes in the hazard that a treaty is signed. The reference condition (no drought), a solid line, shows the cumulative chance of a treaty being signed in ten years to be about 20%. The dashed line shows, all else remaining equal, nearly double the chance of a treaty under shared conditions of PDSI less than -2 during that time.

These results are consistent with the idea that countries take drought seriously and take steps to improve their water supply and water quality, even though they reduce their interactions (positive and negative) with their neighbors during a drought, as seen in chapters 5, 6 and 7. These results support Hypotheses H_4 (drought makes a treaty more likely) and partially support H_{4a} (more intense drought makes a treaty more likely).

The majority of the non-water variables are unrelated to changes in the probability of treaty adoption. Joint democracy tends to lengthen the time between treaties but the remaining covariates are not significant.

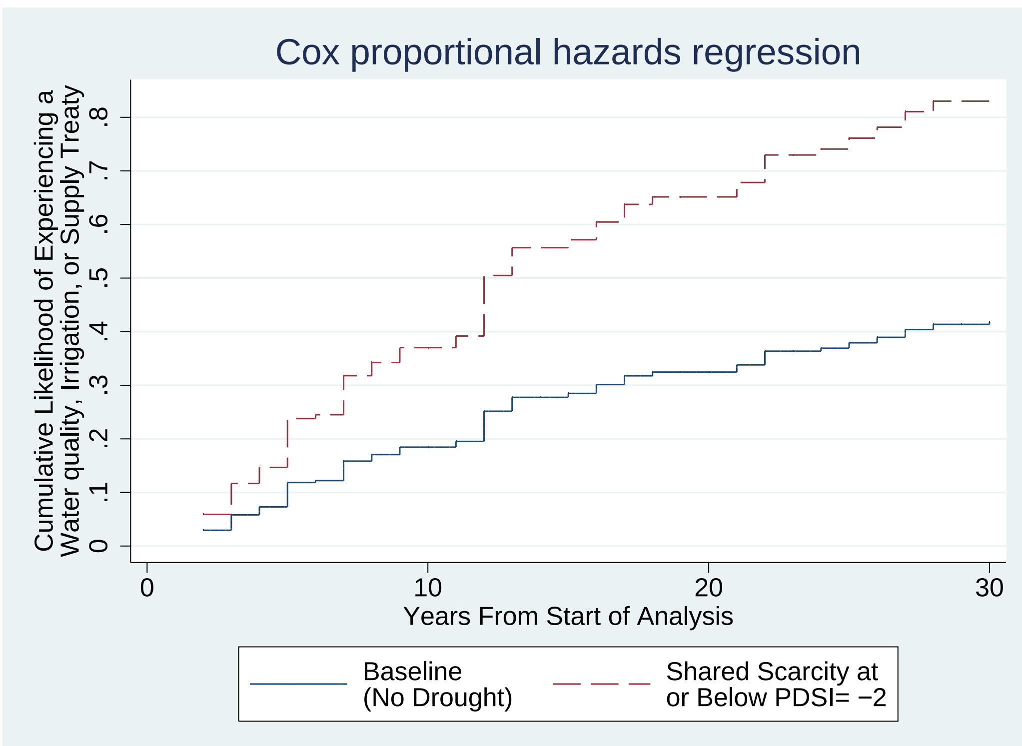

FIGURE 8.2: Water Stress and Water Supply, Irrigation, and Water Quality Treaties. Shared drought increases the hazard that a treaty is signed at a given moment.

TABLE 8.5: Cox Survival-Time Regression, Effect of Individual-Level Drought on Probability of Adoption of Water Supply, Quality, and Irrigation Treaties

Variable	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**
	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	0.170	0.166	0.043	0.060	0.099	0.110
	0.104	0.104	0.120	0.119	0.102	0.102
Log of total dyadic trade	-0.019	-0.021	-0.035	-0.022	-0.010	-0.009
	0.044	0.043	0.045	0.045	0.050	0.046
PDSI avg. (drier) × shared basin	-0.042					
	0.051					
PDSI avg. (wetter) × shared basin		-0.070				
		0.059				
PDSI avg., lagged (drier) × shared basin			0.118*			
			0.059			
PDSI avg., lagged (wetter) × shared basin				0.048		
				0.062		
PDSI avg., three year (drier) × shared basin					-0.021	
					0.075	
PDSI avg., three year (wetter) × shared basin						-0.203*
						0.092
Shared democracy (each score > 6)	-0.664**	-0.675**	-0.467	-0.522*	-0.504*	-0.533**
	0.228	0.227	0.240	0.240	0.200	0.203
log of COW capabilities score (drier)	-0.034	-0.032	0.022	0.022	0.075	0.092
	0.053	0.053	0.071	0.071	0.055	0.056
log of COW capabilities score (wetter)	0.045	0.055	0.013	0.005	0.129	0.151
	0.063	0.062	0.077	0.077	0.081	0.079
χ^2	16.036	17.925	13.601	10.642	16.667	27.942
Log-likelihood	-198.295	-198.034	-196.211	-197.543	-181.407	-179.622
N	6282	6282	6208	6208	6092	6092

Significance levels: $* : < 5\%$ $** : < 1\%$

TABLE 8.6: Cox Survival-Time Regression, Effect of Shared Drought on Probability of Adoption of Water Supply, Quality, and Irrigation Treaties

Variable	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	0.179	0.166	0.156
	0.107	0.112	0.107
Log of total dyadic trade	-0.032	-0.023	-0.020
	0.044	0.043	0.043
PDSI, both states below -1 $\times$ shared basin	0.597*		
	0.243		
PDSI, both states below -2 $\times$ shared basin		0.626*	
		0.248	
PDSI, both states below -3 $\times$ shared basin			0.190
			0.361
Shared democracy (each score $>$ 6)	-0.633**	-0.676**	-0.660**
	0.234	0.226	0.228
log of COW capabilities score (drier)	-0.041	-0.032	-0.033
	0.054	0.052	0.052
log of COW capabilities score (wetter)	0.092	0.067	0.042
	0.066	0.063	0.062
χ^2	24.389	23.308	14.696
Log-likelihood	-196.258	-196.718	-198.447
N	6282	6282	6282

Significance levels: $*: < 5\%$ $**: < 1\%$

8.4.3 Water Supply Treaties Only

Finally I examine the most specific water cooperation—water supply treaties. The individual-level results are presented in Table 8.7; the shared drought models are presented in Table 8.8. No covariates are significant in the model testing individual-level water scarcity models. However, shared mild to moderate drought are both associated with a large increase in the hazard for treaty formation, as evidenced by the positive and statistically significant coefficients for two of the shared drought indicators in Table 8.8. These coefficients have more or less the same impact on the hazard, but the shape of each hazard is different (see Figure 8.3 and 8.4). In other words, when two countries share a mild to moderate drought, they will sign a water treaty sooner than they would have in the ab-

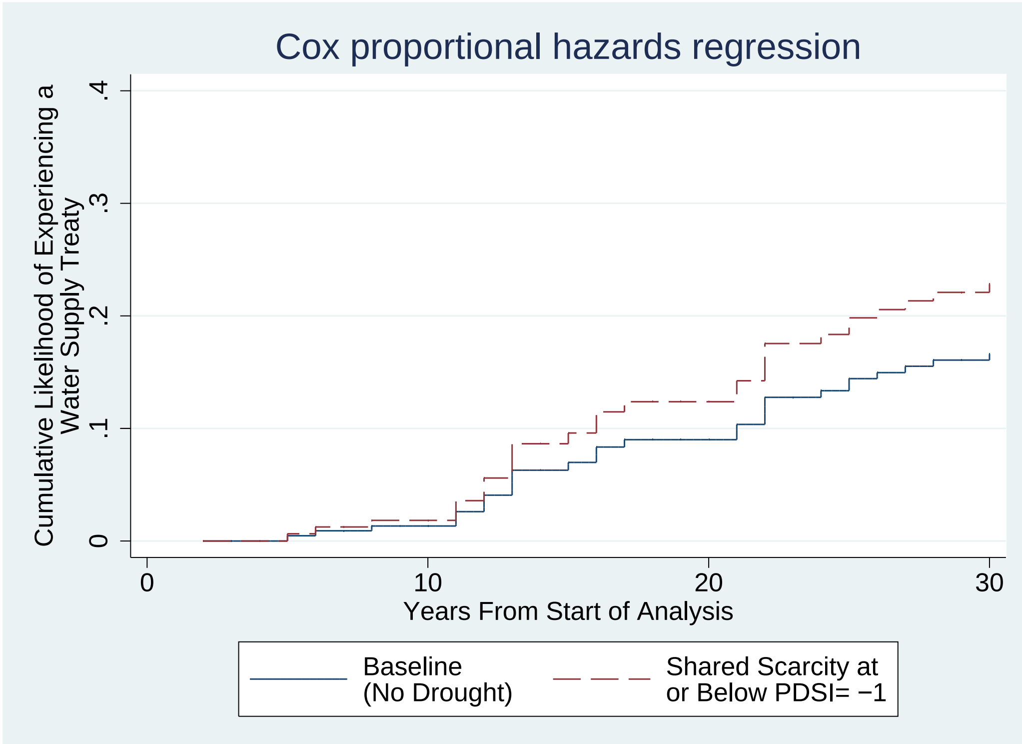

FIGURE 8.3: Water Stress and Water Supply Treaties. Shared drought raises the hazard that a treaty is signed at any given time.

sence of a drought, and the effect is quite strong for moderate shared scarcity. As shown in Figure 8.4, a fifteen-year shared drought more than doubles the cumulative likelihood that the dyad will sign a water supply treaty. A more severe shared drought is not significantly associated with any change in the hazard of a water supply treaty, possibly because of the small number of treaties explicitly dividing water supply and the low incidence of sustained shared droughts of this severity. These results again offer support for H_4 (drought increases the likelihood of a water-related treaty) and partial support for H_{4a} (stronger droughts change the likelihood of a water related treaty).

