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Whither the weather? Climate change and conflict

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Abstract

Until recently, most writings on the relationship between climate change and security were highly speculative. The IPCC assessment reports to date offer little if any guidance on this issue and occasionally pay excessive attention to questionable sources. The articles published in this special issue form the largest collection of peer-reviewed writings on the topic to date. The number of such studies remains small compared to those that make up the natural science base of the climate issue, and there is some confusion whether it is the effect of 'climate' or 'weather' that is being tested. The results of the studies vary, and firm conclusions cannot always be drawn. Nevertheless, research in this area has made considerable progress. More attention is being paid to the specific causal mechanisms linking climate change to conflict, such as changes in rainfall and temperature, natural disasters, and economic growth. Systematic climate data are used in most of the articles and climate projections in some. Several studies are going beyond state-based conflict to look at possible implications for other kinds of violence, such as intercommunal conflict. Overall, the research reported here offers only limited support for viewing climate change as an important influence on armed conflict. However, framing the climate issue as a security problem could possibly influence the perceptions of the actors and contribute to a self-fulfilling prophecy.

Keywords

armed conflict, climate change, security, war

Violence is on the wane in human affairs, even if slowly and irregularly (Goldstein, 2011; Pinker, 2011). In recent years, however, pundits and politicians, along with a few scholars, have raised the specter that this encouraging trend towards peace might be reversed by environmental change generally and by climate change specifically. In his acceptance speech for the Nobel Peace prize, for instance, President Obama (2009) warned that '[t]here is little scientific dispute that if we do nothing, we will face more drought, more famine, more mass displacement – all of which will fuel more conflict for decades'. He would have been more accurate had he said that there is little if any scientific agreement about these points.

Despite the increasing certainty about global warming and the man-made contribution to it, the two central premises of the Intergovernmental Panel on Climate Change (IPCC), uncertainty continues about many of the physical consequences of climate change and even more so about the social consequences. This uncertainty is compounded by confusion about the definition of 'climate', an issue to which I return below. The IPCC is not charged with the task of doing research; rather it 'reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide'.[1] In an area where little or no research has been conducted, the IPCC has a poor basis for an assessment. Therefore, the two most recent assessment reports (IPCC, 2001, 2007) had little to say about the security implications of climate change. Unfortunately, in the absence of peer-reviewed sources, these reports fell prey to the

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[1] From the IPCC homepage, www.ipcc.ch/organization/organization.shtml.

temptation to cite occasional 'grey material', particularly in the Africa chapter of the 2007 report (Nordås & Gleditsch, 2009). Indeed, a document explaining the principles for the preparation of its reports (IPCC, 2008) approves the use of non-peer reviewed sources in areas where few peer-reviewed sources are available. In a wide-ranging examination of the IPCC, the Inter-Academy Council, an umbrella organization of national academies of science, cited a study that found that while 84% of the sources for IPCC's Working Group 1 on the physical science basis derived from peer-reviewed sources, it was only 59% for Working Group 2 on the vulnerability of socio-economic and natural systems to climate change (IAC, 2010: 16). It also acknowledged that some governments, particularly in developing countries, had not always nominated the best experts, that the author selection process suffered from a lack of transparency, and that the regional chapters did not always make use of experts from outside the region (IAC, 2010: 18) – all of which sheds some light on the discussion of security issues in the Africa chapter in the 2007 report.

In the introduction to the first special issue of an academic journal devoted to the topic of climate change and conflict, Nordås & Gleditsch (2007) found little support for the climate–conflict nexus in the academic literature and outlined five priorities for future research in this area:

- a disentangling of the causal chains between climate change and conflict
- a tighter coupling of climate change models and conflict models
- a reconsideration of the kind of violence expected to result from climate change
- a balance of positive and negative effects
- an increased focus on the Third World where climate change will matter most.

Meanwhile, a number of studies relevant to the climate–conflict nexus have been published and this special issue adds 16 more. What have we achieved in terms of the five goals outlined in 2007?

Disentangling causal chains

Virtually all the articles in this special issue try to disentangle the causal chains between climate change and conflict.[2] By far the largest number of studies in the literature generally and in this issue look at how climate variability and specifically changes in precipitation may affect conflict through adverse effects on rainfed agriculture or cattle herding.[3] Adano et al (2012: 77), for instance, find for two districts in Kenya that 'more conflicts and killings take place in wet seasons of relative abundance' and Theisen (2012: 93), who also studies Kenya, concludes that 'years following wetter years [are] less safe than drier ones'. Butler & Gates (2012) derive a similar conclusion from a formal model. Benjaminsen et al. (2012: 108) state on the basis of the Mopti region of Mali, at the heart of the Sahel, that there is 'little evidence supporting the notion that water scarcity and environmental change are important drivers of intercommunal conflicts'.[4] Hendrix & Salehyan (2012) conclude on the basis of a new database of social conflict in Africa, that rainfall deviations in either direction are associated with conflict, but that violent events are more responsive to heavy rainfall. Of course, while providing water in abundance, heavy rainfall can also produce subsequent scarcities through the damage caused by flooding. Raleigh & Kniveton (2012), on the basis of data from East Africa, also find that rainfall deviations in either direction are associated with conflict, but argue that civil war is more likely in anomalously dry conditions whereas wet conditions are more likely to be associated with non-state conflict. Koubi et al. (2012) investigate whether climate variability may influence armed conflict through its effect on economic development. Although their literature review leads them to hypothesize that climate variability should affect economic growth, they do not find (either in a global study or in a separate analysis for sub-Saharan Africa) any statistically significant impact of climate variability on growth. There is no general link between climate variability and conflict through economic growth, although autocracies may be more vulnerable to conflict through this mechanism. A few articles also have data on variations in temperature, a possible climate driver of conflict that has received considerable attention in a prominent cross-disciplinary journal (Burke et al., 2009; Buhaug, 2010).

Two of the articles here (Slettebak, 2012; Bergholt & Lujala, 2012) look at natural disasters as a cause of conflict, although the latter article also uses disasters as an

[2] For a model of possible causal pathways from climate change to conflict, see Buhaug, Gleditsch & Theisen (2010: Figure 6).

[3] Although the importance of agriculture is assumed rather than measured in terms of employment or production.

[4] Theisen, Holtermann & Buhaug (2011–12), who use disaggregated data for Africa, also find no relationship between drought and civil war.

instrument for economic shocks. While Slettebak concludes that there may be an increasing trend in climate-related natural disasters, he sharply contradicts earlier research on the link between natural disasters and conflict (e.g. Nel & Righarts, 2008) and finds support for an argument derived from crisis sociology that people tend to unite in adversity. Bergholt & Lujala find that natural disasters have a negative effect on economic growth, but that this does not translate into an increased risk of conflict. In a scenario study for sub-Saharan Africa, Devitt & Tol (2012) find that the impact of civil war and climate change on economic growth in Africa has been underestimated.

Despite much public concern about the effects of sea-level rise,[5] this is not yet a theme that has received much attention in the conflict literature. Neither are there any articles on possible adverse security effects of possible countermeasures to climate change – the effect of biofuel on agricultural prices and possibly on food riots could have provided an interesting case.[6]

Climate models

Climate research provides an important source of data for much of the research on security effects. The majority of the articles in this issue make use of systematic data on levels and change of precipitation. Most of them use empirical data for the past few decades and assess the empirical regularities that can be assumed to continue at least in the near future. Only two of the articles (Bernauer & Siegfried, 2012 and De Stefano et al. 2012) cite projections from climate models as well, while Devitt & Tol (2012) use economic projections from IPCC's Special Report on Emission Scenarios. While our models of conflict are certainly imperfect, and the ability of social scientists to make predictions is limited (Schneider, Gleditsch & Carey, 2010; Ward, Greenhill & Bakke, 2010), current climate models and even data for the past few decades leave much to be desired in terms of forecasting accuracy and geographical precision.

Types of violence

Traditionally, research on armed conflict has concentrated on interstate war and civil war. By far the largest killer in the 20th century, however, was one-sided violence (including genocide and politicide) and environmental change has already been linked by some to major episodes of such violence in Rwanda and Darfur.[7] While so far there is not much evidence that robustly links climate change to major armed conflict of any of these three types, there is a more plausible argument that it may influence intergroup violence below the state level, 'nonstate violence' in the language of the Uppsala Conflict Data Program[8] or intercommunal conflict in the language of Benjaminsen et al. (2012).

The bulk of the articles, however, deal with internal conflict. Although some of them focus exclusively on state-based civil conflicts, others examine non-state conflicts in a rural setting, or both types. None of the articles examine urban conflict or one-sided violence. Five of the articles in this issue examine aspects of interstate conflict, though for the most part at a lower level of violence – militarized disputes rather than major war. Water resources, in the form of shared rivers or aquifers, play a key role in four of these studies. De Stefano et al. (2012) assess the 276 international river basins for changes in water variability and institutional resilience. They map the basins most at risk for hydropolitical tension and discuss how to target capacity-building to strengthen resilience to climate change and the development of mechanisms for cooperation and conflict resolution. Tir & Stinnett (2012) find that water scarcity increases the risk of militarized conflict, but that institutionalized agreements can offset the risk. Bernauer & Siegfried (2012) examine the Syr Darya catchment, a promising candidate for a neo-malthusian conflict over international water resources, but conclude that a militarized interstate dispute is unlikely. Another worst case in terms of the potential for water conflict, the Israeli–Palestinian conflict, is discussed by Feitelson, Tamimi & Rosenthal (2012). They conclude that it is unlikely that climate change will directly influence the conflict, although the securitization of the water issue may affect the negotiating positions of the parties.

Balancing effects?

None of the articles in this issue focus on possible *positive* effects of climate change. In theory, despite the many

[5] In a wide-ranging review of possible security implications of climate change, Scheffran & Battaglini (2011) include sea-level change as a source of potential conflict in South Asia.

[6] For an ethical argument along these lines, see Gomiero, Paoletti & Pimentel (2010).

[7] For skeptical discussions of the impact of climate change on the violence in Darfur, see Brown (2010) and Kevane & Gray (2008).

[8] www.pcr.uu.se/research/ucdp/datasets/ucdp_non-state_conflict_dataset_/.

pessimistic predictions about global food security under global warming,[9] local or regional improvements in the conditions for food production might offset current food insecurity in some areas and help to lower the risk of local scarcity conflict. But this remains to be studied. Gartzke (2012) argues that economic development, which drives climate change, also lowers the risk of interstate conflict. Therefore, even if climate change drives conflict, the effect may not be visible if it is overshadowed by the peacebuilding effect of economic development. Perhaps the overriding concern with economic development in the Third World can also explain a surprising finding in Kvaløy, Finseraas & Listhaug (2012). Using worldwide public opinion data, they observe widespread concern about global warming, but lower rather than higher in countries that are expected to be more seriously affected.

Where it matters?

There is indeed a focus on the developing world. Apart from the articles with a global scope, there is a strong concentration on Africa, particularly south of the Sahara, while one article deals with the Middle East and another with Central Asia. The bloodiest wars in the second half of the 20th century occurred in East and Southeast Asia, but by the turn of the century there were fewer conflicts in these areas and those that remained were at much lower levels of severity. The scholarly community may have seen climate-related conflicts as more likely to arise in Africa because of that continent's heavy dependence on rainfed agriculture. But in view of the public concern about the effects of sea-level rise and the melting of the Himalayan glaciers, the impact of climate change for conflict in Asia also seems like a worthwhile topic for future research.

Other concerns

Some case study-oriented researchers (Homer-Dixon, 1994; Kahl, 2006) have argued that many case studies find support for a scarcity model of conflict while large-N statistical research generally fails to do so (see e.g. Theisen, 2008). However, other case studies (e.g. Benjaminsen, 2008) are closer to the skeptical position. In this issue, and in the current literature generally, there is no systematic difference between case studies and statistical investigations. While some of the case study literature has been criticized for studying only the conflict cases (Gleditsch, 1998), it can also be faulted for relatively shallow case description and theoretical myopia. More recently, the large-N conflict literature has moved away from an exclusive reliance on the 'country-year' approach, towards geographical and temporal disaggregation (Cederman & Gleditsch, 2009). The ambition is to measure conflict as well as explanatory variables for short time intervals and for subnational regions or territorial grid cells. This approach seems particularly appropriate to the study of effects of variables such as climate change that do not vary along national boundaries, and it may help to bridge the gap between case studies and large-N studies.

One of the lessons that the large-N community could learn from proponents of case studies is the emphasis on interaction effects. Homer-Dixon (1994) and Kahl (2006) do not argue that environmental change generally and climate change specifically have a major impact on conflict – the effect plays out in interaction with exogenous conflict-promoting factors (Buhaug, Gleditsch & Theisen, 2008, 2010). Koubi et al. (2012) and Tir & Stinnett (2012) take a step in this direction in testing for interactions with institutions and regime type respectively. Kofi Annan (2006: 9–10) argued in one of his last reports as UN Secretary-General, that 'pollution, population growth and climate change are ... occurring now and hitting the poorest and most vulnerable hardest. Environmental degradation has the potential to destabilize already conflict-prone regions, especially when compounded by inequitable access or politicization of access to scarce resources.' Here, he is invoking an interaction effect of climate change with no less than three other variables. Unfortunately, it seems unlikely that case study researchers or large-N scholars will launch a systematic investigation of such complicated interaction patterns any time soon.

[9] IPCC (2007: WG2, Ch. 5, Section 5.8.1 Findings and key conclusions) concludes with high confidence that '[p]rojected changes in the frequency and severity of extreme climate events will have more serious consequences for food and forestry production, and food insecurity, than will changes in projected means of temperature and precipitation', that '[c]limate change increases the number of people at risk of hunger' but that '[t]he impact of chosen socio-economic pathways (SRES scenario) on the numbers of people at risk of hunger is significantly greater than the impact of climate change', and that '[c]limate change will further shift the focus of food insecurity to sub-Saharan Africa' (so that '[by] 2080, about 75% of all people at risk of hunger are estimated to live in this region'), and (with medium confidence) that 'moderate warming benefits crop and pasture yields in mid- to high-latitude regions'. Collier, Conway & Venables (2010) argue that the grave consequences of climate change for agriculture in Africa should be countered by industrialization, urbanization, and new agricultural technology (including genetically modified organisms).

In reviewing an article for this issue, William Nordhaus[10] was rather critical: 'this is a paper about weather, not climate'. The Glossary in IPCC (2007) defines climate as 'average weather', usually over a 30-year period.[11] Most of the studies reported here operate over shorter time periods, so this criticism has considerable substance, although Hendrix & Salehyan (2012) and Koubi et al. (2012) measure climate variation as deviations from long-term averages. A few recent studies take a very long-term perspective (e.g. Zhang et al., 2006 for China and Tol & Wagner, 2010 for Europe). With data for a whole millennium,[12] they conclude that war was more frequent in colder periods. However, Tol & Wagner add that the relationship weakens in the industrialized world. A plausible interpretation of this is that agricultural production suffers in the cold periods, but that with increasing industrialization the world moves away from malthusian constraints. The conflict data used in these studies have not been well tested and for obvious reasons there is a lack of control variables. Based on regularities observed by historians in the distant past and using UCDP/PRIO conflict data for the period 1950–2004, Hsiang, Meng & Cane (2011) argue that the El Niño/Southern Oscillation (ENSO) has a significant influence on the onset of civil conflict. The link to global warming is tenuous and questions have been raised about the robustness of this finding. But if it holds up, it provides another indication that armed conflict may be related to the climate even in the modern age. In any case, better integration between the long-term climate studies and the studies of 'weather' changes reported here, is a priority item on the research agenda.

Conclusions

Climate change is the world's first truly global man-made environmental problem[13] and a firm warning that human activities can influence our physical environment on a global scale. The range of possible consequences of climate change is so wide, even for the limited temperature changes foreseen in the IPCC scenarios, that it is difficult to sort out the main priorities. Obviously, if a reversal of the trend towards a more peaceful world was one of these consequences, it should have a prominent place on the policy agenda. Based on the research reported here, such a pessimistic view may not be warranted in the short to medium run. However, as noted by Feitelson, Tamimi & Rosenthal (2012) and Salehyan (2008), framing climate change as a security issue may influence the perceptions of the actors in local and regional conflict and lead to militarized responses and thus perhaps contribute to a self-fulfilling prophecy.

The study of the relationship between climate change and conflict has advanced noticeably in the past five years. With regard to how changes in precipitation may influence internal conflict, the one area where we now have a fair number of studies, the dominant view seems to be that rainfall abundance is associated with greater risks than drought and that in any case other conflict-generating factors are more important. Studies of how climate change may promote interstate conflict over water resources also seem to point in the direction of a weak or a null relationship. In other areas, the number of studies is still very low, so it is premature to offer a summary. On the whole, however, it seems fair to say that so far there is not yet much evidence for climate change as an important driver of conflict. In recent reviews of this literature, Bernauer, Böhmelt & Koubi (2012) and Gleditsch, Buhaug & Theisen (2011) conclude that although environmental change *may* under certain circumstances increase the risk of violent conflict, the existing evidence indicates that this is not generally the case.