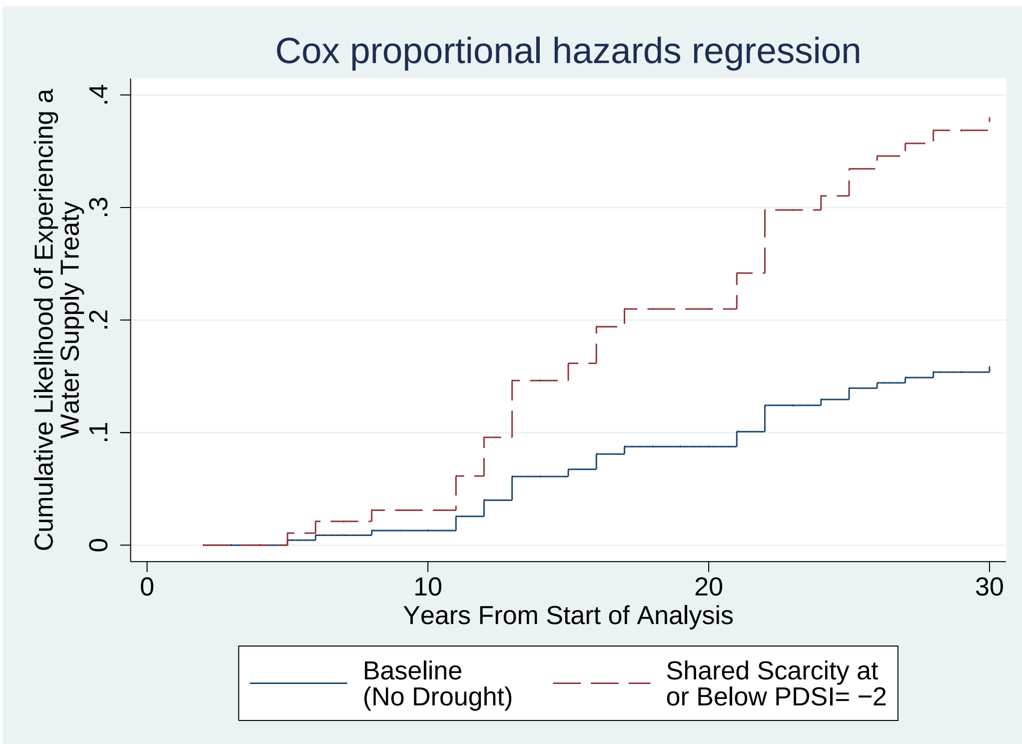

FIGURE 8.4: Water Stress and Water Supply Treaties (2). Shared drought raises the hazard that a treaty is signed at any given time more strongly than for a shared drought level of -1, above.

TABLE 8.7: Cox Survival-Time Regression, Effect of Individual-Level Drought on Probability of Adoption of Water Supply Treaties

Variable	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**	**Coeff.**
	SE	SE	SE	SE	SE	SE
Difference of log RGDP/capita	-0.072	-0.072	0.081	0.097	0.158	0.152
	0.141	0.139	0.155	0.165	0.174	0.173
Log of total dyadic trade	-0.073	-0.076	-0.069	-0.044	-0.031	-0.039
	0.083	0.081	0.093	0.093	0.109	0.100
PDSI avg. (drier) $\times$ shared basin	-0.079					
	0.074					
PDSI avg. (wetter) $\times$ shared basin		-0.152				
		0.102				
PDSI avg., lagged (drier) $\times$ shared basin			0.144			
			0.108			
PDSI avg., lagged (wetter) $\times$ shared basin				0.091		
				0.121		
PDSI avg., three year (drier) $\times$ shared basin					-0.034	
					0.114	
PDSI avg., three year (wetter) $\times$ shared basin						-0.185
						0.126
Shared democracy (each score > 6)	-0.627	-0.640	-0.769	-0.818	-0.786	-0.741
	0.480	0.471	0.500	0.511	0.532	0.522
log of COW capabilities score (drier)	0.034	0.032	0.128	0.144	0.202	0.215
	0.114	0.110	0.135	0.138	0.125	0.125
log of COW capabilities score (wetter)	0.157	0.155	-0.082	-0.082	-0.068	-0.052
	0.122	0.126	0.185	0.188	0.189	0.196
χ^2	13.93	15.12	13.22	14.456	17.74	21.883
Log-likelihood	-64.251	-63.67	-63.659	-64.199	-61.673	-60.881
N	6282	6282	6208	6208	6092	6092

Significance levels: $*: < 5\%$ $**: < 1\%$

TABLE 8.8: Cox Survival-Time Regression, Effect of Shared Drought on Probability of Adoption of Water Supply Treaties

Variable	Coeff. SE	Coeff. SE	Coeff. SE
Difference of log RGDP/capita	-0.070	-0.109	-0.088
	0.131	0.152	0.144
Log of total dyadic trade	-0.061	-0.079	-0.085
	0.080	0.081	0.079
PDSI, both states below -1 $\times$ shared basin	1.333**		
	0.432		
PDSI, both states below -2 $\times$ shared basin		1.212**	
		0.426	
PDSI, both states below -3 $\times$ shared basin			1.039
			0.540
Shared democracy (each score $>$ 6)	-0.622	-0.675	-0.701
	0.443	0.476	0.491
log of COW capabilities score (drier)	0.026	0.076	0.062
	0.105	0.104	0.110
log of COW capabilities score (wetter)	0.207	0.173	0.161
	0.124	0.122	0.123
χ^2	25.864	19.17	15.276
Log-likelihood	-61.115	-62.482	-63.673
N	6282	6282	6282

Significance levels: $*: < 5\%$ $**: < 1\%$

8.5 Discussion

The standard covariates used in chapters 5, 6 and 7 have some effects on the likelihood of water treaties being concluded. Greater levels of dyadic trade are associated with a shortening of the time between navigation and hydropower treaties. This finding probably indicates an increased need for the transport of economic goods and of maintenance on major transportation arteries. This result may also indicate improved relations leading to cooperative projects, when coupled with the findings in Chapter 7 that show an increase in the level of cooperation as dyadic trade rises. Joint democracy greatly lengthens the time between such treaties. Per the liberal peace arguments, these treaties are durable because the states are transparent and known to be cooperative, making durable treaties easier to create.

The probabilities of adoption of the three types of treaties are affected by changes in water availability: hydropower and transportation treaties are less likely (that is, there is a corresponding lengthening of time between events) when conditions are dry. This result is unsurprising given that water storage would not be as critical in the driest years, and hydropower would not overshadow water availability as a source of capital expenditures during those times. High flow years place more strain on navigation structures and maintenance budgets, and raise the possibility of new dams to hold all the excess rainfall.

Regarding the broader "water as water" (instead of a source of transportation or electric power) treaties, it is interesting to see the difference in the less-stressed and more-stressed states, as the three-year averages are associated with opposite effects on the likelihood of a treaty. The less water-stressed state clearly has an advantage: the negative coefficient for the wetter state is about double the size of the positive coefficient for the drier state. It is also interesting that these effects only show up in the three-year averages, suggesting that one- or two-year shortfalls in rain are not viewed with substantial concern.

The most significant finding is that shared drought is strongly associated with an increase in the likelihood of either a "water as water" treaty (including water quality and irrigation issues) or a water sharing treaty. This finding may contradict the realist and malthusian arguments that (international) violence and strife are the most likely under conditions of resource stress. Water treaties that specifically divide up water would create a consistent water supply or supply percentage for each country during uncertain years, but these constraints would apply during water-rich years. These restrictions would potentially impede the progress of water-based activities during moist and dry years, yet the treaties become more likely as drought occurs and/or remains below a PDSI value of -1.