While we primarily hope that the studies presented here will have an impact on scholarly research in this area, they could also have an influence on policymaking. The IPCC is currently working on its Fifth Assessment Report, scheduled for release in 2013. For the first time, this report will have a chapter on the consequences of climate change for human security, including armed conflict (IPCC, no date). We hope that the studies reported here will contribute to a balanced assessment by the IPCC, built on the best peer-reviewed evidence.

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[10] Review, 16 November 2010; permission to cite by name, personal communication, 4 November 2011.

[11] For a critical discussion of different definitions of climate change, see Pielke (2005).

[12] Or even two, as in Zhang et al. (2010).

[13] As distinct from international environmental problems such as transboundary pollution (acid rain, pollution in international rivers). The depletion of the ozone layer was another global problem. But it was solved quite rapidly through a mix of unilateral action and an international agreement, although it will take a few generations for the ozone layer to recover completely.

anniversary. A large 'thank you' is due to the Society and its sponsors for the anniversary conferences: NTNU, Statoil/Hydro, and the Norwegian Ministry of Education and Research. Generous additional financial support was provided by the Research Council of Norway. My fellow members of the organizing committee for the conference, Ola Listhaug and Ragnar Torvik, helped to shape the program, raise funds, and get the event off the ground. Rune Slettebak assisted the committee through the whole process, including the selection of conference papers and presentations invited to submit draft articles. Julien Bessière skillfully created and maintained the conference website. We are also grateful to all the participants of the conference and the dozens of reviewers, who have greatly influenced the contents of the special issue. Finally, most of the contributors to the special issue commented critically and constructively on a draft of this introduction, as did Andrew Mack, William Nordhaus, and Roger A Pielke Jr. None of them share any responsibility for whatever errors remain.

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The publics' concern for global warming: A cross-national study of 47 countries

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Abstract

This article relies on data from the 2005–09 World Values Survey to examine individual and cross-national variation in perception of the seriousness of global warming. The data show that a large majority of the public in all countries are concerned about the problem of global warming and that this assessment is part of a broader concern for global environmental issues. The widespread concern implies that global warming has the potential to generate mass political participation and demand for political action. Motivated by a value-based approach to the study of public opinion, the article shows that perception of the seriousness of the problem is positively correlated with high education, post-materialism, and a leftist position on the left–right scale. In addition, religious beliefs are important, suggesting that there is some diversity in the value basis for the issue and that it is not only linked to the 'new-politics' perspective. Variation across nations in wealth and CO_2 emissions is not significantly related to the publics' assessments of the problem, and, somewhat counterintuitively, people from countries relatively more exposed to climate-related natural disasters are less concerned about global warming. We suggest possible explanations for the latter finding and discuss our results in relation to the broader literature on environmental change, insecurity, and the potential for conflict.

Keywords

cross-national attitude studies, global warming, public opinion

Introduction

Global warming has emerged as a major political concern among scientists, politicians, and citizens across the globe. In this article we study one important aspect of this issue among citizens: the perception of the seriousness of the problem – both in an absolute sense and relative to other major environmental issues. Such perception of seriousness is only one of many relevant issues of global warming (Nisbet & Myers, 2007), but it is the obvious starting point for policy considerations and demand for political action from mass publics.

So far, the issue of global warming has not led to widespread political involvement of the mass public; it has been restricted to smaller activist groups. However, the nature of global warming as a political issue leads us to expect that it has the potential to become an important generator of political participation and policy considerations among the mass publics. Gleditsch (1998: 388f) distinguishes between a broad and a narrow view of

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environmental change as a security issue. A broad view considers severe environmental deterioration as a security threat and thus part of high politics, while the narrower view only takes account of the causal relationship between environmental change and conflict. In his Nobel Lecture, Rajendra K. Pachauri (2007), the chairman of the Intergovernmental Panel on Climate Change (IPCC), redefines peace as 'security and the secure access to resources that are essential for living', and further argues that 'a disruption in such access could prove disruptive of peace'. By such a definition, global warming is an indirect cause of conflict, by hindering the access to clean water, sufficient food, and stable health conditions. That there are physical, psychological, economic, and political aspects of insecurity tied to global warming is not a controversial statement, but there appears to be no clear link between climate change and conflict (e.g. Nordås & Gleditsch, 2007). Nonetheless, 'the security threat from climate change has been presented in public debate in increasingly flamboyant wording' (Nordås & Gleditsch, 2007: 628), suggesting that the public might perceive a connection between global warming and conflict. In the broad definition of environmental change as a security problem, such a widespread perception of seriousness can be seen as an indicator of insecurity and of the potential for conflict. Thus, understanding to what degree and among which segments of the electorate climate change influences perceptions of seriousness is important.

We are not the first to study public concern for climate change using cross-national data (see e.g. Bord et al., 1998; Brechin, 2003; Franzen, 2003; Franzen & Meyer, 2010; Inglehart, 1995; Sandvik, 2008), but our study includes a larger number of countries than previous studies, and few systematic attempts have been made to explain the cross-national variation in environmental concern (but see Sandvik, 2008; Franzen & Meyer, 2010), especially using methodologies that allow concern to be measured at the appropriate, individual level. The most similar study is Franzen & Meyer (2010), but they use a smaller sample of countries and study general concern for the environment and not climate change specifically.

In the next section, we review some of the relevant scholarly literature on political opinion and global warming. On the basis of the literature review we formulate expectations and hypotheses on individual and cross-national variation in perceptions of seriousness. We derive the expectations from two partly competing perspectives: a value-based approach and an 'objective conditions' approach (see Inglehart, 1995 for a somewhat similar approach). In the third section we present the data and method we use to evaluate the hypotheses, while the fourth section presents the empirical results. The data show that concern for climate change is widespread in all countries. In line with the finding that concern for climate change is strong across the globe, we find weak and statistically insignificant correlations between modernization (GDP per capita) and CO_2 emissions while, somewhat counterintuitively, we find less concern in countries most exposed to climate-related natural disasters. At the individual level, we find strong correlations between value orientations and perception of seriousness. In the conclusion, we discuss the implications of our findings for the broader literature on climate change and insecurity.

Theoretical background

We build our analysis of public concern for global warming on two models of public opinion: a value-based approach linking concern about global warming to fundamental political values, and an 'objective conditions' approach, linking concern about global warming to contextual conditions. We present these in turn.

A value-based approach to concern for global warming

To what degree citizens perceive the problem of global warming as serious is likely to be correlated with concern for environmental issues more generally, which again is likely to depend on more fundamental value orientations. Particularly important in this regard is Inglehart's (1977) 'new politics' perspective, although we would also argue that more traditional value orientations ('old politics') linked to religious beliefs are likely to be determinants.

The new politics perspective holds that as countries become affluent, their citizens shift their concern from issues related to economic conditions and personal security ('materialist' concerns) to issues related to political and individual freedom and environmental protection. New politics is primarily a value structure within advanced industrial economies, although it is also supposed to be part of a general model of development (Inglehart & Welzel, 2005).

Based on the new politics literature we classify global warming as a new political issue. Education is a key variable in new politics theory and should correlate positively with perception of global warming as an important problem. Education is a cognitive resource which facilitates the understanding of the phenomenon and provides the citizen with capacity to take part in political action.

Next, concern about new politics issues are argued to grow as new age cohorts replace old age cohorts; thus we expect the young to be more concerned about global warming than the old (Inglehart, 1977; Dalton, 2006):

> *Hypothesis 1:* Younger people and individuals with a high level of education will be more concerned about global warming than the elderly and individuals with a low level of education.

Next, since environmentalism is linked to a post-materialist values system, we expect those who classify themselves as post-materialists to be more likely than materialists to perceive global warming as a serious problem. Left–right ideology, however, is not so obviously linked to concern for the environment, and Neumayer (2003) reports no consistent or robust association between traditional left party strength and air pollution levels. A potential reason for this is that the left–right dimension covers several underlying value preferences (Fuchs & Klingemann, 1989), and some of the preferences, for example those based on the economic dimension of left–right ideology, have an ambiguous relationship with environmental attitudes and values. But overall, it is likely that that those who locate themselves on the left are more pro-environment (see e.g. Neumayer, 2004), and we expect citizens on the left to be more concerned about these problems than those on the right side of the ideological spectrum. Moreover, the mere fact that left political parties, at least those without strong ties to labour unions, are typically more concerned with environmental issues suggests that citizens with a leftist identification will express more concern. This is so since citizens with a political identity are likely to use the stance of parties they sympathize with as cues when forming their own opinion (e.g. Malka & Lelkes, 2010). We posit:

> *Hypothesis 2:* Post-materialists and left-wingers will be more concerned about global warming and the greenhouse effect than materialists and those on the right side of the left–right spectrum.

Traditional values can also influence the concern for environmental issues, in particular religion and religious values, although the theoretical and empirical evidence for the direction of the relationship is mixed. The 'Lynn White thesis' (White, 1962) argues that the Judeo-Christian tradition has promoted values that consider humans masters over nature, allowing or promoting Western societies' exploitation of nature. For this reason they argue that persons belonging to the Judeo-Christian religious tradition are less concerned about the state of nature (Schultz, Zelezny & Dalrymple, 2000; Biel & Nilsson, 2005; Hand & Van Liere, 1984; Eckberg & Blocker, 1989; Greely, 1993). Further, a negative relationship between biblical literalism and environmental concern has been found by Eckberg & Blocker (1989) and Guth et al. (1995). Moreover, Wood & Vedlitz (2007) find a statistically significant negative correlation between religious fundamentalist orientations and concern for global warming. Kanagy & Willits (1993), however, find that religious participation in general is positively correlated to environmental concern, while Seippel & Lafferty (1996) remark that the strong biblical appeal to maintain the creations of God can contribute to making Christians more concerned about environmental issues. We note that the negative relationship between religiosity and concern for the environment is mainly found in the United States. We thus suspect that it is specific to the US context, and expect:

> *Hypothesis 3:* Religious persons will be more concerned about global warming than non-religious persons.

The 'objective conditions' approach

In addition to individual-level characteristics, we believe that individuals' perception of global warming is influenced by characteristics of the country of the individual. We label this an objective conditions approach: given the distribution on pro-environmental value structures, a country's level of concern should co-vary with relevant country-level variables. We emphasize three country-level variables: GDP per capita, CO_2 emissions per capita and exposure to natural disasters.

We start from the assumption that perception of weather changes – and associated media reports on extreme weather – will probably make an impact on citizens' attitudes toward global warming. The cues that people take from weather patterns might not reflect a scientific understanding but will be framed by social factors. Palutikof, Agnew & Hoar (2004) study public perceptions of unusually warm weather in the UK, focusing on southern England and central and southern Scotland. They find that perception differs significantly in the two regions, with residents in England judging unusually warm summers more negatively than those who live in Scotland. This can be seen as a reflection of personal experiences with weather patterns in the two areas. In a recent survey of US public opinion, Borick & Rabe (2010) find that views on climate change are shaped by personal observations and meteorological events and yet are also influenced by partisan leanings.

These studies suggest that we need to take the context into consideration when we model public opinion on global warming. Previous research as well as public debate has focused on the conflict between rich and poor countries and on the cause of the problem as indicated by the level of CO_2 emissions in the country. Franzen (2003) and Franzen & Meyer (2010) find a positive correlation between GDP per capita and an index tapping both general concern for the environment and willingness to pay for environmental protection. Sandvik (2008) studies a larger number of countries with a larger variance in country wealth than Franzen (2003) and Franzen & Meyer (2010) and finds negative correlations between concern for global warming and a country's gross domestic product and per capita CO_2 emissions, though for the latter there is a very weak relationship. He believes that this is so because individuals find it increasingly harder to accept global warming as a problem the more responsibility a person feels for it – a relationship he labels the 'uncomfortable truth'. Norgaard (2006) argues that people from wealthy nations benefit in a psychological and emotional manner by avoiding acknowledgement of such uncomfortable truths. If so, it constitutes a problem for reaching globally binding agreements on policies to reduce CO_2 emissions because countries which contribute the most to emissions have publics who recognize the problem to a lesser degree than the public in poorer countries (Sandvik, 2008: 333). Since our sample is more similar to Sandvik's (2008) than to Franzen & Meyer's (2010), we expect:

> *Hypothesis 4:* People from rich countries or countries with large carbon dioxide emission levels will be less concerned about global warming than people from poor countries or from countries with low emissions of carbon dioxide.

The proposed negative consequences of global warming are, however, not equally distributed across countries, and as noted above, to what degree one has experienced the type of extreme weather predicted to be a consequence of global warming might influence one's perception of the problem. We expect that people living in such countries will be more concerned about global warming, since people from countries exposed to climate-related natural disasters are more likely to either obtain accurate information on its consequences or know someone who has personal experience with the consequences of global warming. Wood & Vedlitz (2007) study information processing with the politics of global warming as a case and find that personal experience with global warming increases the level of concern for the issue. Somewhat relatedly, Franzen & Meyer (2010) find no relationship between an index of environmental quality and their index of concern for the environment, while Gelissen (2007) finds a higher willingness to pay for environmental protection in countries with comparatively good water quality, presumably reflecting reverse causality.

Although the data at hand do not allow us to model detailed meteorological factors, we will include a third macro variable which measures the degree to which the country has been affected by climate-related natural disasters. Having experienced such disasters in their own country might increase the likelihood that citizens see global warming as a serious problem, as we expect that they will link effects of future climate change to previous climate-related disasters. Thus, we expect:

> *Hypothesis 5:* Citizens in countries that are exposed to climate-related natural disasters will be more concerned about global warming than citizens in countries that are less affected by such disasters.

Data and method

We use data from several sources to test the hypotheses. The data at the individual level are from the World Values Survey (WVS). We rely on data from the period 2005–09 (ballot A), which include 67,028 respondents from 47 countries. All continents are represented. Table A.I in the Appendix gives an overview of all the variables in the analysis.

The dependent variable in this analysis is how serious one takes global warming. The dependent variable is the following question in the World Values Survey (originally named V111, V112, and V113 in WVS, 2005): 'Now let's consider the environmental problems in the world as a whole. Please tell me how serious you consider each of the following to be for the world as a whole. Is it very serious, somewhat serious, not very serious, or not serious at all?' The respondents were asked to state the seriousness of 'Global warming or the greenhouse effect', 'loss of plant or animal species or biodiversity', and 'pollution of rivers, lakes and oceans'. We are concerned with the first issue, but, for comparability, we present some descriptive statistics for the two other variables as well. The dependent variables have four valid answer categories; 'very serious', 'somewhat serious', 'not very serious', and 'not serious at all', while 'don't know' is coded as missing. We have switched the original coding, so that low values indicate that one does not find global warming or the greenhouse effect to be serious problems, whereas high values indicate that one finds them to be very serious problems.

We include the following individual-level predictors. Following Hypotheses 1–3 we include age (and its square term), education level, the respondent's score on Inglehart's post-materialist index, the respondent's placement on the left–right scale, and three variables to capture religiousness: how frequently the respondent attends religious ceremonies, how important God is in the respondent's life, and whether the respondent takes some moments of prayer/meditation/contemplation.

In addition we include a dummy representing male gender, since several scholars have noted a linkage between gender and environmental concerns (Eckberg & Blocker,1989; Stern, Dietz & Kalof, 1993), and gender and concern for global warming (Kellstedt, Zahran & Vedlitz, 2008). Next, we include the respondent's answer on a 10-point scale measuring to what degree people shape their own fate, since people with high self-efficacy are expected to be more concerned about environmental issues (e.g. Kellstedt, Zahran & Vedlitz, 2008). A possible explanation for this is that people with high self-efficacy feel that they have the power and possibility to influence their surroundings. Finally, we include the respondent's declared interest in politics, since experimental research has found that getting new information on global warming affects perception of its seriousness (Wood & Vedlitz, 2007). We assume that political interest is correlated with the level of information regarding the threat of global warming.

Moving to the country level and the objective condition hypotheses, GDP per capita is based on data from the World Bank (WDI, 2010a) and available at http://data.worldbank.org/indicator. The numbers are in USD 2007 and log-transformed. CO_2 emissions are measured in metric tons and the data are log-transformed. Again, the variable is available through the website of the World Bank, but the original source is the Carbon Dioxide Information Analysis Center. The variable is described as follows: 'Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring' (WDI, 2010b).

Our final macro variable is based on numbers by EM-DAT, the International Disaster Database, maintained by the Centre for Research on the Epidemiology of Disasters (CRED, 2010), on total number of people affected (deaths, injuries, homelessness, etc.) by climate-related natural disasters (flood, storm, drought, and extreme temperatures) for the period 2000–05. The dataset is available at http://www.emdat.be/database, and disasters that fit at least one of the following criteria are included: 10 or more people killed; 100 or more people affected; declaration of a state of emergency; and/or call for international assistance. We divide the number of people affected by population size, giving us a relative measure, before log-transforming it to reduce the potential influence of extreme observations. Since EM-DAT codes missing data as 0, we are forced to estimate our models conditional on a positive number of reported disasters. The regression analyses include 39 countries.

Since we are interested in estimating the impact of variables at the individual and country levels simultaneously, we analyze the data using multilevel modelling, which is the most common estimation strategy in this situation (see Hox, 2002 for an introduction). We estimate random-intercept models which imply that the intercepts are allowed to vary across countries, and we explore whether the cross-national variation in the intercepts depends on the country-level variables. We explore simultaneously how the individual-level variables explain the individual-level variation in the perception of the seriousness of global warming. In the main analysis we present results from a multilevel linear model, although estimating a linear model is not ideal given that our dependent variable is categorical. To ensure that our results do not depend on our choice to estimate a linear model, we perform a robustness check where we dichotomize the dependent variable and estimate a multilevel logit model.

Findings

Concern for global warming is evident across the world

We begin with a simple descriptive analysis of concern for global warming. Table I presents the mean values on the dependent variable by country, rated from high values (concerned) to low values (less concerned). The table displays a widespread concern for global warming, as the mean value is greater than 3 (remember, a mean of 4 would imply that *all* respondents in the respective country view global warming as 'very serious') for all but three of the countries. At the top among the most concerned, we find countries such as Turkey, Argentina, and Burkina Faso, while the three countries with the least worried populations are Thailand, Rwanda, and Zambia. The 'objective conditions' approach seems to run into problems already, as the table gives the impression of no clear relationship between GDP per capita and concern for global warming. The main impression is a fairly

Table I. Mean values on concern for global warming or the greenhouse effect, by country

Country	*Mean*
Most concerned	
Turkey	3.85
Argentina	3.79
Burkina Faso	3.75
Spain	3.72
Chile	3.71
Andorra	3.71
Cyprus	3.70
Japan	3.69
Egypt	3.67
Italy	3.67
Trinidad & Tobago	3.65
Canada	3.62
Serbia	3.60
Sweden	3.59
Georgia	3.59
Moldova	3.58
Mexico	3.58
Uruguay	3.57
Australia	3.57
Bulgaria	3.56
Peru	3.55
Taiwan	3.55
Brazil	3.53
Mali	3.52
Least concerned	
Slovenia	3.50
Ukraine	3.49
Morocco	3.49
Norway	3.48
South Korea	3.47
Ethiopia	3.47
Poland	3.46
Vietnam	3.44
Finland	3.41
Switzerland	3.40
Germany	3.39
Jordan	3.35
Romania	3.34
Ghana	3.30
India	3.29
South Africa	3.29
USA	3.22
Indonesia	3.18
China	3.17
Malaysia	3.13
Thailand	2.98
Rwanda	2.96
Zambia	2.89

small cross-national variation in expressed concern. This either suggests that media attention to the issue does not vary much across countries, or that media attention is less important for expressed concern than one might suspect. Time-series data would be very useful to disentangle the impact of different predictors of the public's concern, but are unfortunately not available for a wide range of countries. Brechin (2003), however, reports results from US time series showing a fairly stable amount of concern for global warming in the period 1989–2002.

Global warming is not perceived as more serious than other environmental issues

Figure I displays the cross-national concern for global warming compared to the two other environmental issues asked about in the WVS: concern for 'loss of plant or animal species or biodiversity', and 'pollution of rivers, lakes and oceans'. As is evident, all problems are considered as serious problems. Pollution of rivers, lakes, and oceans has the highest percentage rating the problem as very serious, followed by global warming, which is marginally ahead of loss of biodiversity. We should not put too much weight on these rankings, however, as the differences are small. This finding replicates that of previous research that global warming is not considered as an especially important environmental problem by the public (e.g. Bord, Fisher & O'Connor, 1998; Brechin, 2003; but see Yeager et al., 2011).

The determinants of concern for global warming

Next we turn to the multilevel analysis of the variation in concern for global warming. Table II presents the results. We discuss the hypotheses in chronological order, thus beginning with the expectation that the young and those with a high level of education are more likely to perceive global warming as serious. The latter expectation is confirmed. Going from the lowest to the highest education level is, all else equal, estimated to imply a .22 points higher score on the perceived seriousness variable. For age, however, expectations are not met. The relationship with age is curvilinear, and we find that the age group 30–60 years perceives the problem as more serious than the young and the very old, questioning the cohort replacement logic of the new-politics perspective.

Moving to the impact of self-declared post-materialist and left–right ideology, we find that preferences for post-materialist values are positively associated with concern for global warming. In substantive terms, the difference between materialists and post-materialists is surprisingly small, as it amounts to a difference in perception of seriousness of approximately .06. The findings for political ideology support our expectations. Those on the moderate right are less likely than persons in the centre (the

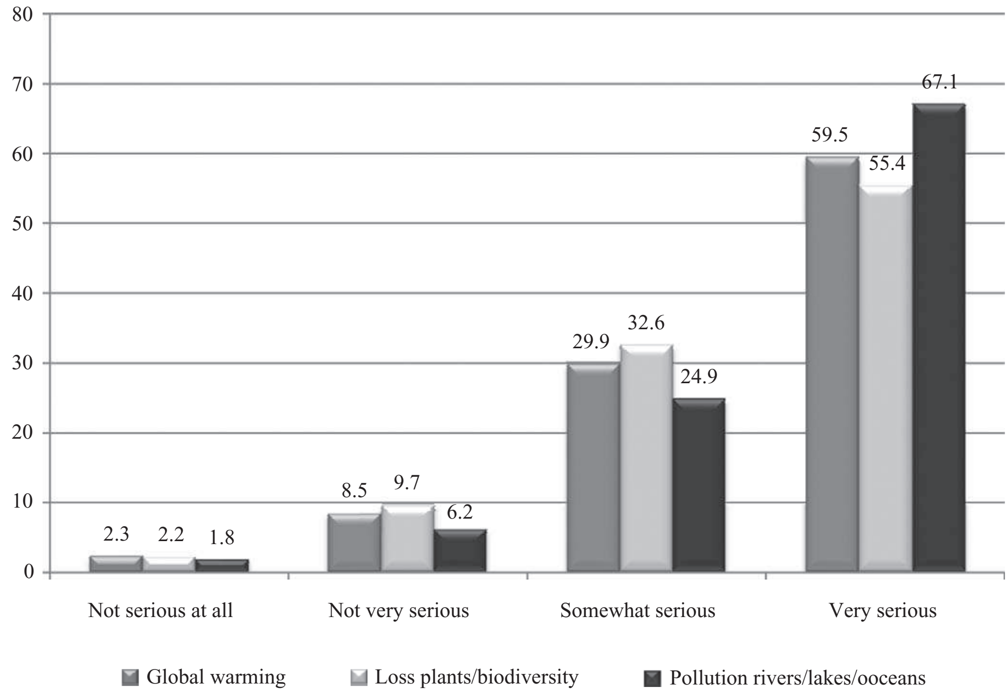

Figure 1. Rating of seriousness of three environmental problems (%)

reference group) to note the problem, and the difference is quite large, as it amounts to .11 on the concern scale. Regarding left–right ideology, it is only on the extreme left that citizens are more concerned than those in the centre (.05 on the concern scale). The group with moderate leftist ideology is not significantly different from the centrists, which is not that surprising given that we probably find most social democratic voters on the moderate left. Historically, social-democratic parties have had strong support among workers in manufacturing and other industries, which might not see it in their own short-term interest to promote environmental concerns.

As mentioned in the previous section, we analyze three indicators of religiosity. We find that concern for global warming is stronger the more often one attends religious services, but the coefficient is very small. We also find more concern about global warming among those who say they take some moments of prayer, meditation or contemplation, and those who feel that God is important in their lives. While the substantive effect of praying is quite small, the difference between someone stating that God is not important (1) and someone stating God is very important (10) is of the same size as the difference between a moderate rightist and a centrist.

The Lynn White thesis (White, 1962) gained some support in an alternative model where religious denomination (coded into dummy categories) was included, as this model showed that Christians were somewhat less concerned about global warming than members of other world religions. We chose not to include this as it was not a satisfactory measure of denomination membership. We find support for the efficacy hypothesis, as both political interest and the belief than one can control one's own fate are positively related to concern about global warming.

To sum up, we find support for the value-based approach, although the substantive effects are moderate. The expected linear relationship between age and concern is the only expectation we do not find full support for, as the middle-aged appear to be more concerned than the young.

Moving to the country-level and the 'objective conditions' approach, results are less in line with expectations. In line with Sandvik (2008), the coefficient for GDP per capita has a negative sign, but is not significant. CO_2 emission has a positive sign, but is not significant either.[1] More surprisingly, the impact of the relative risk of being affected by climate-related natural disasters is negatively correlated with level of concern for global warming, which indicates that people living in countries that are highly

[1] We also tested a model where we excluded education, since a higher level of education might be the causal link between wealth and concern for global warming. In addition, we tested a model where the coefficient for education was allowed to vary across countries. The substantive conclusions did not change.

Table II. Multilevel linear regression of concern for global warming

Variable	*Estimate*
Intercept	2.966 (0.327)***
Male	–0.021 (0.007)***
Age	0.004 (0.001)***
Age squared	–0.00004 (0.00001)***
Education	0.027 (0.002)***
Post-materialism index	0.029 (0.006)***
Extreme left[a]	0.052 (0.013)***
Moderate left[a]	0.0003 (0.011)
Moderate right[a]	–0.109 (0.010)***
Extreme right[a]	–0.054 (0.012)***
Control vs. fate	0.007 (0.001)***
Political interest	0.018 (0.004)***
Attend religious services	0.008 (0.002)***
Prayer[b]	0.047 (0.011)***
God important	0.012 (0.002)***
LN GDP per capita	–0.021 (0.044)
LN CO_2 per capita	0.005 (0.041)
LN Exposed to disaster	–0.040 (0.015)**

Multilevel random-intercept regression model. The table presents regression coefficients with standard errors in parentheses. Dependent variable: Please, tell me how serious you consider each of the following to be for the world as a whole. Is it very serious, somewhat serious, not very serious or not serious at all? Global warming or the greenhouse effect. High values indicate 'very serious'. Level of significance: $^{*}p \leq 0.050$, $^{**}p \leq 0.010$, $^{***}p \leq 0.001$. Description of the variables is found in Table A.I.

[a] Indicator variables for placement on left–right scale. Reference category: Center values.

[b] Reference category: 'Do not take some moments of prayer, meditation or contemplation or something like that'.

exposed to this type of natural disasters are less concerned about global warming than those living in less disaster-prone countries.

The natural-disaster variable used in the main analysis is measured relative to the population size in the country (per capita), and then log-transformed. Thus, we assume that a natural disaster affecting 1,000 people in a small country such as Andorra would make a larger impact on the entire country than if a disaster of the same size affected a large country like China. This is not necessarily the case, and we have therefore also estimated the model in Table II using the measure in absolute numbers (with log-transformation) in our main model. The conclusions are the same.

What can explain this counterintuitive finding? One possibility is that disaster-prone countries are typically countries with other and perhaps more acute problems worrying the public. Moreover, the countries that are most exposed to climate-related natural disasters also to a large extent are countries with less developed information systems and populations with low levels of education. Both factors might weaken the link between natural disasters and assessments of the effects of global warming. To explore this, we included the mean level of education as an additional control variable, but its coefficient is insignificant (see also Franzen & Meyer, 2010) and the natural-disaster coefficient is robust to its inclusion (results available upon request). Another possibility is that countries with a high level of natural disasters of the kind we measure are also more exposed to other types of natural disasters, or they have been exposed to climate-related natural disasters for a long time. If so, citizens might have somehow adjusted to such a situation, and concern for climate change might instead be driven by a recent growth in climate-related natural disasters. Finally, there is within-country variation in exposure to climate-related natural disasters – for studying exposure, country-level data might be too rough an approximation.

As discussed in the previous section, our dependent variable is categorical and not continuous, and results might be sensitive to our choice of estimating a linear model, that is, assuming a continuous dependent variable. Therefore, as a sensitivity check, we dichotomized our dependent variable in two alternative ways and estimated multilevel logistic regressions. First, we collapsed the *not serious at all* and *not very serious* categories into a reference category (0) and coded *somewhat serious* and *very serious* as 1. Second, we coded the *very serious* category as 1, and the rest as 0. We found no large, substantive deviations from the results reported in Table II (results not shown), although some of the estimates of the religious indicators and political ideology had weaker effects.

Conclusion

Global warming is an issue of potentially high significance across the globe, yet the scientific basis for the phenomenon is difficult to understand for lay people. We show that public concern for global warming is nonetheless widespread. At the individual level our findings lend support to a model based on new-politics arguments, as we find that perception of the seriousness of the problem is correlated with high education and post-materialism, and self-identification with the far left. However, we also find that old politics plays a role since traditional values, measured through religious indicators, are related to concern. Thus, our findings suggest some diversity in the value basis for environmental concern.

Next, we find that concern for global warming is relatively evenly distributed among rich and poor countries and among countries with low and high CO_2 emissions, while people from countries relatively more exposed to climate-related natural disasters are less concerned about global warming. The latter finding might reflect an ability to adapt to climate change; however, one should also keep in mind that there is within-country variation in exposure to climate-related disasters. Data about the mass publics' knowledge of disasters in the country would also be desirable, although such information is difficult to establish for a large number of countries.

Climate change can be seen as a security concern in the sense that, across the globe, citizens view global warming as a very serious problem. The widespread concern implies that there is the potential for mass mobilization. However, we do not believe that this can be taken as support for the view that climate change will lead to violent conflict. First, the finding that concern is slightly smaller in countries with a higher exposure to natural disasters provides no support to the view that scarcity due to climate change will increase the potential for conflict, which is typically argued by those warning that climate change might lead to conflict (see Nordås & Gleditsch, 2007 and other articles in this issue for a review of the literature). Second, we find that concern is strongly tied to a value system which is more widespread in rich countries, where the potential for mass violent conflict is smaller. Nonetheless, widespread concern for the consequences of climate change should not be dismissed as politically unimportant. The potential to pay for environmental protection is larger in rich countries, and studies of the public's willingness to pay for environmental protection have found that more are willing to pay in rich countries (e.g. Gelissen, 2007).

Replication data

The dataset, codebook and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Appendix

Table A.I. Documentation of variables included in the analysis

Variable name	Description	Min	Max	Mean	N
Micro variables					
Global warming	Now let's consider environmental problems in the world as a whole. Please, tell me how serious you consider each of the following to be for the world as a whole. Is it very serious, somewhat serious, not very serious or not serious at all? Global warming or the greenhouse effect. 4 = very serious	1	4	3.48	37,739
Loss of plants	Environmental problems in the world: How serious is loss of plant or animal species or biodiversity? 4 = very serious	1	4	3.44	37,520
Pollution	Environmental problems in the world: How serious is pollution of rivers, lakes and oceans? 4 = very serious	1	4	3.60	37,528
Male	Gender. 1 = male	0	1	0.50	37,739
Age	Age	15	98	41.91	37,739
Age squared	Age squared	225	9,604	2,026.21	37,739
Education	Highest educational level attained	1	9	5.48	37,739
Post-mat. index	Post-materialist index 4-item. 1 = materialist, 3 = post-materialist	1	3	1.82	37,739
Extreme left	In political matters, people talk of 'the left' and 'the right'. How would you place your views on this scale, generally speaking? Self-positioning on the left–right scale. 1 = extreme left (1–2 on the left–right scale)	0	1	0.10	37,739
Moderate left	Self-positioning on the left–right scale. 1 = moderate left (3–4 on the left–right scale)	0	1	0.16	37,739
Centre	Self-positioning on the left–right scale. 1 = centre values (5–6 on the left–right scale)	0	1	0.40	37,739
Moderate right	Self-positioning on the left–right scale. 1 = moderate right (7–8 on the left–right scale)	0	1	0.21	37,739
Extreme right	Self-positioning on the left–right scale. 1 = extreme right (9–10 on the left–right scale)	0	1	0.14	37,739
Control vs. fate	Some people believe that individuals can decide their own destiny, while others think that it is impossible to escape a predetermined fate. Please tell me which comes closest to your view on this scale on which 1 means 'everything in life is determined by fate', and 10 means that 'people shape their fate themselves'. 1 = everything is determined by fate, 10 = People shape their fate themselves	1	10	6.37	37,739
Political interest	How interested would you say you are in politics? 4 = very interested	1	4	2.51	37,739
Attend religious services	Apart from weddings and funerals, about how often do you attend religious services these days? 1 = Never, practically never 7 = More than once a week	1	7	3.82	37,739
Prayer	Do you take some moments of prayer, meditation or contemplation or something like that? 0 = No, 1 = Yes	0	1	0.76	37,739

(continued)

Table A.I. (continued)

Variable name	*Description*	*Min*	*Max*	*Mean*	*N*
God important	How important is God in your life? Please use this scale to indicate. 10 means 'very important' and 1 means 'not at all important'	1	10	7.87	37,739
Macro Variables					
LN GDP per capita	Log of GDP per capita, 2006	5.30	11.19	8.61	39
LN CO_2 per capita	Log of CO_2 emissions, per capita (metric tons), 2006	-3.17	3.26	1.09	39
LN Exposed to disaster	Log of number of total affected (deaths, injured, homeless, etc.) by climate-related natural disasters (flood, storm, drought, and extreme temp) per capita.	-11.22	-0.53	-4.97	39

The descriptive statistics are based on the sample used in Table II. N refers to number of individuals for the micro variables, but to number of countries for the macro variables.