It is also possible that a shorter time between treaties means that the agreements are not durable, that drought imposes a tendency to defect on existing agreements (seen in the India-Bangladesh Hooghly River dispute), or that treaties are re-written frequently because of changes in the interstate power structure, per Downs, Rocke and Barsoom (1996) and Powell (1999). However, the null effect of military power of the drier states tends to suppress this description of the outcomes.

If general interstate cooperation rose during periods of drought, then an increase in any specific kind of cooperation would not necessarily be noteworthy, as it would be difficult to differentiate the causes of the specific cooperation from the causes of the general cooperation under similar conditions. But as seen in Chapter 7, overall cooperation *drops* during times of increased water stress, and therefore the increased hazard (the decreased time between events) of water-specific cooperation runs counter to the main incidence of cooperation. This counter-trend offers support for Hypothesis H_4 and also strongly undercuts the "water-war" hypotheses suggested by others and tested in Chapter 5.

Drought creates immediate demands on countries and leaders, but also creates opportunities for entrepreneurial leaders. If these leaders can use the increased pain of a drought to soften the opposition to a water sharing agreement, both countries may benefit as a result from the increased cooperation, economies of scale, and increased assurances to industries and investors that the quantity of water, even if the amount is small, will be constant and known. As such, the results of the tests performed in this chapter are consistent with the expectations of the theory, and of Hypothesis H_4—water-specific cooperation is more likely under conditions of water scarcity.

Chapter 9

Conclusion

> Deswegen sagt Agassiz, dass wann eine neue Lehre vorgebracht würde, sie drei Stadien durchzumachen habe; zuerst sage man, sie sei nicht wahr, dann, sie sei gegen die Religion, and im dritten Stadium, sie sei längst bekannt gewesen. [Thus says Agassiz, that when a new doctrine is brought forth, it has to go through three stages. At first, people say that it is not so, then that it is against religion, and, in the third stage, they say it has long been known.]
>
> *Karl Ernst von Baer (1866)*

This dissertation examines the impact of scarce water on the interactions between countries. A constellation of authors has offered theory and evidence in favor of opposing positions: some, the realists / malthusians, offer that violence between countries will occur (or worsen) as a result of water stress. Others, the neoliberals and cornucopians, propose that water is too important to damage as a result of fighting, or that better results can be achieved without resorting to armed conflict to divide up the water. As with most statistical tests in the social sciences, the results are imperfect and subject to interpretation. Broadly, it appears that, using new data, "water wars" are not yet upon us, and that a drought is usually accompanied by a period of quiet, rather than a surge in conflict or military activity between adjacent countries that share a water resource. It is possible that these droughts negatively affect the economy or the home population and focus the attention of leaders on their domestic situations. The idea that water shortages lead to broad or diffuse cooperation finds no support among the tests I performed, though there is an apparent increase in the willingness of states to conclude a water sharing treaty when a drought takes hold.

9.1 Water Conquests

I argue that military conquest to secure additional water resources or to alleviate a drought is not unthinkable, but merely impractical. Relieving a drought requires more immediate measures than invading a country; military activity would only be able to slake the thirst of a country if the country were downstream from a water-rich neighbor with a large volume of water stored behind dams. Even in the most acrimonious situations where this situation exists, countries like Iraq or Syria have not attacked their upstream neighbors (in this example, Turkey) to gain access to the neighbors' water resources. Water conquest, to be effective at improving the attacking country's situation, depends on a quick victory; the effects of drought are most easily reversed early in a drought, when leaders are unlikely to view the conditions as severe, or at least early in the growing season when manpower (potentially likely to end up in the army if hostilities break out) is most needed for preparing the land and planting.

The MID data of purely military conflict between countries yield strong and robust results undermining the idea that water scarcity leads to a propensity for violent conflict. The MID analyses support the idea that states do not divide up water resources by violence, even though other means of coercion are still available to a hegemonic state. The events conflict data, divided into event-count analysis and aggregate event intensity analysis, yield less consistent results, but they never countermand the MID results, and offer a more nuanced approach to the question of drought and international interactions. Overall, the strength and robustness of the findings in Chapters 5 and 6, while not proof of any hypothesis or theory, make it difficult to claim that water wars are any part of our past. Earlier efforts by those proposing such an idea have used less-granular data (or no data at all), and have not taken full advantage of statistical techniques and/or new technologies such as geographic information systems. Few scholars, especially in the realm of resource conflict, have done statistical analyses of their questions, and fewer still have ventured to use several data sets, different analytical techniques, and multiply-defined critical variables to gain insight into their particular question. Violent water conflict is limited to the intra-national or smaller scales. Water conflict between countries is limited to the political realm.

9.2 Diffuse Cooperation?

Turning from military conflict and other forms of conflict to questions of cooperation, I find no evidence supporting the idea that crises (here, of water access and scarcity) will drive countries together and induce diffuse reciprocity. The analyses in Chapter 7 show that under conditions of water stress, countries decrease their international cooperation. Domestic issues draw the attention and concerns of leaders and governments away from neighbors. Particularly in agricultural economies, drought is a serious problem, but even where agriculture makes up a small percentage of GDP, drought causes disruption and unease, leading investors to worry and consumer confidence to dip. While it can be advantageous to cooperate with one's neighbors, drought is more associated with "turning inward" rather than "looking outward."

9.3 Hydro-Cooperation

Examining water-specific cooperation, on the other hand, produces results that run counter to the effects seen in Chapter 7. Perhaps resulting from the influence of endowment effects (from prospect theory) or functional solutions, water-specific cooperation is not hindered by the effects of drought. Treaty conclusion is more likely to occur during a shared drought between two neighbors. If signed quickly, the treaties have probably been under negotiation at a lower level of interstate diplomacy already; if no such proposals exist, the drought probably moves negotiations to a higher priority, even though infrastructure and large collaborative water projects would not bring immediate relief to the state. That states can reach agreements *more often under conditions of scarcity*, compared to the baseline water supply conditions, is interesting. I offer several reasons why it is not inexplicable, merely running counter to the realist expectations. In a world where confidence in an economy is critical to a stable life and livelihood for a country, a lack of confidence is troubling indeed. As such, restoring confidence in the future of a water supply—even if the overall supply is smaller—can have great benefits for a country, looking forward. Economically diverse and prosperous countries can better withstand drought and better prepare for it. Further, they can afford to efficiently use water or find serviceable substitutes. The benefits of a water-sharing agreement extend beyond the sometimes impressive benefits of "orthodox cooperation" (Young 1989) such as economies of scale, transparency, reduction of transaction costs, or of comparative advantage: an agreement can stabilize an economy and improve the likelihood that it will grow at a steady rate.

9.4 Implications for States Affected By Drought

States affected by a drought can remedy their situation in multiple ways: first, they can avoid worsening the situation by putting money into more efficient uses of the existing water. Depending on the agricultural level of the economy and other economic activities, it may be more economically rational to import a greater proportion of food, and allocate water to the economic activities with higher returns than agriculture, or to agricultural sites and crops that most efficiently use the water.

States considering a military option would do well to consider the difficulties of capturing, securing, re-routing, and transporting water from a neighboring country. The instability and economic repercussions might be very expensive even if the conquest succeeds. Destroying a dam or emptying a reservoir would be difficult and might take too much time to accomplish before the damage of a drought had already been done. Efficiency, conservation, and cooperation are better solutions and cheaper than warfare.

Second, a state can seek to improve its drought situation by cooperating with neighbors in all directions with which the state may share a water resource. Upstream neighbors may be receptive to allowing a guaranteed flow level or percentage of flow (instead of "whatever is left") to the downstream state, while allowing the upstream state to take all surplus over and above that guaranteed flow level during years with better rainfall or moisture conditions. Upstream neighbors might agree to store water at higher, cooler elevations, in existing or new reservoirs, thereby saving more water than if the downstream state tried to store it and lost a great amount to evaporation. Economies of scale apply to water resources, and states should take full advantage of them, where they exist.

9.5 Implications for Governmental and Non-Governmental Organizations

The results in Chapter 8 indicate that droughts make treaty negotiations more likely to successfully conclude. Once one or more states have endured the pain of a drought, negotiation will be more acceptable to a home population than such negotiations—and their possible loss of some autonomy—might be at other times. The results in Chapter 5 are very significant trends, but not a guarantee that a state will not prefer violence to peaceful cooperation and negotiation, or that a state cannot be more easily provoked during tense domestic situations such as droughts. As such, diplomats and non-governmental organizations would be served well to provide routine and detailed assurances that states are not cheating on existing agreements, and that no state is depriving neighbors of high-quality water and allowing others to suffer. Cooperation-minded leaders should be sought out and given as much assistance as possible, because once the drought abates, the public's willingness to consent to a loss of sovereignty will probably evaporate.