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African range wars: Climate, conflict, and property rights

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Abstract

This article examines the effect of climate change on a type of armed conflict that pits pastoralists (cattle herders) against each other (range wars). Such conflicts are typically fought over water rights and/or grazing rights to unfenced/unowned land. The state is rarely involved directly. The rangeland of East Africa is a region particularly vulnerable to drought and livestock diseases associated with climate change. To analyze the possible effects of climate change on pastoral conflict, we focus our analysis on changes in resource availability, contrasting cases of abundance and scarcity. The role of resources is further contextualized by competing notions of property rights, and the role of the state in defining property and associated rights. We employ a contest success function (CSF) game-theoretic model to analyze the logic of range wars. This CSF approach emphasizes the low-level, non-binary nature of raiding behavior between pastoralist groups over limited natural resources. A central contribution of this approach is that the logic of raiding behavior implies a *positive* relationship between resources and conflict. This positive relationship is supported by several studies of the rangeland of East Africa, but is generally dismissed by the literature on the 'resource curse'. This relationship is contingent on other factors examined in the model, producing the following results. First, the level of property rights protection provided by the state generally reduces conflict between pastoralist groups. Second, if property rights protection is provided in a biased manner, then conflict between pastoralist groups increases. Third, severe resource asymmetries between two pastoralist groups will induce the poorer group to become bandits (focusing their efforts on raiding and not producing), while the richer group raids in retaliation.

Keywords

climate change and security, communal violence, game theory, non-state actor violence, property rights, resources and conflict

Introduction

Dealing with impending change has long brought out the alarmists. Indirectly relevant to the climate change debate is Thomas Malthus's (1798/1826) argument that a geometrically expanding population would outstrip arithmetically expanding agricultural production, leading to starvation, conflict, and war. Such alarmist arguments are not unique to the 19th century. With respect to climate change and conflict, Lee (2009) argues that interstate conflict (though perhaps short of war) will be more prevalent at higher latitudes over access to newly exposed resources while intrastate conflict will be more prevalent near the equator over scarcer resources.[1] We try to step back from these alarmist arguments by presenting a model that points to situations where we should expect more conflict as well as situations where we should expect less conflict.

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[1] In fairness, Lee does say that conflict due to climate change is not inevitable, but will depend on how we react to these changes.

Much of the research examining the role of climate change and armed conflict has focused on intrastate and interstate conflict; however, if there is going to be a relationship between ecological degradation (leading to scarcity) and armed conflict, it should be most strongly evident in the form of intercommunal or ethnic violence. More particularly, it should be most evident among those populations most directly affected by such scarcity. The pastoralists of the range lands of East Africa are among the most vulnerable to drought and stock disease (e.g. rinderpest, which can devastate a herd) and other disasters associated with climate change. Herders are directly affected by changes in climate that affect the vitality of their herds. If climate change, in the form of water availability, is going to affect any group's proclivity to violence, then it will be a group most directly dependent on war and land, such as a herding group. In contrast, the effect of climate change on urban groups will be more indirect and complex. Pastoral conflict, mostly in the form of cattle rustling as the main form of violence, thus constitutes a more direct test of the environmental scarcity proposition and provides an opportunity to examine the analytical logic underlying the debate.

The idea that resources affect conflict is not unique to the climate change and conflict literature. Resources are also linked to conflict in a literature of its own. Yet, few if any large-N empirical studies have been able to establish any relationship between scarcity and interstate war or intrastate war or conflict (Nordås & Gleditsch, 2007; see also other articles in this issue of *JPR*). With regard to intercommunal violence, which constitutes the larger classification of violence to which pastoral range wars belong, there does appear to be some case study support for the scarcity argument for intercommunal violence (Mkutu, 2008; Fukui & Turton, 1979), but these cases are strongly contradicted by empirically based case studies such as Witsenburg & Adano (2007, 2009), Adano et al. (2012), and Theisen (2012). What is missing in this literature is a systematic analysis of how resource availability relates to pastoral violence.

In this article we focus on the mechanisms by which resource scarcity or plenty lead to armed conflict or peaceful relations between pastoral groups. While our analytical approach is a formal analytical model that could be classified as political economy, our approach is more similar to that of 'political ecology' (Johnson & Anderson, 1988; Bassett, 1988; Le Billon, 2001; Turner, 2004; Benjaminsen & Ba, 2009; Benjaminsen, Maganga & Abdallah, 2009). Advocates of the 'political ecology' approach stress that conflicts between agrarian groups should be understood as more than just resource conflicts and that the politics of land plays a critical role. We reflect this perspective by focusing on the limited but potentially biased role the state plays in establishing, protecting, and recognizing property rights in Africa's rangelands. More particularly, we analytically examine the role of resource scarcity and abundance as affected by property rights protection and bias to examine how this protection shapes pastoral violence. Through our analytical framework, we demonstrate that resources alone (whether scarce or abundant) only go so far in explaining this form of communal violence. We show how differences in property rights protection and the state's bias in protection of these rights can explain why in most cases pastoral violence is associated with resource abundance, but also the conditions for other cases when resource scarcity leads to violence.

Political economists such as North (1990), Knack & Keefer (1995), Acemoglu, Johnson & Robinson (2001), and Knack (2003) have persuasively shown how property rights protection can affect economic growth and development. But these works ignore the role of bias in protection. Neutral application and interpretation of property rights is often impossible. One group invariably benefits at the expense of another. Indeed, the establishment of entitlement will most often be biased. This bias is critically important for understanding communal conflict.

Bates (2001), informally, and Gonzalez (2007), more formally, model the non-uniform application of property rights. In particular, they focus on the endogenous nature of property rights and those in control of the state apparatus. But they focus on the application and non-application of property rights. They do not feature the inherent bias of property law, which favors one type of user over another.

Since colonial times, the pastoral policy discourse in Kenya and Tanzania, as well as other East African countries, has been shaped significantly by a modernist ideology (Raikes, 1981). Modern husbandry, it is said, entails land titling, enclosing the commons, and establishing permanent settlements (Benjaminsen, Maganga & Abdallah, 2009; Kennedy et al., 2010). Such policies fundamentally alter land use policy by affecting the nature of property rights.

The degree to which property rights are protected and biased plays a significant role in shaping how resource scarcity or abundance are related to armed conflict. The role of property rights is particularly important for understanding pastoral conflict. The article proceeds as follows: we introduce our modeling technique and how we model resource scarcity and plenty as well as property rights protection and bias. We then present the analytical structure of our model. A presentation of the different equilibria of our game follows with explication of each equilibrium, drawing on case examples from African range wars. We end with a discussion of climate change, property rights, and pastoral conflict.

Resource allocation and conflict

We analyze pastoral conflict through the development of a contest success function model. Contest success functions (CSFs) offer a flexible way to model the dynamics of conflict. CSFs are economic models of conflict. Rather than featuring only the technologies of production as most other economic models do, they also incorporate the technologies of appropriation and war (see Skaperdas, 1996, for a review). Contest success functions allow us to model both aspects of an economy, the productive and the predatory. In an environment of a weak or fragile state, contracts are weakly enforced. Property rights, in particular, tend to be weakly enforced at best. The institutions that serve to regulate the economy work inefficiently and perform even more poorly when violence is endemic. Consequently, conventional models of economic production fail to accurately model the political economy of violent conflict. Indeed, the original idea of a CSF is that actors choose how they are going to allocate their individual resources in the total absence of property rights. Resources can be allocated either into production or appropriation. In this respect, the CSF modeling approach offers an effective way to model conflict between pastoralist groups as they choose how to allocate their time either into caring for their own animals (production) or raiding the animals of other groups (appropriation).

Conventional production models assume perfect property rights and enforceability of contracts. Hirshleifer (2001) purposely examines the 'dark side' of economic activity in which the opposite is true on both counts. The two types of model are at opposite ends of an institutional spectrum. Part of our purpose here is to examine the full range of institutional possibilities. Rather than the stark contrast of binding, enforceable contracts versus the complete absence of moderating institutions, we examine interactions of non-state actors under the imperfect gaze of the state. State institutions are neither perfect nor absent. Instead, we examine how the biases inherent in state institutions and their relative strength can be significant factors accounting for the level of conflict between pastoral groups.

CSFs are not the only way of modeling conflict, but they do have advantages over other modeling techniques for examining the raiding behavior of pastoralist groups. Most models of conflict in political science are discrete in nature; actors decide to fight or not to fight, ending in war or not war. Such models are useful for a wide variety of questions, but they are not generally able to examine the *level* of conflict. The closest alternative model to a CSF model is that of Powell (1999). In his model, actors first have a choice between allocating resources to 'guns or butter' and then have a choice whether to attack the other actor. An equilibrium military allocation in a guns-versus-butter (GvB) game represents a peaceful allocation in which neither actor finds it in his interest to attack. An equilibrium allocation in a CSF model in which at least one actor invests in 'guns'[2] implies a decision to steal from the productive effort of the other group. Rather than having two decision stages, CSF models have only one. Furthermore, the positive allocation in appropriative effort is variable such that it can be relatively low or high. When wars do occur in equilibrium in a GvB game, they should be thought of as all-out affairs. If the actors calculate that deterrence will fail, they will invest all of their resources in guns. Put another way, GvB games are good at modeling the deterrent level of military allocation but not a level of military allocation for persistent fighting over time. As such, GvB games are not suited for modeling low-intensity conflicts.

An additional important point is that allocating resources toward appropriation in a CSF model need not immediately translate into direct fighting between the two groups. The most successful raiding would go undetected when it is occurring (though it will not go unnoticed forever). Such successful raiding is simply theft and may not involve any violence against the other group. This distinction is similar to the legal distinction between burglary and robbery. Robbery implies at least a threat of violence because the perpetrator is stealing from you when you are present. Burglary happens to your property when you are not present; so, you were never under threat of violence. Raiding need not be so 'successful'. The act of raiding also carries a risk of being detected while it is occurring – that is, a risk of violence when the raiding party comes in contact with the other group and not just their livestock. Thus, we believe it is reasonable to assume that the total violence between the two groups will be *proportional* to total appropriative

[2] In CSF models, the allocation decision is between appropriation and production rather than guns versus butter. Thus, the allocation decisions between the two models are analogous but not perfectly so.

effort (i.e. total raiding behavior or TRB) as more raiding leads to a greater chance of members of the groups meeting and engaging in violence.

Property rights and (not necessarily ethnic) conflict

While the traditional economic production model assumes perfect property rights, the basic CSF model assumes the complete absence of property rights. We build on a particular functional form of the CSF model developed by Neary (1997) to examine intermediate and potentially biased property-rights regimes.[3] Of particular interest to us is that different groups might be differentially protected or favored by the government.[4] We focus in particular on one type of conflict – communal violence between pastoralists (herding groups). In particular, we examine the level of property rights protection (PRP) and the government's bias in property rights enforcement (Bias). In modeling PRP as a variable, we are able to examine the interactions of non-state actors in a weak state environment in which state institutions are neither perfect nor absent. By bias we mean a pattern of interpretation of property rights that favors one group over another.

By PRP we mean the absolute level of effort the state puts into enforcement of property rights. Our CSF model incorporates the notion that increasing property rights protection reduces the effectiveness of fighting, which implies increasing the equilibrium allocation of productive effort. Our model also accounts for the potential bias towards one interpretation of property rights over another interpretation. Property rights bias can occur between pastoralist groups when territory is divided between groups granting exclusive rights to one particular group, excluding others from grazing rights.

Bias and property rights protection interact to produce a non-monotonic result affecting the level of conflict in a society. More particularly, if a society has a moderate level of PRP, but some degree of bias away from equity, an increase in PRP can result in either a decrease or an increase in the amount of fighting between the two groups. Thus, simply increasing PRP without addressing equity and bias issues can actually increase the risk of armed conflict between pastoralists.

Enforcement of property rights need not be biased, but it usually is. Bias in property rights protection relates closely to the notion of horizontal inequality (Stewart, 2000; Murshed & Gates, 2005; Østby, 2008). The notion of horizontal inequalities between groups, classified by ethnicity, religion, linguistic differences, tribal affiliations, caste, etc., is distinguished from vertical inequality, which is the inequality between individuals within an otherwise homogeneous population. Horizontal inequality usually stems from historical discrimination or systematic patterns of economic exclusion of a particular group, typically distinguished by ethnicity or religion identities. What really matters are the differences between the two groups, not the within group inequalities in each of these individual identities (Murshed, 2009). Bias in property rights protection constitutes one aspect of economic horizontal inequality.

Our article examines how changes in the resources available to two pastoral groups might change their equilibrium splits between production and appropriation. Before examining that core question, we now discuss how climate change may affect resource levels.

Climate change, resources, and conflict

Strictly speaking, this article is about weather change, particularly about drought, which in turn affects resource availability, which then affects pastoral conflict. To study the phenomenon that we are investigating, we need not look at climate change per se. According to the World Meteorological Organization, climate is the statistical description (mean and variability) of surface weather conditions such as temperature, precipitation, and wind over a period of 30 years. 'Climate *change* is a statistically significant and persistent (decades or longer) variation in the mean state or variability of climate' (IPCC, 2001: appendix; see also Cioffi-Revilla et al., 2010). Climate change will affect the weather, thereby, at one extreme, increasing the frequency of droughts. But we need not have climate change to have drought. By analyzing the relationship between droughts and pastoral conflict, we can shed some light on the relationship between climate change and conflict.

What constitutes resources that can be allocated is an important question for our analysis. Some of these resources are affected by changes in weather while others are not. Within limits discussed below, livestock will be more plentiful when fresh water is more available.

[3] Neary (1997) offers interesting and important insights into issues of conflict and rent-seeking but does not examine the roles of property rights protection and bias. The functional form of Neary's CSF model, nevertheless, does provide an elegant way to incorporate the issues of protection and bias into the CSF.

[4] The model merely presumes the prior existence of two groups. These could be Sneetches with or without stars on their bellies as far as the model is concerned (Seuss, 1961).

Livestock can be bred, or can be sold and the proceeds reinvested. Cattle can also be substituted for goats in times of drought or traded for cattle in wetter times (Anderson, 2002). A group can devote its time and effort to herding and breeding or they can rustle cattle from other groups. They can produce or they can appropriate.

We are making an explicit assumption that more rain leads to more resources for allocation and that less rain leads to fewer resources. However, two extremes need to be discussed. On the one hand, an over-abundance of water (whether through heavy rain or through excessive glacial runoff) cannot be effectively harnessed without significant public infrastructure and can, in fact, reduce the productivity of the land by destroying crops and killing livestock. Thus, above some limit, more rain does not lead to more resources but is likely to lead to fewer resources. Flooding is also associated with such diseases as Rift Valley Fever, foot rot, and diseases born by biting flies. El Niño floods in 1997–08 were disastrous for pastoral communities in northern Kenya and southern Somalia (Little, Mahmoud & Coppock, 2001). On the other hand, a short-term shortage of water is different from a long-term drought. It is conceivable for a community to live off of previous reserves given one dry season. This would fit our 'less rain, fewer resources for allocation' assumption.

Modeling resource fluctuations, property rights, and conflict

Our model has several assumptions in common with other CSFs. Each group optimizes its welfare given the anticipated behavior of the other group. Each group has some initial resources ($R_i > 0$) that are then allocated into productive and appropriative effort. The appropriative effort is conceptualized as fighting effort, $F_i \in [0, R_i]$, or 'raiding'.[5] In the absence of enforceable contracts, all productive effort is assumed to create a collective income (I) that is divided between the two groups according to their appropriative effort. Collective income is assumed (for simplicity) to be the sum of productive effort.

$$I = (R_i - F_i) + (R_j - F_j) \tag{1}$$

We then adopt a modified version of a CSF model first presented by Neary (1997). The proportion of collective income that group i gets (p_i) is a function of its fighting effort divided by the total fighting effort of both groups. In addition, we allow for some level of protection of each group's productive allocation through an additional parameter, η>0. The η terms allow for definition of this function when fighting effort is zero.[6] It is through these additional terms that we will analyze property rights and bias – because one group's productive allocation can be better protected than the other group's – later in the article.

$$p_i = \frac{F_i + \eta_i}{(F_i + \eta_i) + \left(F_j + \eta_j\right)} \tag{2}$$

Given this division mechanism, each group maximizes its share of the collective income ($I_i = p_i I$).

$$I_i = \frac{F_i + \eta_i}{(F_i + \eta_i) + \left(F_j + \eta_j\right)} \left[(R_i - F_i) + \left(R_j - F_j\right)\right] \tag{3}$$

When $\eta_i = \eta_j$ and neither actor invests in fighting effort, collective income is divided equally (i.e. $p_i = 0.5$). We argue more generally that in situations of no conflict, the division of income would be premised on an expected division of collective income based on boundaries or norms. In this regard, the ratio $\eta_i/\left(\eta_i + \eta_j\right)$ can be interpreted as the no-conflict division to group i when $F_i = F_j = 0$. This no-conflict division is offset in practice by investments in fighting effort.

Both groups are assumed to make their allocation decisions simultaneously. Group i's reaction curve is found by taking the derivative of (3) with respect to F_i and then solving for F_i.

$$F_i = \sqrt{\left(F_j + \eta_j\right)\left(R_i + R_j + \eta_i + \eta_j\right)} - F_j - \eta_i - \eta_j \tag{4}$$

Group j's reaction curve is found the same way.

$$F_j = \sqrt{(F_i + \eta_i)\left(R_j + R_i + \eta_j + \eta_i\right)} - F_i - \eta_j - \eta_i \tag{5}$$

Before finding the equilibrium levels of fighting effort for the relevant cases, we now discuss how these reaction

[5] We recognize that non-productive effort could be invested in a defensive way. Given our substantive context of open range lands, we think raiding and fighting effort are reasonably synonymous.

[6] This alters Neary's (1997) CSF by subscripting the η terms. Our interpretation of the meaning of the η terms differs quite substantially from Neary's.

curves relate to levels of property rights and bias in property rights.

Property-rights regimes

While we are interested in how changes in resources affect fighting effort, we also want to understand how property rights affect these effects. Do similar changes in resources have the same effects in altering fighting effort under different property-rights regimes? Does a simultaneous change in property-rights regime and resources lead to more or less fighting effort?

Two property rights parameters are incorporated into our model. The level of property rights protection (PRP), $\rho = \eta_i + \eta_j$, is related to how much the government has invested in property rights. Merely investing in property-rights protection, however, is not sufficient to define the property-rights regime. We also need to know how equitable that protection is or, alternatively, how biased that protection is toward one group. Focusing on bias, we define $\beta_i = \eta_i/\rho$ as the bias in property-rights protection with respect to group i and $(1 - \beta_i) = \eta_j/\rho$ as the bias in property-rights protection with respect to group j. Given just two groups, we can define equitable protection in terms of $\eta_i = \eta_j$. Thus, when $\beta_i = 0.5$, property-rights protection is equitable. When $\beta_i > 0.5$, property-rights protection is biased against group i and, conversely, when $\beta_i > 0.5$ property-rights protection is biased in favor of group i.

Substituting these parameters into Equations 4 and 5 where appropriate, we can rewrite the reaction curves as follows.

$$F_i = \sqrt{\left(F_j + (1 - \beta_i)\rho\right)\left(R_i + R_j + \rho\right)} - F_j - \rho \quad (6)$$

$$F_j = \sqrt{\left(F_i + \beta_i\rho\right)\left(R_j + R_i + \rho\right)} - F_i - \rho \quad (7)$$

Drawing on this model, we can graphically display these relationships. Figure 1 holds $R_j = 0.5$ and $\rho = 0.5$ as constants; the z-axis represents the sum of fighting effort or 'total raiding behavior' (TRB $= F_i + F_j$).[7] This leaves R_i and β_i as free parameters. TRB is lowest in this figure when PRP is equitable and group i's resources are near zero. When group i's resources are relatively small, more biased PRP produces more TRB. If the bias is in favor of group i, group j contributes more toward TRB; if bias is against group i, group i contributes more toward TRB. For higher levels of group i's resources, TRB increases linearly with total resources until an edge solution kicks in. At that point, $F_j^* = R_j$ and TRB goes up at a slower rate with further increases in R_i (without asymptote). This edge solution is reached more quickly when PRP is biased in favor of group i. Once reached for a given level of R_i, TRB is higher when PRP is biased against group i.

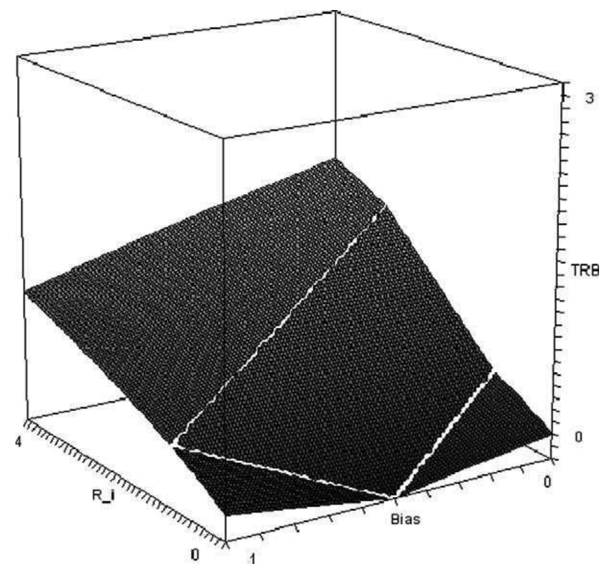

Figure 1. Total raiding behavior for R_i and Bias given PRP = 0.5 and $R_i = 0.5$

The process of exclusion serves as the motivation to engage in violence (Cederman, Wimmer & Min, 2010; Murshed, 2009), but subject to resource availability. Given the positive relationship between resources and fighting, we should expect to see more total conflict when the wealthy group faces extreme bias (upper-right corner of Figure 1) than when the wealthy group is protected by the state (upper left corner). When the resources of the two groups are closer to even (lower/closer portion of Figure 1), increasing bias toward either group combined with relatively low PRP increases the total conflict between the groups (lower-left and lower-right corners).

Equilibrium cases

Given different levels of PRP and bias, several equilibrium cases emerge. In order of introduction, these cases involve: (1) some raiding by both groups, (2) no raiding by either group, (3) some raiding by one group and no raiding by the other group, and (4) strictly raiding by one group and some raiding by the other group.

[7] These parameters were chosen arbitrarily, but the general picture holds for other parameter choices. If R_j is higher, TRB is higher. If PRP is higher, TRB is lower.

Both groups raid some

The first equilibrium case involves some raiding by both groups. This is also known as an 'interior' solution because each group's appropriative effort is within its resource range: $F_i \in (0, R_i)$ and $F_j \in (0, R_j)$. If the best reply given by a reaction curve is outside its resource range, then one of the other equilibrium cases applies. Finding these equilibrium levels merely entails substituting (7) for F_j in (6) and solving for a more specific F_i^* (and vice versa). These equilibrium levels of appropriative effort are given by (8) and (9).

$$F_i^* = \frac{R_i + R_j - 4\rho\beta_i + \rho}{4} \tag{8}$$

$$F_j^* = \frac{R_i + R_j + 4\rho\beta_i - 3\rho}{4} \tag{9}$$

Very briefly, when both groups engage in some raiding activity, the following partial effects hold. Increases in the resources available to either group increases the raiding activity of both groups equally. Increases in bias in favor of one group decrease that group's raiding while simultaneously increasing the other group's raiding. Increases in PRP generally decreases the raiding activity of both groups, provided bias is not too extreme, in which case PRP increases the raiding activity of the disadvantaged group. The case-study material below exemplifies portions of this interior solution.

Witsenburg & Adano (2009: 515) argue, as we do, that the prevailing belief is 'neo-Malthusian' and summarize this idea in the following way: 'When pressure on resources ... increases, it seems likely that people will fight over access to these resources'. Furthermore, 'growing populations using ever dwindling common property resources will engage in more violent conflicts' (p. 518). They have tested this idea both statistically and qualitatively at the micro-level of two districts in Kenya over time. A significant part of their skepticism regarding the neo-Malthusian belief revolves around macro- versus micro-levels of analysis. 'Being part of a region where violence captures the attention regularly, it may not be surprising that the violence is believed to be scarcity-induced' (p. 517).

To test this neo-Malthusian idea, they rely on an explicit resource availability chain. 'Rain determines, despite its unreliability, the availability of water, pasture, crop yields, milk and meat' Witsenburg & Adano (2009: 515). In turn, 'water, arable land, pasture are scarce resources' (p. 515) that affect the allocation of labor and decisions regarding raiding activity. In their statistical analysis, they find 'an increase in violent deaths in the rainy seasons April–June, and a lower rate for the other seasons' (pp. 522–523). They back this up with qualitative evidence that is encapsulated in the following summary.

> Especially during droughts, people are more inclined to cooperate and use wells together. When a drought is expected, warring communities often reconcile in order to use water and pastures together. On the other hand, violent livestock raiding is mostly done during wet years: then, the livestock is stronger and fatter, and vegetation and surface water are more readily available, which is necessary during a long trek. The vegetation is also thicker which makes it easier to hide after an attack. (Witsenburg & Adano, 2009: 520)

Witsenburg & Adano (2009) analyze monthly rainfall and cattle raiding data from 1960–2006 in the Marsabit district of northern Kenya and find that wetter years on average are associated with more than twice as many killed as compared to drier years (50 vs. 23). They argue that livestock raids, especially violent episodes, result from opportunistic behavior. Attacks occur during wet seasons when water is abundant, pastures are lush, and livestock (particularly cattle) are abundant and in good health. When rangeland resources are abundant, labor will tend to be in surplus, which provides a large pool of young men to recruit into a cattle-raiding party. Moreover, abundant vegetation makes it easier to hide and take advantage of the element of surprise. Readily available water and vegetation also make it easier to drive the stolen cattle long distances. And given that the cattle are healthier, they are better able to make a long trek. Rainfall also serves to wash away the tracks.

This relationship has been found by others as well. 'In the North Rift, raiding tends to fluctuate seasonally, reaching a major peak during the rainy season. Fear of raids during the start of the rains (usually late March to early April) often leads to a major exodus of people away from ethnic boundaries' (Eaton, 2008: 100–101).

The empirical evidence above supports our first equilibrium case. Specifically, it supports our first-order result that increases in resources produce consequent increases in raiding activity. Recall that this equilibrium is the 'interior solution' in which PRP levels are sufficiently low, bias in property rights protection is not extreme, and, as a result, both groups engage in some level of raiding activity. Aggregating over pairs of groups averages out what variation in PRP and bias might exist among the different pastoral groups in the Witsenburg & Adano statistical analysis. Thus, the general tendency in their data – that more rainfall produces more violent raiding behavior – fits our theoretical argument regarding this equilibrium case.

An addition element of the interior solution to our model is that increasing PRP in a biased manner can increase conflict. This only shows up when PRP is very low to start with. Rather than 'turning on' PRP, as Bates (2001) and Gonzalez (2007) do, we allow PRP to vary, in line with Neary (1997). By adding bias in PRP as well, we are able to tease out this additional result.

In Kenya, trust land reserved for pastoralists has been controlled by county councils, but governed by customary law. Access to water in particular is governed by traditional use rights. 'Water sources are usually owned by individuals or clans, but use rights traditionally override ownership rights. This means every nomad has the right to use a well, also on the land governed by a neighboring ethnic group' (Witsenburg & Adano, 2009: 532). During drought, access to water was traditionally successfully negotiated. The modernist ethos works to change all this through the clear demarkation and designation of property rights.

> With the creation of boundaries, whereby ... new divisions and locations are meant to mark ethnically 'pure' territories, it is increasingly hard to maintain traditional arrangements of water and land sharing. The violence between the Gabra and Borana in Turbi, between Redille and Gabra around Medatte (or Mayidahad), and between the Gabra and Turkana in Moite can be seen in that light. In all these places, water points were 'territorialized' after the creation of new boundaries, and traditional use rights were violated. (Witsenburg & Adano, 2009: 532)

The shift from traditional notions of communal property (in this case, access to water) to notions of designated property rights highlights the nature of how the installation of property rights may be biased against particular groups.

Neither group raids

The second equilibrium case involves no raiding by either group ($F_i = 0$ and $F_j = 0$). There are two very different circumstances that yield no raiding in equilibrium. On the one hand, very high PRP essentially deters raiding. On the other hand, an absence of resources means that there is no effort to allocate toward raiding. We discuss each circumstance in turn.

If PRP is sufficiently high and equitable, neither group has an incentive to raid. Given the context of, relatively, a developing country and low PRP, the conditions for this equilibrium case are not likely to be satisfied. Indeed, we have no cases that fulfill these conditions. In general, pastoral groups are not found where property rights are highly enforced. The cattlemen of the US Western Range constitute a form of pastoralism, but the Homestead Act and settlement of the US West led to increasing enforcement of individual property rights and the end of the common rangeland. Thus, while PRP became sufficiently high, the nature of property was inherently changed from genuinely pastoral.

When neither group possesses adequate resources with which to fight ($R_i = 0$ and $R_j = 0$), no raiding by either group occurs ($F_i = 0$ and $F_j = 0$). Moreover, with so few resources, there would be little worth fighting over. If both groups lack the resources to fight, the equilibrium is no fighting by either group. Given extreme drought conditions, this condition may exist in African rangelands. Resource scarcity also tends not to lead to conflict, but to peace. As noted by Eaton (2008: 101):

> The people of the North Rift are aware that intensive fighting during a drought would be suicidal; at the end of the dry season, they often are faced with the choice of sharing what little grazing and water remains, or fighting to defend their resources against a well-armed opponent with nothing left to lose. The choice is obvious, and only in rare circumstances will a destitute ethnic group be denied access to scarce resources.

In times of drought, herds tend to decrease in size and the herds shift from cattle to camels and goats which are better adapted to dry conditions. Herding groups will be focused on survival and will be moving with their herds over wide areas. Labor demand in dry times is taken up looking for far-away pastures instead of engaging in cattle raids (Witsenburg & Adano, 2009).

> Every male in the family might accompany the stock on these movements, sometimes remaining away from the permanent homestead for two or three months. Close friends, age-mates, or clansmen combined their herds for these trips, for safety and companionship. Extra labor was also demanded to find food for cattle when grazing was not available. (Anderson, 2002: 82)

Moreover, stealing cattle is less lucrative during drought. In an analysis of the relative prices of commodities in pastoralist areas of the Horn of Africa, Mkutu (2008: 17) reports that the price of cattle drops in drought years, whereas the prices of grains necessary for survival rise. Even if you don't steal cattle during a drought, why fight over a dry well? Theisen (2012) finds preliminary support in a statistical analysis of geo-referenced data that violent clashes between groups in Kenya do not occur in years when water is scarce, but when it is plentiful. Finally, Meier, Bond & Bond (2007) find no relationship between rainfall deficiency and violence in their study of the borderlands of Uganda, Kenya, and Ethiopia, but they do find in their examination of seasonal variation over a two-year period that a greater abundance of vegetation is associated with an increase in the frequency of raids.

Only one group raids

Another equilibrium case involves raiding by only one group. If the level of PRP is moderately high and property rights sufficiently biased, then the protected group will engage in no raiding activity while the other group will have $F_i \in (0, R_i)$. When property rights is sufficiently biased favor of group *j*, $F_j^* = 0$ while F_i^* is given by (10). Conversely, when property rights is sufficiently biased favor of group *i*, $F_i^* = 0$ while F_j^* is given by (11).

$$F_i^* = \sqrt{R_i + R_j + \rho}\sqrt{\rho(1-\beta_i)} - \rho \qquad (10)$$

$$F_j^* = \sqrt{R_i + R_j + \rho}\sqrt{\rho\beta_i} - \rho \qquad (11)$$

Within this equilibrium case – provided that changes in the other parameters do not produce a different equilibrium case, the following partial effects hold. Increases in either group's resources increase the disadvantaged group's raiding activity. Increases in bias against the disadvantaged group increase that group's raiding activity. Increases in the level of PRP can either increase or decrease the disadvantaged group's raiding activity depending on the degree of bias and on the total resources between the groups.[8]

In this equilibrium, when property rights is sufficiently biased in favor of one group, that group's fighting effort will tend to zero, as is given by Equation 11. The disadvantaged group raids and the privileged group does not. Examples of cases exhibiting this equilibrium are also hard to come by, at least between pastoral groups. A condition approximating this equilibrium case existed during the British colonial rule of Kenya. The Tugen and other pastoralists raided the settlers' herds, while settlers did not engage in raiding behavior. Both sides engaged in violence, but the violence took place when the settlers defended themselves against trespass and what the native pastoralists viewed as their right of access to pasture and water. The settlers did not engage in cattle-raiding. Anderson (2002), examining the colonial history of Baringo in the Rift Valley of Kenya from 1890 to 1963, describes the violence between the white settlers and the pastoralists that was particularly prevalent in the 1920s. Strictly speaking, this example is not between two pastoralist groups, but between farmers and herders. But it does highlight how the resource imbalance between the two groups led to very different types of violent behavior.

One group only raids, the other raids some

The last equilibrium case involves raiding by both groups, but with one group allocating *all* of its resources to raiding. This equilibrium case comes about when the distribution of resources between the groups is highly skewed. The degree of skewness is exasperated by high levels of PRP combined with property rights biased against the poorer group.[9] The richer group still invests in raiding activity but, facing comparatively less appropriation from the poorer group, does not need to engage in as much raiding activity as if the other group were richer.

When *j* is sufficiently poor that it has $F_j^* = R_j$, F_i^* is given by (12). When *i* is the sufficiently poor group having $F_i^* = R_i$, F_j^* is given by (13).

$$F_i^* = \sqrt{R_i + R_j + \rho}\sqrt{R_j + \rho(1-\beta_i)} - R_j - \rho \qquad (12)$$

$$F_j^* = \sqrt{R_i + R_j + \rho}\sqrt{R_i + \rho\beta_i - R_i - \rho} \qquad (13)$$

Finding a real world case reflecting the boundary condition equilibrium in which one group dedicates all of its resources to fighting while the other spends a considerable amount on conflict is difficult to find. We find no cases that match these conditions precisely, but we do find conditions in which one group devotes considerable resources to raiding and the other group reciprocates with a good degree of fighting. The Pokot and Tarkana of the North Rift have been engaged in a longstanding rivalry.[10] The general raiding pattern fits this case at different points of time. Sometimes the Turkana raid very much and the Pokot raid, but not so much. There

[8] For example, the first derivative of (11) with respect to ρ is $\frac{\sqrt{\beta_i \rho}}{2\sqrt{R_i + R_j + \rho}}$.