9.6 Future Research

As with many undertakings, much work remains to be done. The impact of water scarcity in a given region of a country—whether the capital city, agricultural regions, a boundary area, or an empty interior—may have a significantly different impact than the more general measures I have used. Examining droughts within specific river basins instead of country-wide may provide a higher resolution on political, social and economic issues that result from drought. Redundancy checks for water resource measures such as river flows, rainfall, and temperature measures would be useful. Extending the temporal scope of the inquiry into earlier international relations would probably have little use, since the international system changed greatly after World War II, but there are possibilities for specific country pairs or instances where this pursuit would be interesting. Generalizing the water resources question to more natural resources, and the drought question to more types of natural disasters, will be fruitful work. Lastly, civil conflicts are more common and more deadly than interstate warfare in the last few decades, and the malthusian theory has more anecdotal support at the sub-state level than the international level that I examined here. Examining resource scarcity, natural disasters, and water resources in countries at risk for civil conflict may provide further insight into the causes of, and means to avert, these conflicts.

9.7 Conclusion

This work makes a broad and definitive contribution to the study of international conflict, cooperation, and water resources. In it, I describe a new dataset of country maps and take advantage of new water data that is far better than previous data used in similar inquiry. I find that water scarcity is not a cause of international violence, and that natural disasters such as droughts seem to cause states to look inward and eschew international interactions, at least somewhat, during these periods. Lastly, despite the internal focus of government during a drought, water-specific cooperation tends to increase during droughts shared by neighboring states. As such, it appears that drought affects both conflict and cooperation in ways unexpected by previous scholarship.

Appendix A

The Golan Heights in 1967

Israel's conquest of the Golan Heights during the 1967 six-day war has been the subject of much speculation from the resource-war/Neo-Malthusian theorists. Geographically and hydrologically, by occupying the Golan, Israel secured nearly all of the upper Jordan river basin, and with it, the ability to use the water resources from that area. From one perspective, this action greatly benefited Israel such that Homer-Dixon, Gleick, Westing (1986*c*, 206) and others point to it as the pioneering example—from which many more would surely follow—of resource-imperialism. However, military considerations always came first in Israel, and Asher and Hammel (1987), Oren (2002) and Haddadin (2002) paint a different picture of the conquest in the Golan.

> Defense minister Moshe Dayan ... wanted to defeat Egypt, but he also desired to punish Syria. "The war should cost Syria so dearly," he affirmed, "that they will regret what they did." Dayan nearly regretted his rhetoric, for the Northern Command representative translated the defense minister's statement to mean that IDF forces deployed on the Golan should push the Syrians far enough back to render Syrian ar-

> tillery incapable of reaching Israeli villages in and beyond the Jordan River Valley. Such a move would have been tantamount to an all-out invasion of Syria (Asher and Hammel 1987, 262–263).

Dayan initially opposed the Golan invasion, preferring instead to relocate the Jewish settlers currently in range of the Syrian shelling (Oren 2002, 276). He was busy fighting a three-front war and did not want to divert military resources to an offensive into Syria. Political pressures prevailed in favor of the offensive, but not uniformly (Oren 2002, 279–280, 291–292).

There is significant tactical and strategic advantage to owning the Golan Heights: the owners of the heights can shoot slightly further and *can observe their fire better* from the heights than their opponents in the lowlands, who cannot observe the accuracy of their shelling up onto the plateau. Thus, the advantage to having the high ground does not accrue because of range, but more because of observation.

In the 1960s, the best heavy artillery from the Soviets (who supplied the Syrians and Egyptians) could fire 30 km, or nearly 44 km with rocket-assisted projectiles (Foss 1984, 579-580). The Arabs did not have artillery with that range, as their equipment was not state of the art (Foss 1984, Oren 2002),[1] though whether the Israelis knew this is unclear (Zeev, Gihon and Levkowich 1974, 16). Oren reports that "launching the salvos [on Northern Israeli settlements] were two Syrian battalions—the 129th and 168th—of 130mm guns, in addition to four companies of heavy mortars and antitank weapons" (229).[2] Arab artillery could therefore probably reach Tiberias and Nazareth, but not Haifa.

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[1] See also Blunt and Taylor (1977).

[2] Hammel (1992, 387–388) reports that there were "at least 265 medium- and heavy-caliber field pieces, heavy mortars, heavy-rocket launchers, and even permanently emplaced obsolete tanks along the Golan Plateau within range of many northern Israeli villages, towns, and cities. These artillery weapons were capable of firing 10 tons of shells and rockets per minute."

While it was possible to build or procure super-heavy artillery to fire 80 miles or more as early as 1918 (Manchester 1968, 291),[3] these weapons would require immovable emplacements or railroad carriages that the Israelis could easily find and attack.[4] In attacking the Golan, the Israelis may have considered the longer-distance threat of missile artillery, but most importantly, a small territorial gain in the Golan Heights and up to the mountain ridge of the Hermon would significantly and immediately cripple the Arabs' ability to attack Israel (Zeev, Gihon and Levkowich 1974, 14). "The Syrian Army would have to be destroyed and Syria's ability to dominate northern Israel from the protected heights would have to be terminated. If no other good came of the entire 1967 war, these objectives—at least—were to be achieved" (Hammel 1992, 387).

Some may argue that the Israelis planned much further ahead when they took the heights, and this strategic thinking could include autarkic reasons such as control of the Jordan rivershed. Oren reports that Levi Eshkol

> had deep sympathy for the northern settlers—and an abiding interest in the Jordan headwaters. . . .But not all Eshkol's ministers shared his Golan obsession. Zalman Aran and Haim Moshe Shapira, among others, still feared the opening of yet another front and possible intervention by the Soviets (Oren 2002, 228–9).

Political pressure made it imperative to stop the Arab shelling of Israeli territory and, to a lesser degree, threaten Damascus. They accomplished both. Oren

[3] See also Batchelor and Hogg (1972, 42).

[4] Krupp armaments originally built the *Pariskanone* for the German navy in 1917, and though deployed on land, the artillery was staffed by sixty seamen and commanded by a naval flag officer. Germany allocated a squadron of aircraft to protect it. It cost 35,000 Marks to fire a single shot and the team could only fire up to three rounds each hour. Each barrel could fire only 65 rounds before needing replacement. In twenty weeks, the lone artillery piece killed over 1,000 Parisians from a distance of around 77 miles, but scarcely had a tactical impact on the war (Manchester 1968, 291–292). The effective range of artillery remained below 30km/19 miles.

notes that Eshkol and his wife Miriam both used the Syrian artillery as additional pressure to take the Golan and control the Banias river (Oren 2002, 261–262), as did Rabin (231), though he reports that this desire was not widespread in the government elite (229), and Moshe Dayan more or less had the final say either way. However, the initial objectives of the Golan invasion included the Dafna stream (part of the boundary with Syria) and the Banyas springs (Hammel 1992, 397). On the other hand, by the end of the conflict, "the Israelis held all the best ground or were in position to seize all the best ground" (Hammel 1992, 415), so it is possible these targets would have been taken regardless of the initial objective.

As a counterpoint, Israeli general Avraham Tamir, who helped "outline Israel's strategic needs in 1967 and 1982" (Wolf 2000, 92) said "why go to war over water? For the price of one week's fighting, you could build five desalination plants. No loss of life, no international pressure, and a reliable supply you don't have to defend in hostile territory."[5] Rational actors seeking to make absolute development gains through territorial expansion could therefore increase their power better and more securely by internal mobilization than by war.

Beyond the tactical advantage, what about the water supply? There is not much water in the Golan, because the catchment area is so small. To sustain agriculture in the area, Israel must pump water into the region, up a 600 meter vertical wall—a very expensive proposition. And what about the water supplies under the Sinai? If these existed and if Israel was operating under a hydraulic imperative, it is unlikely that it would have returned the Sinai in 1978 after fighting so hard for it at least three times (Wishart 1989, 48).