[9] For example, $F_j^* = R_j$ when $R_j \leq \frac{R_i + \rho(4\beta_i - 3)}{3}$.

[10] The Pokot have also been in an age-old rivalry with the Marakwet.

are also times in which the Pokot raid more than the Turkana, and other periods in which the two groups are at peace (Bollig, 1990; Eaton, 2008).

The Turkana through the centuries have developed a reputation as raiders. For much of the available history, the Turkana have been discriminated against by the ruling power. The British in particular engaged in policies that were biased against the free movement of the Turkana and their cattle. Post-independence Kenya has also enacted policies creating more and more boundaries in the Turkana District of the Rift Valley Province, which have served to limit the mobility of Turkana herders.

> The shift toward greater state control of pastoral affairs through legal and administrative frameworks introduced in colonial times has also exacerbated raiding. Restrictions placed on pastoral mobility by conflict in the region have joined with those imposed by colonial and post-independence administrations severely to curtail the pursuit of normal productive activities. (Hendrickson, Mearns & Armon, 1996: 23)

Discussion

This article examined the effect of climate change on pastoralist conflict (range wars). The rangeland of East Africa constitutes a region particularly vulnerable to drought, which is associated with climate change. To analyze the possible effects of climate change on pastoral conflict, we focus our analysis on changes in resource availability, contrasting cases of abundance and scarcity. We adopt a 'political ecology' approach and feature the role that the politics of land plays in pastoral conflicts. In particular we focus on property rights protection and the bias in interpretation and administration of property rights protection. Violence between pastoral groups should be understood as more than just resource conflicts. Moreover, we demonstrate that any analysis of climate change and conflict needs to account for property rights protection and, even more importantly, the bias in these property rights. In this way, we account for the role the state plays in establishing, protecting, and recognizing property rights in Africa's rangelands. Using the analytical framework of a contest success function (CSF), we formally demonstrate that conflict is generally increasing with resource abundance contingent on property rights bias.

The model presented here allows us to examine the mechanisms that potentially link climate change and conflict. Advocates of the proposition that 'climate change causes conflict' fail to offer a convincing explanation for this relationship. First, empirical evidence supporting this contention is spotty. Indeed, we find some evidence to the contrary. Second, advocates of the 'climate change causes conflict' camp rely on a crude causal explanation – resource scarcity leads to conflict. It's not that simple. By analytically focusing on property rights (protection and bias) as well as resource scarcity (and plenty), we examine the mechanisms that explain both conflict and peace.

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Climate change, rainfall, and social conflict in Africa

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Abstract

Much of the debate over the security implications of climate change revolves around whether changing weather patterns will lead to future conflict. This article addresses whether deviations from normal rainfall patterns affect the propensity for individuals and groups to engage in disruptive activities such as demonstrations, riots, strikes, communal conflict, and anti-government violence. In contrast to much of the environmental security literature, it uses a much broader definition of conflict that includes, but is not limited to, organized rebellion. Using a new database of over 6,000 instances of social conflict over 20 years – the Social Conflict in Africa Database (SCAD) – it examines the effect of deviations from normal rainfall patterns on various types of conflict. The results indicate that rainfall variability has a significant effect on both large-scale and smaller-scale instances of political conflict. Rainfall correlates with civil war and insurgency, although wetter years are more likely to suffer from violent events. Extreme deviations in rainfall – particularly dry and wet years – are associated positively with all types of political conflict, though the relationship is strongest with respect to violent events, which are more responsive to abundant than scarce rainfall. By looking at a broader spectrum of social conflict, rather than limiting the analysis to civil war, we demonstrate a robust relationship between environmental shocks and unrest.

Keywords

Africa, conflict, environment, protest, rainfall, rioting

While water is essential for human consumption, agriculture, and industry, a significant share of the world's poor lacks access to clean water, irrigation, sanitation facilities, and hydroelectric capacity. This is especially true in sub-Saharan Africa, where according to the United Nations World Water Development Report (UNESCO, 2009), 340 million people lack access to clean drinking water, 4% of annual renewable flows are stored (compared with 70–90% in developed countries), and less than 5% of cultivated areas are equipped for irrigation. Thus, many countries depend directly on rainfall for crops, livestock, and human consumption, meaning variable access to a critical resource. Flooding and droughts can destroy livelihoods, undermine macroeconomic growth, and place strains on government revenues.

The IPCC warns: 'Climate change and variability are likely to impose additional pressures on water availability, water accessibility and water demand in Africa' (Boko et al., 2007: 435). Erratic rainfall, longer dry periods, and more intense rainfall events are expected to place increased pressure on African agriculture and economies. While some areas of Africa are expected to become drier, others – such as East Africa – are projected

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to become wetter as the climate changes. Most importantly, traditional planting and harvest cycles are likely to be disrupted.

In this article, we examine the relationship between rainfall, water, and sociopolitical unrest in Africa. We are interested in how deviations from normal rainfall patterns – which are linked to droughts and floods – affect political behavior and the propensity of individuals and groups to engage in disruptive activities such as demonstrations, riots, strikes, communal conflict, and anti-government violence. Does the weather influence political disturbances and social conflict? If so, what forms of conflict are most likely? This topic is pressing as the process of global climate change accelerates, potentially making rainfall more unpredictable and severe weather events more common (IPCC, 2007: 49).

Possible links between climate change and conflict have gained considerable attention, including at the United Nations General Assembly (UN, 2009). Some have blamed climatic conditions for particular civil wars, such as Darfur (Faris, 2009). While we eschew simple, direct casual pathways from water resources to civil war and avoid mono-causal explanations for political violence, we argue that water shocks may lead to social conflict via their effects on resource competition, poor macroeconomic outcomes, and reduced state capacity. However, in contrast to many other studies, we do not necessarily expect full-blown civil wars to emerge from water scarcity.[1] Launching an insurgency entails significant start-up costs, planning, and organizational capacity. Moreover, governments must be unable or unwilling to accommodate or repress opposition groups for armed rebellions to emerge. However, grievances and competition over water resources can generate significant social conflict in ways that do not require the level of organization and funding needed for sustaining an insurgency.

Using a new database of over 6,000 instances of social conflict in Africa – the Social Conflict in Africa Database (SCAD) – we examine the effect of deviations from normal rainfall patterns on various types of conflict. Using data on 47 countries from 1990 to 2008, we find that rainfall shocks have a significant effect on both large-scale and smaller-scale instances of political conflict. We find that rainfall correlates with civil conflict and insurgency, although wetter years are more likely to suffer from violent events. Extreme deviations in rainfall – particularly dry and wet years – are associated with all types of social conflict (violent and nonviolent, government-targeted and non/government-targeted), though the relationship is strongest with respect to violent events, which are more responsive to abundant rather than scarce rainfall.

In the next section, we develop a theory of how rainfall and water resources affect political stability, and we present our hypotheses. We then describe SCAD, operationalizations of key variables, and our methods. Following this we discuss our results. In the final section, we offer some concluding remarks on the implications of the findings for theories of violent social mobilization.

Rainfall deviations and conflict

The last decade has seen interest in the relationship between natural resources and conflict. One body of literature argues that the abundance of natural resources – particularly minerals and oil – can lead to political violence (Bannon & Collier, 1999; de Soysa, 2002; Collier & Hoeffler, 2004; Ross, 2004; Humphreys, 2005; Lujala, 2009). Such resources can be looted to fund rebel organizations, resources can lead to friction over their allocation, and dependence on primary commodities can weaken state capacity (Hendrix, 2010). Others scholars have argued that the scarcity of vital resources – particularly water and food – can lead to conflict (Percival & Homer-Dixon, 1996; Hauge & Ellingsen, 1998; Maxwell & Reuveny, 2000; Homer-Dixon, 2001; see Le Billon, 2001 for a review of both literatures). Resource scarcity is argued to generate grievances and fuel conflict over their distribution. These literatures do not necessarily contradict each other, as the former focuses on the availability of lucrative commodities such as gemstones and oil while the latter focuses on basic needs.

With growing concern over the human implications of climate change, many scholars have undertaken quantitative tests of links between environmental scarcity, natural disasters, and civil war. Researchers have tended to look at land and water resources to determine whether or not there is a direct link between scarcity and war (Hauge & Ellingsen, 1998; Homer-Dixon, 2001; Miguel, Satyanath & Sergenti, 2004; Hendrix & Glaser, 2007; Raleigh & Urdal, 2007; Theisen, 2008; Koubi et al., 2012). Yet, there is hardly a consensus about causal relationships, and findings have been weak and inconsistent (Salehyan, 2008). In a related body of work, studies

[1] Others have also noted that human security problems and other forms of unrest, short of international and civil war, may result from environmental factors and resource scarcity (see Barnett & Adger, 2007; Wolf, 1998).

of international conflict find little interstate violence over water and demonstrate that cooperative arrangements are more likely (Wolf, 1998; Toset, Gleditsch & Hegre, 2000; Gleditsch et al., 2006).

In this article, we examine several forms of conflict short of full-blown civil war and state failure. Much of the civil war literature argues that grievances – including over access to water and other resources – are not sufficient to explain armed conflict. While grievances are certainly important, mobilizing a rebellion is a costly and risky endeavor which requires long-term planning, leadership, funding, and sanctuaries to evade government repression (Tilly, 1978; Collier & Hoeffler, 2004; Fearon & Laitin, 2003; Salehyan, 2007). For most aggrieved actors, most of the time, rebellion is not a viable option. In addition, the resort to armed conflict requires that the government be unwilling or unable to reach a compromise with the opposition that is mutually preferred to war (Hegre et al., 2001; Walter, 2009). In the context of resource scarcity, armed conflict does nothing to increase the supply of resources and may indeed diminish it (Maxwell & Reuveny, 2000). Therefore, conflicts arise over the *distribution* of resources rather than their absolute *level*, and distributional issues are inherently part of a political bargaining process.

With this in mind, we argue that extreme deviations from normal rainfall patterns may lead to other forms of social and political disorder short of civil war. Some forms of politically motivated conflict, such as protests and riots, do not require the high levels of organization or funding typical of armed rebellion. In addition, individuals and groups competing for resources may fight directly rather than engage the government, which is often far riskier given the state's preponderance of coercive force. Often times, groups will find neighboring communities, rather than the government, the most appropriate target for making demands; this is especially true if the state is known to be unwilling or unable to redistribute resources in a society. And as Raleigh (2010) argues, communities most vulnerable to climate change are also the least equipped to challenge the government; therefore, conflicts not involving the state may be more likely.

Thus, our analysis is in line with research that argues there may be distinct sets of variables that explain rebellion versus protests and other disturbances (Scarritt & McMillan, 1995; Regan & Norton, 2005), as well as studies that investigate the impact of environmental factors on social violence, such as cattle raiding, that does not fit neatly into the state-centric armed conflict paradigm (Meier, Bond & Bond, 2007; Urdal, 2008; Witsenburg & Adano, 2009). While under certain circumstances and in particular contexts, rainfall deviations may contribute to armed rebellion, we believe that unorganized dissent, mass demonstrations, and communal conflicts are more likely responses.

It should not be assumed that such conflicts are always less significant than armed insurgencies. Indeed, they can be quite disruptive. For instance, following elections in Kenya in 2007 – in which land rights were a major campaign issue – thousands of people died during weeks of rioting and the government was forced to accept a power-sharing deal. In the early 1990s, mass demonstrations in Zambia forced the government of Kenneth Kaunda to accept multiparty elections. In Ghana in 1994, ethnic riots erupted after a dispute in a market, killing approximately 3,000 people and displacing tens of thousands more. While these events are typically less deadly than full-scale civil wars, many cost more lives than many low-level insurgencies and disrupt basic government functions.

The literature on environmental security, which we discuss below, suggests at least five mechanisms through which rainfall deviations may lead to sociopolitical conflict. While negative rainfall shocks imply reduced water availability, drought, and potential crop failure, extreme positive shocks may be equally disruptive as excess rain can lead to crop damage, flooding, mudslides, and increased water-borne disease. We emphasize the importance of extreme events since societies develop expectations about normal rainfall patterns and plan crops and coping strategies accordingly (Reardon & Taylor, 1996). Deviations from normal rainfall disrupt these expectations and can negatively affect human well-being.

First, rainfall deviations may lead to conflict among consumers of water, including those who depend on water as an input for their products. As water stores decline, consumers may come into conflict with one another over access to wells, riverbeds, and the like (Kahl, 2006). Water is a major input for agricultural producers and pastoralists as well as for manufacturing and mining. Thus, farmers, herders, manufacturers, and other producers may come into conflict over water rights and access (Eriksen & Lind, 2009). In addition, rainfall shortages exacerbate the encroachment of deserts into formerly productive land and can lead to increased competition over cropland and pastures.[2]

[2] However, research has found that the Sahel zone is becoming greener after a period of sustained rain and land use change (Olsson, Eklundh & Ardö, 2005).

Second, both excess (i.e. flooding) and shortages of water can lead to price disputes between rural producers and urban consumers. Droughts and damage to cropland after excess rain can lead to temporary food shortages and spikes in market prices. For instance, although weather-related conditions were one of many causal factors (Alexandratos, 2008), the rising price of staple crops in 2008 and 2011 led to massive protests and riots in dozens of countries, especially as urban consumers demanded relief from price inflation. Food price inflation clearly has a negative impact on the welfare of urban dwellers. However, the net impact on rural welfare is ambiguous as small-scale farmers are often net purchasers of food, and some farmers may see a decline in living standards (Barrett & Dorosh, 1996).

Third, as livelihoods in affected areas come under stress, many will opt to migrate to urban areas in search of alternative work. Migration – both within countries and across national boundaries – can lead to intensified competition over jobs, housing, and other resources. It can also lead to shifts in ethnic settlement patterns, which may intensify intercommunal conflict (Suhrke, 1997; Reuveny, 2007). Urban growth also places strain upon governments as demand increases for basic services such as sanitation, electricity, police protection, and roads (Neuwirth, 2005). Thus, migration can create friction between locals and new arrivals as well as place increased demands on providers of local services.

Fourth, states often intervene in markets in order to increase their revenues and expand patronage opportunities. In Africa, market distortions are often very large (van de Walle, 2001). States intervene in the economy through taxation, subsidies, marketing boards, price controls, and trade restrictions, among other means, which are designed by incumbents to maintain political control (Bates, 1989; Krueger, 1996; Kasara, 2007). Given the central importance of agriculture and other water-intensive sectors to African economies, extreme weather events can have particularly pronounced effects for public finance (Benson & Clay, 1998). Natural disasters can place strains on government revenues through the reduction of the tax base as well as increased demands for services and assistance by the hardest hit. Moreover, the ability of incumbents to maintain patronage networks and reward core supporters – either through direct transfers or through manipulating markets – can be undermined. For instance, Robert Bates (1989: ch. 4) discusses how drought in Kenya led to increased demands on the Kenyan Maize Board, an institution which worked primarily to influence food prices, and in turn, political stability. Planning failures caused episodic droughts to turn into major food crises, which ultimately threatened the survival of the regime.

Finally, rainfall variability can have negative macroeconomic effects. Rainfall deviations can present an enormous human and financial toll on developing economies and government resources. Displacement, loss, crop failure, etc., associated with water scarcity and overabundance, can hurt overall economic productivity. Research has shown generally that adverse rainfall shocks have a negative effect on overall growth (Miguel, Satyanath & Sergenti, 2004; Barrios, Ouattara & Strobl, 2008; Jensen & Gleditsch, 2009). General economic malaise may in turn lead to civil conflict and social disorder.

Our expectation is that extreme events *in either direction* make a society more prone to conflict. While many have focused on drought, we also consider the disruptive effect of excessive rain. Moderate increases in rainfall can enhance land productivity; more wealth in a society may lead to more opportunities for looting and theft (Witsenburg & Adano, 2009). However, excessive rain is damaging to agriculture, leading to scarcity and economic contraction (Wilkie et al., 1999; Rosenzweig et al., 2002). Also, floods and mudslides are discrete, rapid-onset disasters that can quickly destroy lives and property, leading to social discontent, particularly if the response is poor.[3] Finally, given that many roads in Africa are unpaved or of poor quality, extreme rain can destroy infrastructure, limiting state capacity to respond to disturbances around the country.

Many of these effects are far-reaching and impact economies and societies as a whole. Recent research has sought to find *local* patterns of conflict and natural disasters by looking for correlations between environmental conditions and conflict at the sub-national level (Buhaug & Lujala, 2005; Buhaug & Rød, 2006; Raleigh & Urdal, 2007). While these studies have revealed many interesting relationships, many of the most significant effects are likely to be felt across the country. For instance, droughts in agricultural regions may lead to migration to urban areas and increased prices for urban consumers; declining state revenues can lead to strains on public finances and negatively affect public-sector employees across the economy; finally, disaster-affected populations can take their protests and demands directly to the national capital. Causal pathways may be long and far-reaching.

[3] As a case in point, our dataset shows protests and riots against the Algerian government following excessive rain and flooding in November 2001, November 2002, and October 2008.

Hypotheses

The discussion above suggests several non-exclusive pathways to sociopolitical conflict. The literature thus far has mainly consisted of theoretical treatments of individual mechanisms, or has provided detailed accounts of a relatively small set of cases. In addition, cross-national, quantitative work has focused primarily on armed conflict (Buhaug, 2010; Burke et al., 2009), rather than a broader array of conflict outcomes. Our contribution is to provide a systematic analysis of the relationship between rainfall deviations and social conflict across the African continent.[4] It is important to first establish a general link between water shocks and sociopolitical instability before validating various causal mechanisms. Environmental security theories suggest that rainfall deviations, defined as extreme deviations from normal rainfall patterns, will increase the likelihood of social conflict. Thus, our main hypothesis is:

> *H1:* Extreme deviations from normal rainfall patterns will increase the frequency of social conflict.

We differentiate between social conflict and armed conflict. The former is the broader category, which includes various forms of contentious behavior. Social conflict includes peaceful protests, rioting, strikes, mutinies, and communal violence. Armed conflict is a subset of social conflict, requiring organized, armed violence against the government or between governments, in the case of international war. As we have argued above, armed conflict may not be the most likely consequence of environmental disasters. Given the large costs and risks associated with challenging the state, we expect interpersonal and intercommunal violence to be the norm, rather than direct opposition to governmental authorities. Nonetheless, we also examine the effect of rainfall deviations on civil wars and insurgencies.

Scholars note that low legitimacy and weak capacity characterize many African states (Herbst, 2000; Van de Walle, 2001). Many African governments have also proven unable to contain conflict in peripheral areas (Meier, Bond & Bond, 2007; Obioha, 2008). Given our focus on Africa, we expect particular forms of social conflict when societies are faced with extremes in rainfall. Therefore, we disaggregate our social conflict indicator into various types to test a pair of additional hypotheses. First, because regimes with low legitimacy and accountability may be less responsive to peaceful protest, we expect violent conflict to be more sensitive to rainfall deviations than non-violent conflict. As Lichbach (1987) argues, a history of regime repression makes actors more likely to turn to violent strategies. Given the poor record of many African regimes, opposition groups may perceive their governments to be unwilling to accommodate peaceful demands and thus turn to violence. Second, African states are often seen as unwilling or unable to redistribute resources in society, smooth income shocks resulting from environmental stress, and contain peripheral violence. Therefore, because the government may not be the most appropriate target, we expect social actors to come into conflict with one another, rather than challenge the state.

> *H2:* Extreme deviations from normal rainfall patterns will increase the frequency of violent conflict more than the frequency of nonviolent protest.

> *H3:* Extreme deviations from normal rainfall patterns will increase the frequency of nongovernment targeted action more than the frequency of actions targeting the state.

Data and methods

The dependent variables: Social conflict and armed conflict

We test for the effect of climatic factors on six different dependent variables: civil conflict onset, total events, nonviolent events, violent events, government-targeted events, and nongovernmental events. Civil conflict onset is a dummy variable that takes a value of 1 if the country-year contained the onset of an intrastate conflict characterized by 25+ annual battle deaths, and 0 otherwise. These data are from the UCDP/PRIO Armed Conflict Dataset, updated through 2009 (Gleditsch et al., 2002; Harbom & Wallensteen, 2010).

All of the event variables are counts of the number of events in a given year. These are from the Social Conflict in Africa Database (SCAD),[5] which contains information on instances of contentious action such as *protests*, *riots*, and *strikes*; but it also includes *intra-governmental violence*, such as coups or factional fighting within the military; violent *repression* by the government or its agents; *anti-government violence* that does not meet the conventional thresholds for civil conflict (as defined by the Armed Conflict Dataset); and *extra-governmental violence*, or violence by a non-state, organized militant group against individuals, rival communal groups, or other social actors not involving the state.[6] Every country

[4] Unlike Miguel, Satyanath & Sergenti (2004) and Hendrix & Glaser (2007), we analyze North African cases as well.

[5] http://www.scaddata.org. See website for codebook.

[6] See the codebook for a full description of the different event types.

Table I. Social conflict events in 47 African countries, 1990–2009

Variable	*Obs.*	*Mean*	*Std. dev.*	*Min.*	*Max.*
Civil conflict onset	937	0.06	0.24	0	1
Total events	937	6.66	11.18	0	95
Nonviolent events	937	3.62	5.50	0	42
Violent events	937	3.05	6.65	0	67
Government–targeted events	937	3.55	5.49	0	40
Non–government–targeted events	937	3.12	6.95	0	74

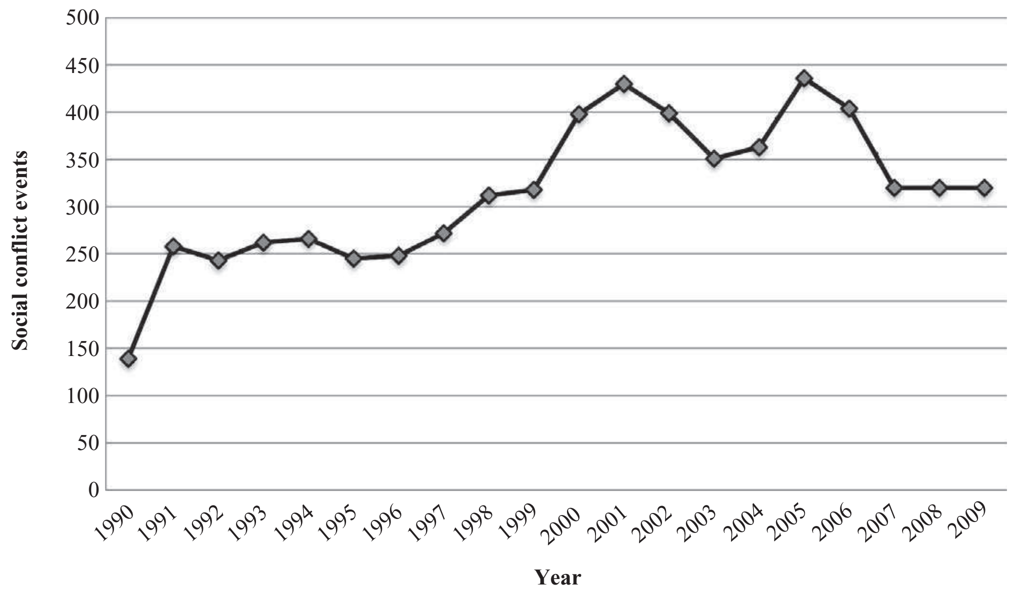

Figure 1. Social conflict events in Africa, 1990–2009

in Africa (with a population greater than one million), including North Africa, is coded for the period 1990–2009. The data are compiled from Associated Press and Agence France Presse newswires and contain detailed information about event duration, magnitude, the actors and targets involved, state repression, issues, and locations. A total of 6,305 distinct events have been coded. These events do not include, however, violent events that occur during periods of armed conflict that are directly related to the conflict dynamic. Individual battles within civil conflicts are coded in the Armed Conflict Location and Event Dataset (ACLED) (Raleigh et al., 2010).

Total events are all events for a country-year across event types. *Nonviolent events* are those events, such as protests and strikes, which are not intended to cause damage to people or property. *Violent events*, such as riots, government repression, anti-government violence, and both intra- and extra-governmental violence, are those in which the actor initiating the event acted to cause injury to people or property. *Government-targeted events* are those where the central or a regional government was a target. Finally, *non-government-targeted events* are those where the targets are nongovernmental entities. Descriptive statistics for our dependent variables are presented in Table I. Figure 1 displays the distribution of social conflict events in Africa over time. Civil conflict onsets are rare, occurring in 6% of country-year observations, while the average country-year experienced roughly seven social disturbance events.

Independent variable: Rainfall deviations

Our measure of rainfall deviations is the annual standardized *rainfall deviation* from the long-term (1979–2008) panel mean of rainfall for a given country.[7] Our measure is based on the Global Precipitation Climatology Project

[7] We include data prior to our time frame above in order to include more observations for calculating means and standard deviations and reduce the influence of outliers.

(GPCP) database of monthly rainfall estimates, version 2.1, aggregated at the country-year level. The data have 2.5° latitude by 2.5° longitude native resolution and cover the period 1979–2008. Because the data combine measurements from remote-sensed sources and rain gauges, they are more accurate and less affected by human factors than gauge-based estimates alone. To generate our standardized *rainfall deviation* variable, we measure deviations from the long-term means for a given country and divide them by the panel's standard deviation.[8] Values for standardized *rainfall deviation* have a mean of 0.05 (near zero), a standard deviation of 1, and range from –3.74 to 3.91. This measure more accurately accounts for cross-sectional differences in both mean values for rainfall, which range from 3.1 cm/yr (Egypt) to 233.3 cm/yr (Sierra Leone), and within-panel variance, measured by the variation coefficient, which ranges from 0.05 (Democratic Republic of Congo) to 0.27 (Botswana). We test for both linear and curvilinear relationships between the standardized *rainfall deviation* and disturbance events by running the analysis with both the linear measure and its squared term. We expect very low and very high rainfall years to be associated with conflict.[9]

Several studies of rainfall and conflict (Miguel, Satyanath & Sergenti, 2004; Hendrix & Glaser, 2007; Jensen & Gleditsch, 2009) operationalize rainfall shocks as the percentage change in annual rainfall in country *i* in year *t* from the previous year. As a measure of whether or not a given country-year was a particularly wet or dry year, this can be misleading (Ciccone, 2011). While the two variables are positively correlated ($r = 0.62$), it is clear that a year with zero increase following an unusually wet year would still be an unusually wet year, while a year of 50% rainfall growth following an unusually dry year might still be a less-than-average year. For this reason, our *rainfall deviation* more accurately measures relative rainfall abundance, given historical expectations for that country.

Several measures of environmental scarcity, such as deforestation or unclean water, may be endogenous to human activity and political processes. While global rainfall is expected to change due to anthropogenic forcing, in the proximate sense rainfall is independent of human activity: on a yearly basis, the level of development or social conflict in a country cannot 'cause' the amount of rainfall. Thus, endogeneity between our independent and dependent variables is not a concern. Moreover, this should mitigate the risk of omitted variable bias since it is unlikely that unmodeled features of a country would affect both conflict and precipitation.[10]

Controls

While omitted variables should not be of great concern, we include a number of additional variables for comparison purposes. We employ a battery of controls typical to the literatures on protest and civil conflict. First, we control for regime type. Many studies have found an inverted-U shaped relationship between regime type and various contentious outcomes: political protest and violence are least common in highly authoritarian regimes and in full democracies (Muller & Weede, 1990; Hegre et al., 2001). To model the inverted-U hypothesis, we include the revised combined Polity score, commonly referred to as *Polity2*, and its squared term. *Polity2* ranges from –10 (full autocracies) to 10 (full democracies).[11]

Second, we control for level of development and economic growth. The negative relationship between economic development and civil conflict is the most robust finding to emerge from the conflict literature (Hegre & Sambanis, 2006). Moreover, various studies indicate that economic growth is associated with a decrease in political violence and protest (Collier & Hoeffler, 2004; Miguel,

[8] More formally, this is $(X_{it} - \bar{X}_i)/\sigma_i$, where $\bar{X}_i$ is the panel mean for country *i*, X_{it} is the current rainfall in time *t* for country *i*, and σ_i is the standard deviation for country *i*.

[9] Extreme values of *rainfall deviation* are few: only 42 country-years (out of 935) have rainfall deviation values either greater than 2 or less than –2. Large deviations are rare, but their rareness is accounted for in the estimation of standard errors and estimated confidence intervals for predicted probabilities of onset/counts of events.

[10] Several studies of rainfall and conflict (Miguel, Satyanath & Sergenti, 2004; Jensen & Gleditsch, 2009; Koubi et al., 2012; Ciccone, 2011) use an instrumental variables approach, in which rainfall is used as an instrument for economic growth. Dunning (2008) criticizes this approach on the grounds that different components of growth could have countervailing effects on conflict, and that including rainfall as an instrument only captures one aspect of economic growth. Moreover, these studies assume that national-level economic growth rates are a plausible proxy for personal incomes and the opportunity cost to participating in violence, and that the effect of rainfall is through growth rather than directly on conflict. In much of Africa, where the small-scale agricultural sector provides the majority of employment but few cash crops and mineral exports drive export earnings and growth statistics, rainfall is a better proxy for societal grievances and opportunity cost. The instrumental variables approach precludes us from testing this possibility directly.

[11] As per the *Polity IV Dataset Users' Manual*, standardized authority scores are handled in the following manner: –66 (cases of foreign interruption) is treated as 'system missing'; –77 (cases of interregnum) is treated as 0; –88 (cases of regime transition) is the difference between the beginning and ending Polity code, prorated for the duration of the transition (Marshall & Jaggers, 2009).

Satyanath & Sergenti, 2004; Hendrix, Haggard & Magaloni, 2009). Data are from the Penn World Table version 6.3 (Heston, Summers & Aten, 2009).

Third, we control for population and population growth. For any given level of grievance, we would expect that larger populations would see more political protest (Fearon & Laitin, 2003). Population growth is included to control for the possibility that countries undergoing rapid demographic transformation will be more prone to political disorder (Urdal, 2005). Countries with large populations and large economies may also have greater news coverage, making these controls important to include. Data are from the Penn World Tables version 6.3 (Heston, Summers & Aten, 2009).

Finally, in models that use SCAD as our dependent variable, we control for the incidence of civil conflict. Reporting on civil conflict might 'crowd out' reporting on other forms of contentious collective action, and under some circumstances the conflict itself may make the expression of popular grievance more risky. However, conflicts themselves are often the cause of large-scale protest (as in Rwanda in 1995 and Liberia in 2001 and 2003). Thus, the expected effect of civil conflict is indeterminate.

Estimation and results

For modeling civil war/insurgency, we use logistic regression with errors clustered at the country level and a count of years since last conflict along with its squared and cubic terms (Carter & Signorino, 2010).[12] For modeling the SCAD event data, because the distribution of events is highly skewed, we use negative binomial regression. Negative binomial models are similar to other event count models, such as Poisson regression, but are more appropriate for over-dispersed data.

We estimate the event count models with a lagged dependent variable and robust standard errors clustered on countries. As a robustness check, we include conditional country fixed effects. The conditional fixed-effects model converts observed values for the dependent and independent variables into deviations from their mean values within each unit, thus eliminating the cross-sectional elements from the data. The estimated coefficients report only longitudinal changes within countries. This also accounts for unmodeled attributes of the country as a whole, and for the fact that some countries may have greater news coverage than others. We also use year dummies to control for factors that might affect levels of disturbances across all countries in a given year. The civil conflict onset model is run on a sample of 47 countries for the years 1991–2008, while event count analyses are run on a sample of 46 countries for the years 1991–2007.[13]

Table II reports logit coefficient estimates of the effects of our various climatic shock variables on civil conflict onset. Model 1 includes the both the linear and squared *rainfall deviation* measures, the lag of the rainfall measures, and a battery of lagged control variables. The present effect of *rainfall deviation* is positive. The positive, linear effect of present *rainfall deviation* is strongly statistically significant ($p < 0.01$) and the marginal effect is large in percentage terms. Holding all the control variables at their mean, a one standard deviation increase from mean rainfall increases the probability of conflict onset from 0.038 to 0.055, an increase of 44.7%; a two standard deviation increase from mean rainfall increases the probability of conflict onset by 116%. One and two standard deviation decreases from mean rainfall are associated with –30.2% and –50.3% decreases in the probability of onset, respectively.

Contrary to some arguments in the literature, increased rainfall, rather than water scarcity, increases the probability of conflict onset. Moreover, we find no evidence of a curvilinear effect. This finding confirms two previous studies using civil conflict as the dependent variable. Buhaug (2010: Model 7) finds that rainfall is positively related to the onset of low-level civil conflict (using a 25 battle deaths threshold). Burke et al. (2010: Table 3, Model 3) find some evidence for a positive correlation between contemporaneous rainfall and the incidence of civil conflict.[14]

[12] As opposed to the event count models discussed below, we do not use fixed effects logit to estimate civil conflict onset. This is because a fixed-effects estimator is inappropriate in situations where there is no variation in the dependent variable as the fixed effect is perfectly collinear with the DV. Many of our cases never experience a civil conflict onset and would drop out of the analysis.

[13] Somalia is excluded from the event count analysis for two reasons. First, the dynamics addressed in our theoretical argument presume at least a minimally functioning state, which Somalia lacks. Second, patterns of conflict in Somalia have been driven by interactions with intervening third parties (the USA and UN forces in the early 1990s, Ethiopia more recently). The inclusion of Somalia somewhat diminishes the explanatory power of our various models.

[14] Along with our analysis, these two studies examine the direct effect of rainfall on civil conflict. Others (Miguel, Satyanath & Sergenti, 2004; Jensen & Gleditsch, 2009; Koubi et al., 2012) use rainfall as an instrument for economic growth before estimating effects on conflict, or employ other dependent variables such as regime transitions (Brückner & Ciccone, 2011). These differences in modeling choices have led to somewhat divergent findings, although they are often not directly comparable.