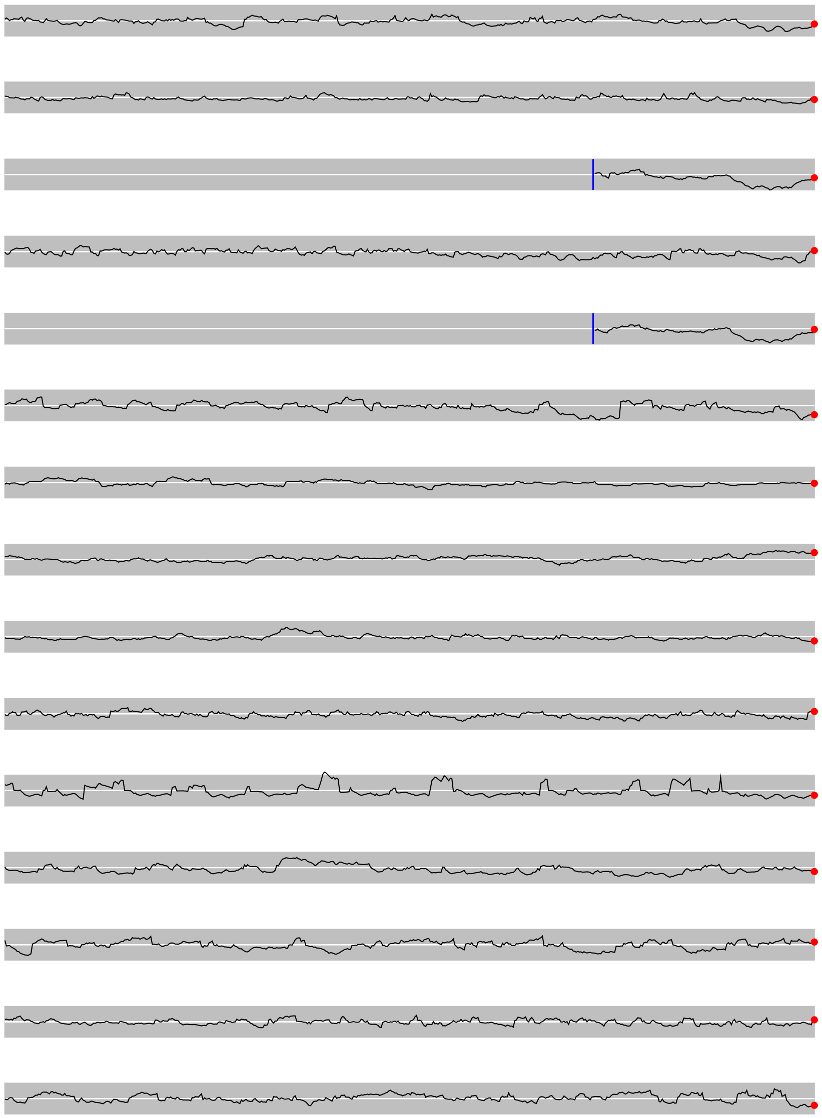
[5]See also Soffer (1999, 249), though note that my theoretical expectations suggest that desalination plants bring their own set of financial and international leverage problems.

The Israeli government was quite aware of Syria's close ties with the Soviet Union, and was uneasy about provoking the Russian bear, not to mention the difficulties of scaling the Golan and occupying any significant territory before a cease-fire. However, at the end of the immediate hostilities, Israel had secured her borders, silenced the Syrian artillery atop the Golan, occupied the headwaters of the Jordan basin, and stood uncomfortably close to Damascus, Cairo, and Amman. While water figured in the calculations of some Israelis, artillery was the primary motivation for taking the Golan. Further, there was no mention of water issues in UN resolution 242 (Haddadin 2002, 326), that addressed settlement of the cease-fire. In conclusion, it appears hydrologically, economically and politically unlikely that the Golan was seized because of lateral pressure theory or a "hydraulic imperative," but rather because possession of the Golan protected Israeli settlers on the plains below, gave the Israeli military an excellent view of Syria and Lebanon, and denied this view to Syrian artillery observers.

Appendix B

PDSI Values

In this appendix, the monthly values of the Palmer Drought Severity Index are displayed for 1959–2002 for each country in the Correlates of War state system. The vertical (PDSI) scale runs from $[-10, 10]$ and a white line runs through the zero value. The value of the final (shaded) point is listed with the subscript "last," as are the 3- and 6-year averages of the PDSI leading up to the final point. If the country no longer exists, then the average values reflect the values leading up to the country's last year in existence.



Afghanistan -2.18_{last} -5.08_{3yr} -3.34_{6yr}

Algeria -1.37_{last} -2.69_{3yr} -2.07_{6yr}

Azerbaijan -2.11_{last} -6.78_{3yr} -5.32_{6yr}

Albania 0.65_{last} -4.17_{3yr} -2.88_{6yr}

Armenia -0.45_{last} -5.84_{3yr} -4.58_{6yr}

Andorra -6.05_{last} -4.57_{3yr} -3.44_{6yr}

Angola -0.47_{last} -0.42_{3yr} -0.73_{6yr}

Argentina 4.55_{last} 4.91_{3yr} 3.46_{6yr}

Australia -2.78_{last} -0.53_{3yr} -0.42_{6yr}

Austria 1.50_{last} -1.95_{3yr} -1.21_{6yr}

Bahrain -3.06_{last} -3.87_{3yr} -2.72_{6yr}

Botswana -2.55_{last} -1.01_{3yr} -1.18_{6yr}

Belgium 1.75_{last} 1.73_{3yr} 0.53_{6yr}

Bangladesh 1.31_{last} -1.05_{3yr} -1.20_{6yr}

Belize -4.41_{last} -1.06_{3yr} -0.49_{6yr}

 Bosnia and Herzegovina -2.07_{last} -3.21_{3yr} -1.92_{6yr}

 Bolivia -1.95_{last} -0.37_{3yr} -0.20_{6yr}

 Burma -1.13_{last} -2.83_{3yr} -3.46_{6yr}

 Benin -7.68_{last} -6.46_{3yr} -5.39_{6yr}

 Belarus -2.68_{last} -2.05_{3yr} -0.74_{6yr}

 Brazil -2.06_{last} -0.75_{3yr} -1.10_{6yr}

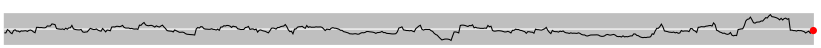
 Bhutan 1.61_{last} 0.11_{3yr} -0.55_{6yr}

 Bulgaria -2.71_{last} -6.50_{3yr} -3.42_{6yr}

 Brunei -2.57_{last} -0.15_{3yr} -0.59_{6yr}

 Burundi -1.93_{last} -3.11_{3yr} -2.93_{6yr}

 Canada -1.51_{last} -1.19_{3yr} -2.61_{6yr}

 Cambodia -1.00_{last} 3.18_{3yr} 1.99_{6yr}

 Chad -2.11_{last} -1.81_{3yr} -1.45_{6yr}

 Sri Lanka -4.58_{last} -3.02_{3yr} -3.01_{6yr}

 Congo -4.16_{last} -1.16_{3yr} -1.58_{6yr}


Zaire 0.36$_{\text{last}}$ 0.41$_{\text{3yr}}$ 0.38$_{\text{6yr}}$


China -0.81$_{\text{last}}$ -1.72$_{\text{3yr}}$ -1.42$_{\text{6yr}}$

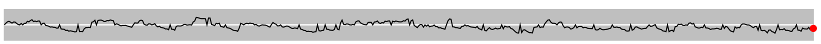

Chile 0.61$_{\text{last}}$ 1.06$_{\text{3yr}}$ 0.40$_{\text{6yr}}$

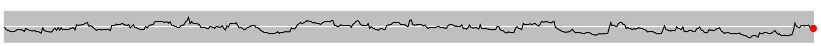

Cameroon -2.66$_{\text{last}}$ -3.44$_{\text{3yr}}$ -5.23$_{\text{6yr}}$


Colombia -1.87$_{\text{last}}$ -1.08$_{\text{3yr}}$ -0.65$_{\text{6yr}}$

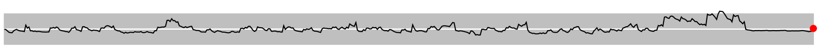

Costa Rica -2.66$_{\text{last}}$ -1.80$_{\text{3yr}}$ -1.27$_{\text{6yr}}$


Central African Republic -4.75$_{\text{last}}$ -2.96$_{\text{3yr}}$ -2.88$_{\text{6yr}}$


Cuba -2.30$_{\text{last}}$ -3.09$_{\text{3yr}}$ -2.42$_{\text{6yr}}$

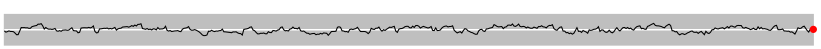

Cyprus -1.04$_{\text{last}}$ -2.76$_{\text{3yr}}$ -3.46$_{\text{6yr}}$

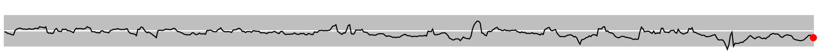

Denmark -1.52$_{\text{last}}$ -0.86$_{\text{3yr}}$ -1.48$_{\text{6yr}}$

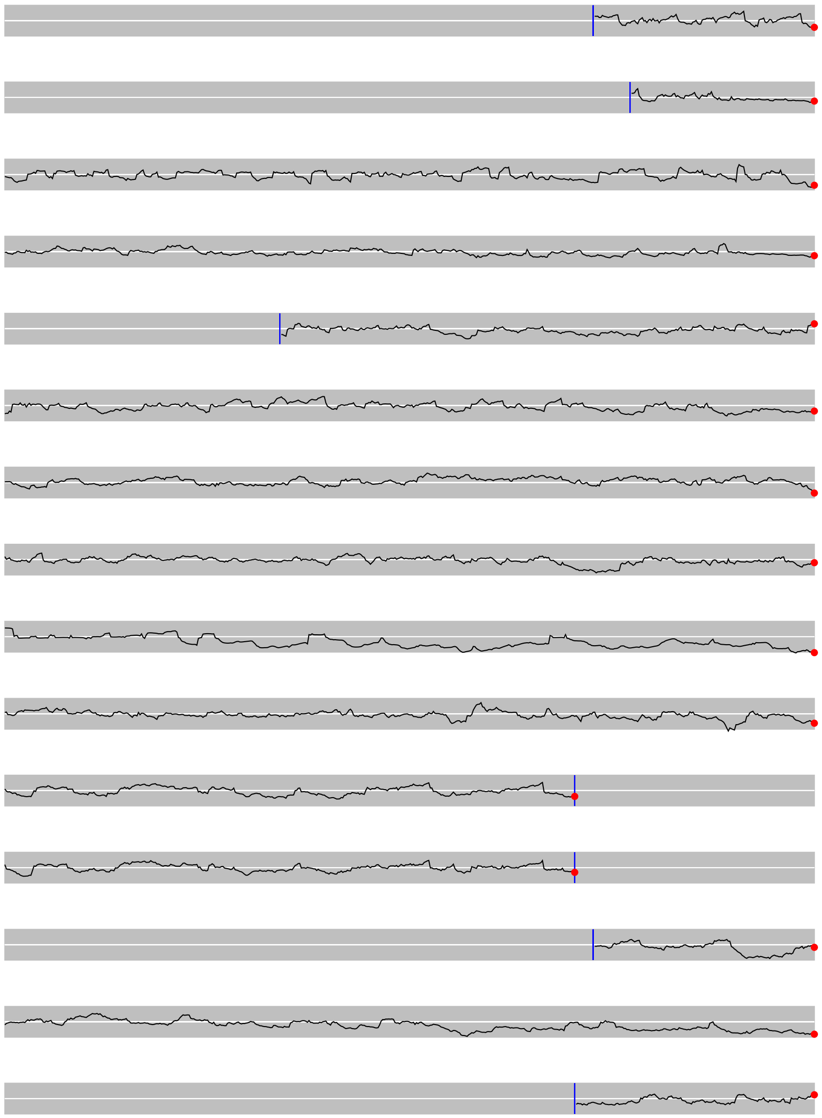

Djibouti 0.45$_{\text{last}}$ -1.07$_{\text{3yr}}$ 2.26$_{\text{6yr}}$


Ecuador -0.61$_{\text{last}}$ 0.24$_{\text{3yr}}$ 0.85$_{\text{6yr}}$


Egypt -1.87$_{\text{last}}$ -1.51$_{\text{3yr}}$ -1.07$_{\text{6yr}}$


Ireland 0.26$_{\text{last}}$ 0.26$_{\text{3yr}}$ 0.54$_{\text{6yr}}$


Equatorial Guinea -4.54$_{\text{last}}$ -4.07$_{\text{3yr}}$ -4.84$_{\text{6yr}}$



Estonia -4.35_{last} 0.26_{3yr} 0.83_{6yr}

Eritrea -2.39_{last} -1.93_{3yr} -1.31_{6yr}

El Salvador -7.00_{last} -2.73_{3yr} -1.76_{6yr}

Ethiopia -2.65_{last} -2.13_{3yr} -1.07_{6yr}

Czech Republic 3.16_{last} -1.33_{3yr} -0.56_{6yr}

French Guiana -3.65_{last} -3.50_{3yr} -3.78_{6yr}

Finland -6.86_{last} -0.19_{3yr} 0.72_{6yr}

France -2.00_{last} -1.50_{3yr} -1.49_{6yr}

Gambie -10.39_{last} -7.84_{3yr} -6.37_{6yr}

Gabon -6.14_{last} -2.68_{3yr} -3.50_{6yr}

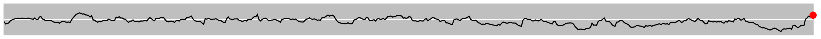
DDR -3.81_{last} -0.28_{3yr} -0.32_{6yr}

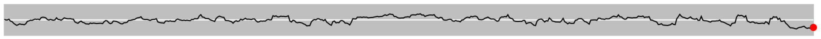
West Germany -3.06_{last} -0.08_{3yr} -0.07_{6yr}

Georgia -1.70_{last} -5.08_{3yr} -3.76_{6yr}

Ghana -8.08_{last} -6.42_{3yr} -5.88_{6yr}

Germany 2.48_{last} -0.55_{3yr} -0.90_{6yr}


Greece 2.77_{last} -4.47_{3yr} -2.95_{6yr}


Guatemala -4.86_{last} -2.73_{3yr} -1.70_{6yr}


Guinea -6.99_{last} -4.99_{3yr} -3.85_{6yr}


Guyana -1.96_{last} -0.81_{3yr} -1.05_{6yr}


Haiti -8.34_{last} -8.00_{3yr} -5.51_{6yr}


Hong Kong -1.68_{last} -0.45_{3yr} -0.50_{6yr}


Honduras -7.25_{last} -2.98_{3yr} -2.42_{6yr}


Croatia -2.52_{last} -4.03_{3yr} -2.34_{6yr}


Hungary -3.25_{last} -3.62_{3yr} -1.16_{6yr}


Iceland -0.06_{last} -0.47_{3yr} -0.31_{6yr}


Indonesia -2.67_{last} -0.85_{3yr} -1.08_{6yr}


India -2.90_{last} -2.65_{3yr} -1.57_{6yr}


Iran -3.74_{last} -6.10_{3yr} -4.01_{6yr}

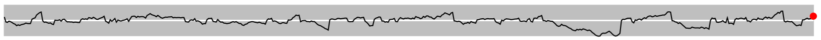

Israel -0.87_{last} -2.68_{3yr} -2.55_{6yr}

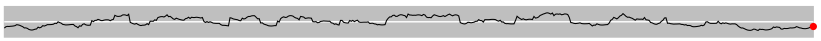

Italy -3.62_{last} -4.07_{3yr} -2.77_{6yr}

 Cote d'Ivoire (Ivory Coast) -7.03_{last} -4.60_{3yr} -4.93_{6yr}

 Iraq -2.93_{last} -4.13_{3yr} -3.20_{6yr}

 Japan 0.25_{last} -0.86_{3yr} -0.49_{6yr}

 Jersey 2.83_{last} 0.96_{3yr} 0.23_{6yr}

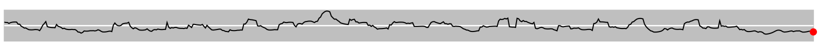
 Jordan -3.06_{last} -4.19_{3yr} -3.30_{6yr}

 Kenya 1.28_{last} -1.61_{3yr} 0.26_{6yr}

 Kyrgyzstan 0.71_{last} -1.15_{3yr} -0.81_{6yr}

 Korea -0.72_{last} -2.29_{3yr} -1.73_{6yr}

 Korea 1.57_{last} -0.64_{3yr} 0.58_{6yr}

 Kuwait -4.11_{last} -4.02_{3yr} -2.90_{6yr}

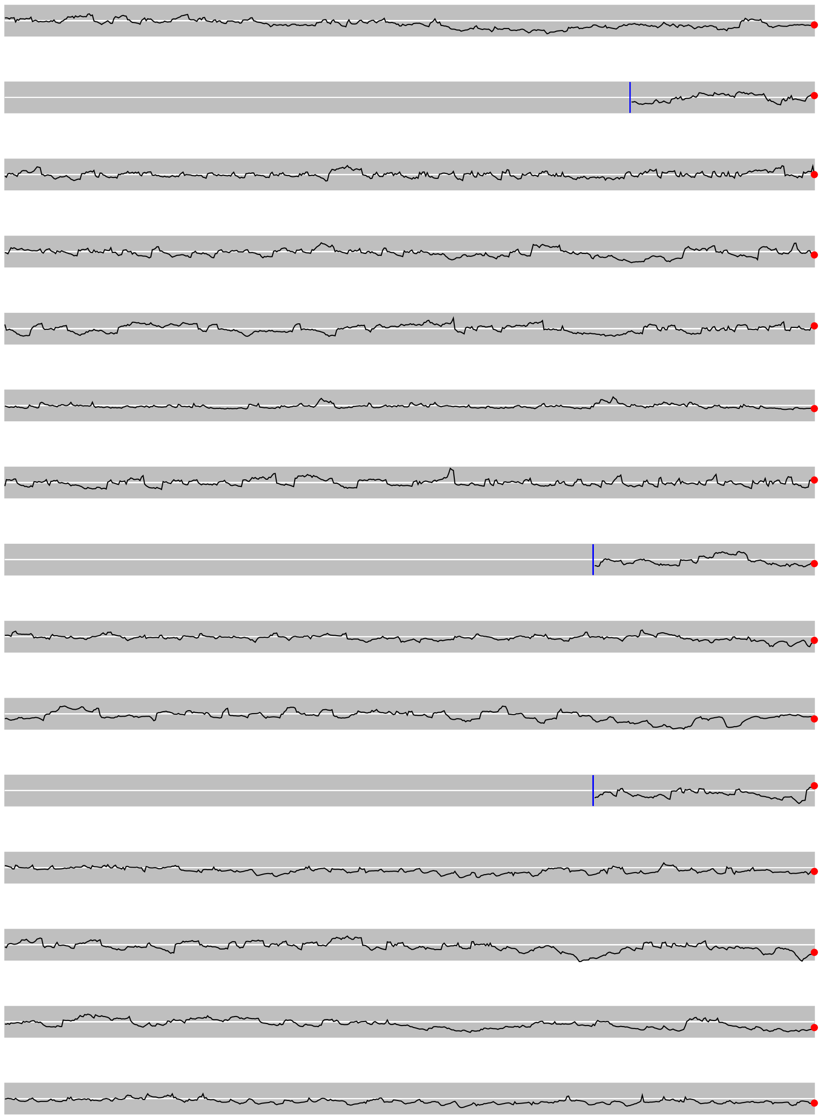
 Kazakhstan 0.06_{last} -0.55_{3yr} -0.77_{6yr}

 Laos 1.64_{last} 1.94_{3yr} 0.45_{6yr}

 Lebanon 0.73_{last} -4.39_{3yr} -3.51_{6yr}

 Latvia -4.12_{last} -1.17_{3yr} -0.11_{6yr}

 LIthuania -4.19_{last} -2.12_{3yr} -1.01_{6yr}



Liberia -2.77_{last} -2.91_{3yr} -2.88_{6yr}

Slovakia 1.20_{last} -1.11_{3yr} 0.48_{6yr}

Liechtenstein -0.04_{last} 1.50_{3yr} 0.90_{6yr}

Lesotho -2.17_{last} 0.61_{3yr} -0.22_{6yr}

Luxembourg 1.82_{last} 0.80_{3yr} 0.51_{6yr}

Libya -2.04_{last} -1.90_{3yr} -1.49_{6yr}

Macau 1.65_{last} -0.03_{3yr} -0.17_{6yr}

Moldova -2.60_{last} -3.07_{3yr} -0.26_{6yr}

Mongolia -2.37_{last} -4.15_{3yr} -3.04_{6yr}

Malawi -3.35_{last} -1.77_{3yr} -3.16_{6yr}

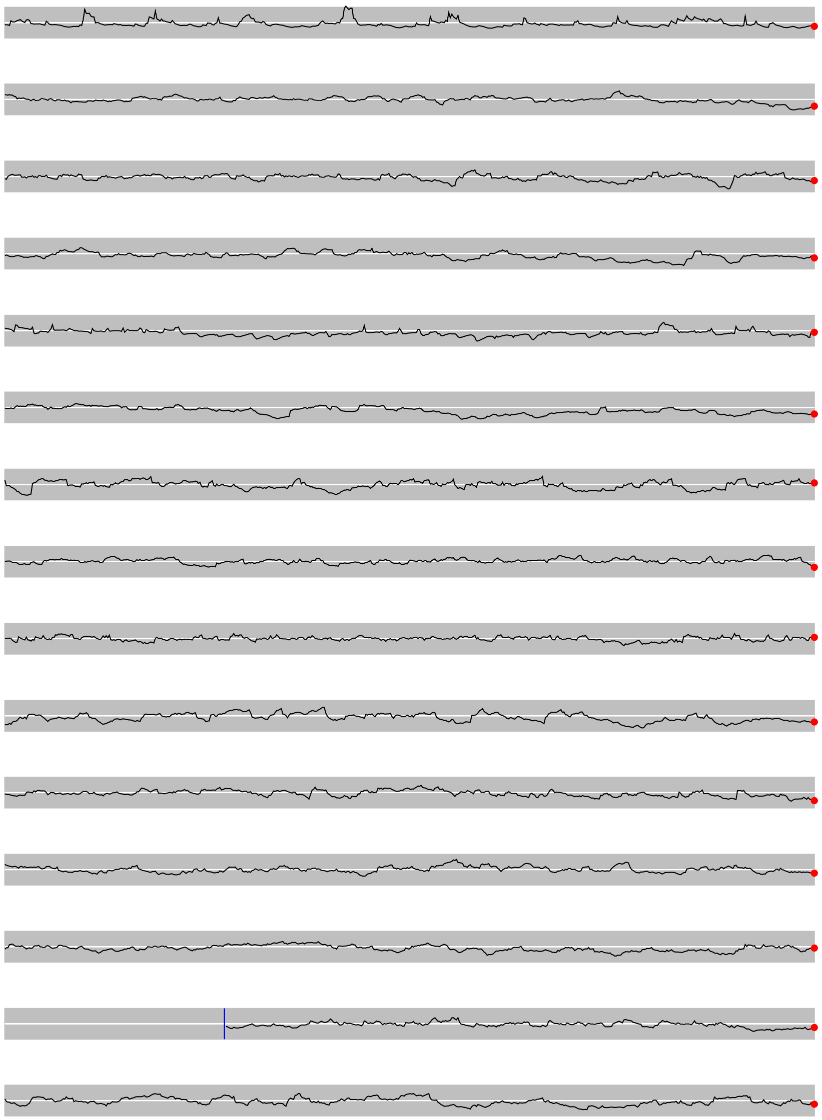
Macedonia 3.13_{last} -4.10_{3yr} -2.85_{6yr}

Mali -2.45_{last} -2.82_{3yr} -2.48_{6yr}

Monaco -4.98_{last} -5.46_{3yr} -3.71_{6yr}

Morocco -3.75_{last} -5.39_{3yr} -3.64_{6yr}

Mauritania -2.94_{last} -2.62_{3yr} -2.59_{6yr}



Oman -2.38_{last} -2.41_{3yr} -1.34_{6yr}

Mexico -4.41_{last} -4.72_{3yr} -3.16_{6yr}

Malaysia -2.67_{last} -0.35_{3yr} -1.22_{6yr}

Mozambique -2.83_{last} -2.01_{3yr} -2.24_{6yr}

Niger -1.06_{last} -2.21_{3yr} -1.40_{6yr}

Nigeria -4.29_{last} -3.47_{3yr} -3.71_{6yr}

Netherlands 1.03_{last} 1.14_{3yr} 0.21_{6yr}

Norway -3.70_{last} 1.22_{3yr} 0.98_{6yr}

Nepal 0.88_{last} -0.11_{3yr} -0.06_{6yr}

Suriname -4.02_{last} -2.89_{3yr} -3.36_{6yr}

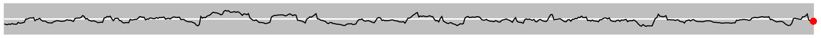
Nicaragua -5.27_{last} -3.12_{3yr} -2.54_{6yr}

Paraguay -2.27_{last} -1.44_{3yr} -0.39_{6yr}

Peru -0.86_{last} -0.67_{3yr} -1.58_{6yr}

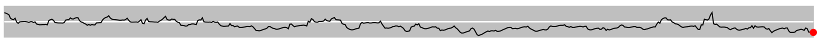
Pakistan -2.39_{last} -3.45_{3yr} -2.65_{6yr}

Poland -2.35_{last} -1.40_{3yr} -0.26_{6yr}

 Panama -1.53_{last} -0.57_{3yr} -0.98_{6yr}

 Portugal 0.35_{last} -1.14_{3yr} -0.77_{6yr}

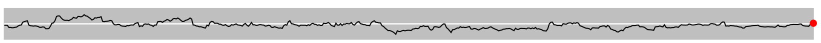
 Papua New Guinea -1.25_{last} -0.78_{3yr} -0.42_{6yr}

 Guinea-Bissau -6.98_{last} -5.30_{3yr} -4.03_{6yr}

 Qatar -2.91_{last} -3.75_{3yr} -2.50_{6yr}

 Romania -3.77_{last} -4.96_{3yr} -1.63_{6yr}

 Russia -2.05_{last} -1.40_{3yr} -0.94_{6yr}

 Rwanda 0.42_{last} -1.23_{3yr} -1.11_{6yr}

 Saudi Arabia -3.26_{last} -4.04_{3yr} -2.67_{6yr}

 South Africa -1.65_{last} -0.31_{3yr} -0.68_{6yr}

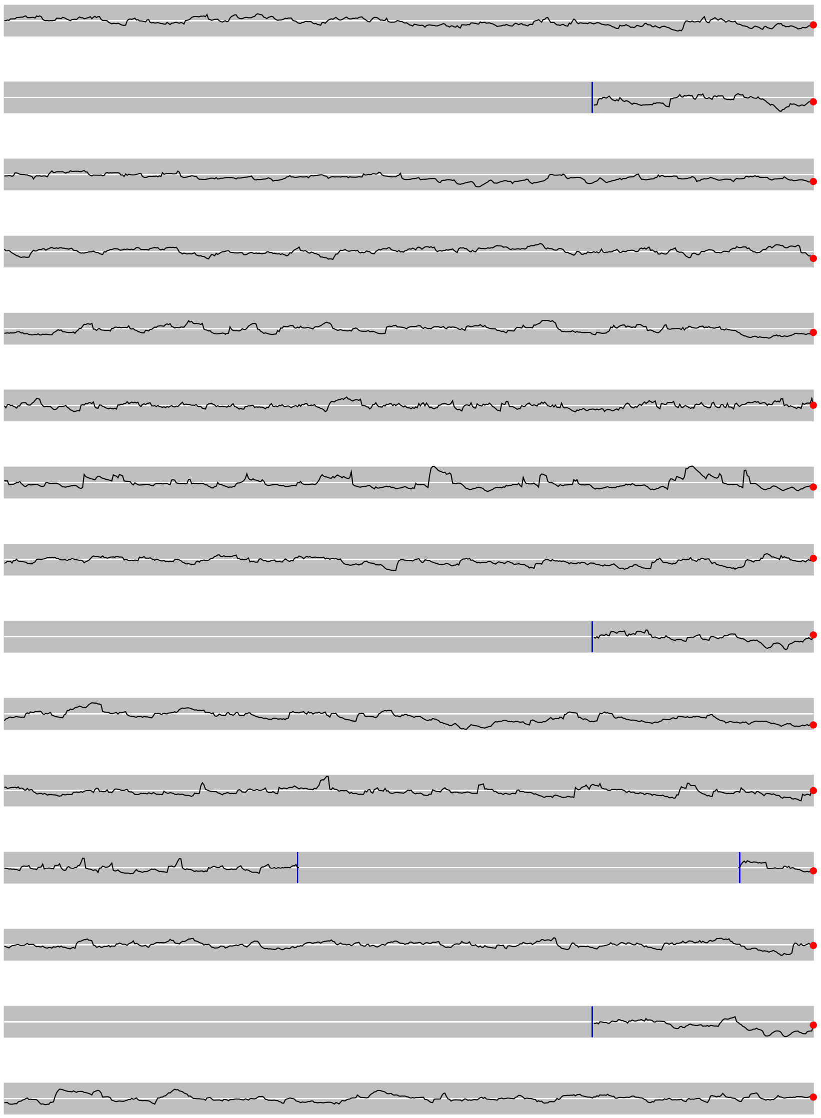
 Senegal -8.23_{last} -6.77_{3yr} -5.60_{6yr}

 Slovenia -0.94_{last} -2.83_{3yr} -1.87_{6yr}

 Sierra Leone -3.13_{last} -2.57_{3yr} -2.32_{6yr}

 Singapore 0.07_{last} -0.74_{3yr} -1.80_{6yr}

 Somalia 0.53_{last} -1.15_{3yr} -0.01_{6yr}



Spain -2.74_{last} -3.96_{3yr} -2.66_{6yr}

Serbia -2.85_{last} -4.73_{3yr} -2.31_{6yr}

Sudan -4.55_{last} -3.18_{3yr} -2.87_{6yr}

Sweden -4.44_{last} 1.70_{3yr} 1.33_{6yr}

Syria -2.42_{last} -4.39_{3yr} -3.11_{6yr}

Switzerland 0.16_{last} 0.93_{3yr} 0.60_{6yr}

United Arab Emirates -2.91_{last} -3.67_{3yr} -1.18_{6yr}

Thailand 0.86_{last} 0.68_{3yr} -1.07_{6yr}

Tajikistan 1.15_{last} -4.32_{3yr} -2.60_{6yr}

Togo -7.27_{last} -6.80_{3yr} -5.61_{6yr}

Tunisia -0.02_{last} -3.41_{3yr} -2.36_{6yr}

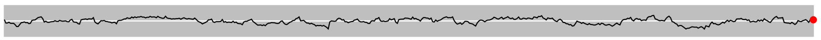
Timor-Leste -2.06_{last} -0.18_{3yr} 0.48_{6yr}

Turkey -0.50_{last} -3.07_{3yr} -1.10_{6yr}

Turkmenistan -2.10_{last} -7.12_{3yr} -4.43_{6yr}

Tanzania 0.96_{last} 0.55_{3yr} 0.71_{6yr}


Uganda -2.75_{last} -3.36_{3yr} -1.58_{6yr}


United Kingdom 0.77_{last} 0.19_{3yr} -0.25_{6yr}

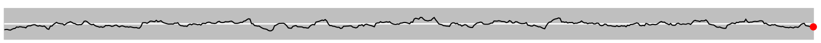

Ukraine -2.12_{last} -1.42_{3yr} 0.17_{6yr}


United States -1.13_{last} -1.16_{3yr} -0.66_{6yr}


Burkina -9.09_{last} -5.65_{3yr} -5.08_{6yr}


Uruguay 5.99_{last} 2.73_{3yr} 1.52_{6yr}


Uzbekistan -0.58_{last} -4.84_{3yr} -2.93_{6yr}

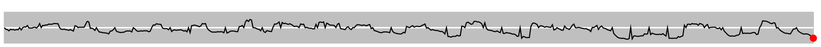

Venezuela -1.95_{last} -1.08_{3yr} -0.45_{6yr}


Vietnam -1.16_{last} 2.31_{3yr} 1.31_{6yr}


Republic of Vietnam 0.92_{last} 0.13_{3yr} -0.17_{6yr}

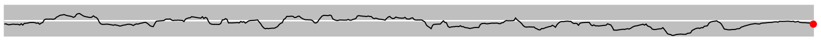

Namibia -1.49_{last} -0.56_{3yr} -1.19_{6yr}


Western Sahara -0.88_{last} -1.38_{3yr} -1.57_{6yr}


Swaziland -6.89_{last} -1.22_{3yr} -1.86_{6yr}


Yugoslavia -4.21_{last} -3.44_{3yr} -2.62_{6yr}


Yemen -2.04_{last} -2.11_{3yr} -1.25_{6yr}

 Zambia -2.26$_{\text{last}}$ -1.05$_{\text{3yr}}$ -2.16$_{\text{6yr}}$

 Zimbabwe -3.34$_{\text{last}}$ -1.34$_{\text{3yr}}$ -1.14$_{\text{6yr}}$

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Colophon

This document was produced using the LaTeX[1] document preparation system using the Palatino font for text and equations, Bitstream Vera for graphics, and Courier for computer-specific text such as command-line items, uniform resource locators (world wide web addresses) or binary executable names. All text and graphics were produced by the author using free, open source software, including TeXShop,[2] BibDesk,[3] Inkscape,[4] GRASS GIS,[5] and the GIMP.[6] Stata[7] version 10 for Mac OS X was used for statistical computations and subsequent graphs.

The GIS data and statistical results were created using over 5000 lines of code, written in the Perl,[8] `bash`,[9] MySQL,[10] and Stata scripting languages. Fortran source code was compiled using the open source `g95` compiler.[11]

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[1] `http://www.ctan.org/` and `http://tug.org/mactex/`

[2] A Mac OS X native LaTeX editor. `http://www.uoregon.edu/~koch/texshop/`

[3] A BibTeX citation database manager. `http://bibdesk.sourceforge.net`

[4] A vector graphics editor comparable to Adobe Illustrator. `http://www.inkscape.org`

[5] Geographic Resources Analysis Support System software. `http://grass.itc.it`

[6] The GNU Image Manipulation Program. `http://www.gimp.org`

[7] `http://www.stata.com.`

[8] Perl is a high-level interpreted programming language; `http://www.perl.org` and also `http://www.perlfoundation.org`

[9] The **B**ourne-**A**gain **Sh**ell (a shell is a command language interpreter with a text interface); `http://www.gnu.org/software/bash`

[10] MySQL is an implementation of the Structured Query Language database standard; `http://dev.mysql.com`

[11] Fortran is the oldest programming language still in use (IBM 1954), and is especially suited to numeric computation. There are numerous implementations of Fortran. I used the Fortran 95 compiler from `http://www.g95.org`