Table II. Rainfall deviations and civil conflict onset, 1991–2008

Variable	*(1)*
Lagged DV	–2.494***
	(0.689)
Rainfall deviation	0.405***
	(0.156)
Rainfall deviation^2	–0.077
	(0.069)
Rainfall deviation, lagged	–0.101
	(0.151)
Rainfall deviation^2, lagged	–0.043
	(0.088)
Polity2, lagged	0.013
	(0.031)
Polity2^2, lagged	–0.010
	(0.009)
log Population, lagged	0.079
	(0.110)
Population growth, lagged	0.014**
	(0.006)
log Real GDP per capita, lagged	–0.191
	(0.288)
Real GDP growth, %, lagged	–0.004
	(0.010)
Constant	–0.425
	(2.157)
Controls for temporal dependence	Yes
Observations	828
Countries	47

Robust standard errors, clustered on countries, in parentheses. * significant at 10%, ** significant at 5%, *** significant at 1%.

None of the standard controls in the civil conflict literature are significant in the model, including level of economic development and rates of economic growth. Contrary to Urdal (2005), we find some evidence that population growth is positively related to conflict onset. A one standard deviation increase in population growth from the mean value is associated with a 32.3% increase in the probability of onset in the following year.[15]

Turning to our event data, Table III reports coefficient estimates of the effects of *rainfall deviation* on our five dependent variables. Even-numbered models are estimated on the pooled time-series cross-sectional (TSCS) sample with standard errors clustered on countries. Odd-numbered models are estimated with conditional fixed effects.

[15] Environmental scarcity theories focus on the potential for population growth to lead to conflict as resources become scarcer on a per capita basis. See Kahl (2006) for a discussion.

The TSCS findings indicate a U-shaped relationship between contemporaneous *rainfall deviation* and all five dependent variables: all five coefficient estimates are statistically significant (in joint tests) and positive. In terms of magnitude and strength of effect, the largest is on *violent events*, with a one-unit increase in *rainfall deviation* from the panel mean associated with a 0.084 increase in the difference in the log of expected counts (significant at $p < 0.01$), followed by *government-targeted events* (0.074, $p < 0.01$), *total events* (0.072, $p < 0.01$), and *nonviolent events* (0.068, $p < 0.01$). The statistical significance of effect is slightly lower for *non-government-targeted events* (0.072, $p < 0.05$).

The results of the conditional fixed-effects models largely corroborate the TSCS results, save for the effect of *rainfall deviation* on *nonviolent events* and *non-government-targeted events*. Both the coefficient estimates and levels of statistical significance are somewhat smaller. Lagged *rainfall deviation* is only weakly associated with *non-government-targeted events*, with the linear and square terms failing a joint significance test, contrary to our expectations in Hypothesis 3.

Our control variables performed inconsistently. Our findings lend some support to the inverted-U relationship between regime type and social conflict: *Polity2-squared* is negatively associated with *total events*, *violent events*, and *non-government-targeted events*, though the relationship is only significant under fixed-effects specifications. This indicates that institutional coherence explains variation in social conflict within countries better than variation across countries. It also indicates that political institutional coherence matters more for deterring violent rather than nonviolent mobilization, a finding consistent with the literature (Muller & Weede, 1990; Hegre et al., 2001). *GDP growth* is negatively associated with all event types, though the levels of statistical significance vary from model to model. Unsurprisingly, more populous countries are characterized by more social conflict events across model specifications. If anything, population growth is associated with less social conflict, though high levels of social conflict may lead to outmigration.

We use the CLARIFY software (King, Tomz & Wittenberg, 2000) to estimate the effect of changes in *rainfall deviation* on the quantities of interest: expected counts of events. Holding all control variables at their mean values, a two standard deviation increase from mean rainfall is associated with a 30.68% increase in expected *total events*, while a two standard deviation decrease in rainfall deviation is associated with a 38.09% increase in expected *total events*. A three standard deviation increase

Table III. Rainfall deviations and social conflict events, 1991–2007

Variables	*(2)* Total events	*(3)* Total events	*(4)* Nonviolent events	*(5)* Nonviolent events	*(6)* Violent events	*(7)* Violent events	*(8)* Government–targeted	*(9)* Government–targeted	*(10)* Non–government–targeted	*(11)* Non–government–targeted
Lagged DV	0.049***	0.019***	0.093***	0.033***	0.081***	0.029***	0.091***	0.034***	0.080***	0.026***
	(0.009)	(0.002)	(0.015)	(0.005)	(0.015)	(0.004)	(0.014)	(0.005)	(0.019)	(0.004)
Rainfall deviation	–0.015	–0.016	–0.042	–0.025	0.032	0.011	–0.012	0.003	–0.023	–0.017
	(0.032)	(0.028)	(0.039)	(0.033)	(0.035)	(0.039)	(0.043)	(0.034)	(0.037)	(0.037)
Rainfall deviation^2	0.072***	0.046**	0.068***	0.031	0.084***	0.061**	0.074***	0.044**	0.072**	0.021
	(0.018)	(0.018)	(0.021)	(0.022)	(0.026)	(0.025)	(0.025)	(0.022)	(0.031)	(0.025)
Rainfall deviation, lagged	–0.018	–0.007	–0.027	–0.026	0.014	0.024	–0.058	–0.035	0.044	0.073*
	(0.038)	(0.030)	(0.035)	(0.034)	(0.056)	(0.042)	(0.042)	(0.035)	(0.049)	(0.038)
Rainfall deviation^2, lagged	0.015	0.033	0.002	0.023	0.033	0.035	–0.003	0.019	0.039	0.028
	(0.028)	(0.021)	(0.026)	(0.024)	(0.040)	(0.031)	(0.029)	(0.025)	(0.034)	(0.027)
Polity2	–0.015	–0.004	–0.017	–0.007	–0.003	0.014	–0.016	–0.009	–0.002	0.028*
	(0.012)	(0.011)	(0.012)	(0.012)	(0.014)	(0.014)	(0.013)	(0.012)	(0.015)	(0.015)
Polity2^2	–0.000	–0.005***	0.003	–0.002	–0.005	–0.009***	0.001	–0.004*	–0.003	–0.011***
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
log Population	0.331***	0.164**	0.290***	0.109	0.439***	0.207**	0.276***	0.056	0.494***	0.429***
	(0.062)	(0.080)	(0.053)	(0.094)	(0.075)	(0.100)	(0.058)	(0.091)	(0.092)	(0.120)
Population growth, %	–4.134*	–1.770	–3.894	–1.723	–4.747**	–1.253	–4.733	0.326	–4.563**	–2.826
	(2.112)	(2.311)	(2.442)	(2.365)	(2.213)	(3.525)	(2.918)	(2.731)	(2.096)	(2.948)
log GDP per capita	–0.107	0.049	–0.090	0.104	–0.116	–0.046	–0.105	0.136	–0.058	0.058
	(0.074)	(0.097)	(0.079)	(0.113)	(0.079)	(0.125)	(0.087)	(0.116)	(0.113)	(0.122)
Real GDP growth, %	–0.012**	–0.007*	–0.009	–0.007	–0.017**	–0.007	–0.013**	–0.004	–0.013*	–0.009*
	(0.005)	(0.004)	(0.006)	(0.005)	(0.007)	(0.005)	(0.006)	(0.004)	(0.008)	(0.005)
Civil conflict incidence	0.055	–0.025	0.123	0.082	–0.046	–0.251*	–0.018	0.002	0.136	–0.037
	(0.098)	(0.095)	(0.095)	(0.109)	(0.152)	(0.131)	(0.107)	(0.113)	(0.153)	(0.118)
Time trend	–0.017	–0.003	–0.024	–0.004	–0.011	–0.008	–0.023	–0.010	–0.008	–0.007
	(0.014)	(0.011)	(0.017)	(0.013)	(0.016)	(0.016)	(0.017)	(0.013)	(0.013)	(0.014)
Constant	33.648	5.405	46.372	6.830	19.034	14.289	45.737	19.478	11.842	10.794
	(28.782)	(22.823)	(33.231)	(25.891)	(31.003)	(31.055)	(34.121)	(26.724)	(25.266)	(28.647)
Observations	765	765	765	765	765	765	765	765	765	765
Countries	46	46	46	46	46	46	46	46	46	46
Period dummies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects?	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Clustered errors?	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table IV. Marginal effects of rainfall deviations on social conflict

	Total events	*Nonviolent events*	*Violent events*	*Government-targeted*	*Non-government-targeted*
– 3 Standard deviations	103.5%	109.9%	98.5%	108.0%	107.4%
– 2 Standard deviations	38.1%	42.2%	31.9%	38.6%	39.4%
– 1 Standard deviation	9.2%	11.3%	5.3%	9.0%	9.8%
+ 1 Standard deviation	6.1%	2.8%	12.6%	6.5%	4.8%
+ 2 Standard deviations	30.7%	21.4%	51.2%	32.0%	27.2%
+ 3 Standard deviations	88.2%	66.2%	145.0%	92.8%	82.2%

in *rainfall deviation* is associated with an 88.19% increase in expected *total events* from the mean, while a three standard deviation decrease is associated with a 103.49% increase in expected *total events* from the panel mean. Thus, *total events* are more somewhat more sensitive to negative rainfall deviations than positive ones. Figure 2 depicts this curvilinear relationship.

Hypotheses 2 and 3 suggest *violent conflict* and *non-government* conflict to be more sensitive to rainfall shocks. We find evidence in support of Hypothesis 2. The link between *rainfall deviation* and *violent events* is significant under both TSCS and fixed effects specifications, while it is only significant for *nonviolent events* under the TSCS specification. The evidence for a link between violent conflict and rainfall patterns is thus more robust.

Rainfall appears to have differential effects on violent and nonviolent social conflict. Table IV reports marginal effects of *rainfall deviation* on percentage changes in expected events from the panel mean value for the five event types. For both violent and nonviolent social conflict, deviations from mean rainfall levels in both directions are associated with increased incidence of social conflict. The magnitude of the effect for nonviolent protest is roughly twice as large for negative rainfall shocks as for positive ones. Peaceful mobilizations, such as demonstrations and labor actions, are more prevalent in response to rainfall scarcity than rainfall abundance. The relationship for *violent events* is the opposite: the marginal effect for positive rainfall shocks is larger than that for negative ones. Taken with the findings from our analysis of civil conflict onset data, we show that political violence is more likely in wetter years.

We find less support in favor of Hypothesis 3, however. We expected rainfall deviations to have a larger effect on non-government-targeted events, given the perceived inability of many African regimes to meet social demands or contain peripheral conflict. However, our findings show that rainfall shocks have similar effects on non-governmental and government-targeted conflict, though the findings are less robust for *non-government-targeted events*. Rainfall shocks have roughly similar effects on *government-targeted events* and *non-governmental events*, with a two standard deviation drop in rainfall increasing the former by 38.6% and the latter by 39.4%. The marginal effect of positive rainfall shocks is somewhat larger for *government-targeted events*. Therefore, African publics do make increased demands upon both state and private actors.

In additional models, we investigated the potential for the effect of *rainfall deviations* being contingent on level of development, the size of government, and level of agricultural dependence, as these are factors commonly cited as reasons for expecting strong environment and conflict links in Africa. Our analysis reveals the effects are roughly equivalent across lower- and higher-income, and less agriculturally-dependent and more agriculturally-dependent African countries, with the effect being slightly larger at higher levels of income, smaller government size, and higher levels of agricultural dependence. However, there is a relatively limited range within Africa. For regression output and expanded discussion, see Appendix 2 (published online).

Our results suggest several main findings. First, we find some evidence that rainfall correlates with civil war and insurgency, although conflict outbreak is more likely in wetter years. This may be due to tactical considerations: violent actors may be less likely to launch campaigns when there are severe water shortages, making it difficult to care for combatants in the field, and they will be more vulnerable when there is less foliage to provide cover (Meier, Bond & Bond, 2007; Witsenburg & Adano, 2009). During periods of extreme scarcity (i.e. drought), people may be more concerned with survival rather than fighting. Also, too much rain can also destroy infrastructure, particularly unpaved roads, thereby limiting government ability to respond to violence.

Second, very high and very low rainfall years increase the likelihood of all other types of political and social

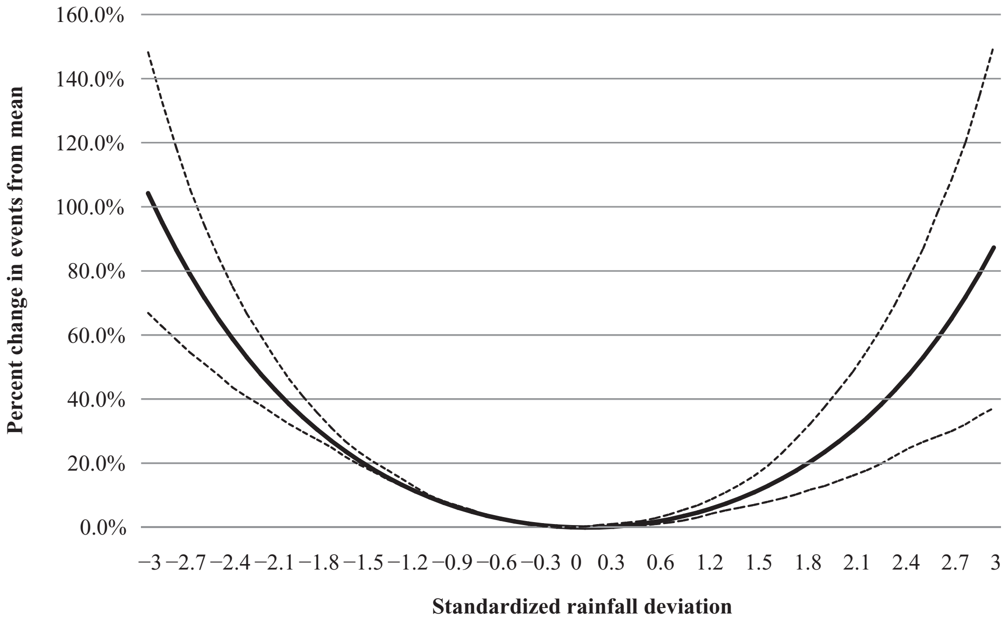

Figure 2. Marginal effect of rainfall deviations on total social conflict events
The solid line is the estimated percent change; the dashed lines represent the estimated 95% confidence interval. Marginal effects estimated using CLARIFY (King, Tomz & Wittenberg, 2000).

conflict, confirming our main hypothesis. Extremes in rainfall have large effects across the board on all types of political conflict, though the relationship is strongest with respect to violent events, which are more responsive to abundant rainfall. Using data from Kenya, Theisen (2012) also finds that wetter years are associated with more violence. Future research must explore whether this increase in violence is due to the looting of abundant resources, the damaging effects of floods, or both.

Third, we find that rainfall scarcity and excess have differential impacts across the various types of social conflict events. All types of events are more numerous in extreme years than in years of average rainfall. Violent events – such as riots, communal violence, and factional conflict within the government – are more prevalent in abnormally high years of rainfall than abnormally low ones. Non-violent events, such as protest and strikes, are almost twice as sensitive to rainfall scarcity as abundance. Somewhat surprisingly, we find that rainfall shocks have roughly equal impacts on government-targeted and non-government-targeted social conflict. Though African states may be comparatively weak, they are still a focal point for popular discontent.

Conclusions

We have demonstrated a curvilinear relationship between rainfall and social conflict. We have also demonstrated the importance of looking at various forms of conflict, including, but not limited to, civil war and insurgency. While armed conflict is more likely to break out in wetter years, we show that other forms of conflict are strongly influenced by extreme positive and negative deviations from normal rainfall. While we have not provided evidence from other regions, Africa may be especially sensitive to rainfall shocks, given the dependence of many African economies on agriculture.[16] Given low adaptive capacity across the continent, climate change effects are likely to be pronounced in Africa.

Given concerns about climate change, what does this study imply for the future? The IPCC climate scenarios generally agree that northern and southern Africa will become significantly dryer, while eastern Africa will be significantly wetter. Moreover, rainfall will become clumpier, with more of it coming all at once – leading to flooding and runoff – with longer dry periods in between. Thus, mean levels of rainfall will change, but so will variance: extreme rainfall events may become much more common. If the historical relationship between social conflict and rainfall continues, the future will likely see more social conflict. Therefore,

[16] See Koubi et al. (2012) and Hendrix & Salehyan (2011) for discussions of the climate–conflict link in Africa in a more broadly comparative context.

policymakers should focus on ways to cushion rainfall shocks through improving water storage capacity and irrigation systems, introducing improved varieties of seeds, providing access to insurance markets, and preventing flood damage. It is also important to promote accountable, transparent government institutions to better meet citizen demands through regular, peaceful means.

Data replication

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Appendix 1: List of countries included in the analysis

Country	*Total events, 1990–2009*	*Country*	*Total events, 1990–2009*
Algeria	201	Malawi	115
Angola	57	Mali	48
Benin	57	Mauritania	79
Botswana	14	Mauritius	8
Burkina Faso	56	Morocco	91
Burundi	107	Mozambique	48
Cameroon	79	Namibia	21
Central African Republic	124	Niger	176
Chad	50	Nigeria	855
Cote D'Ivoire	234	Republic of Congo	36
Democratic Republic of Congo	327	Rwanda	58
Egypt	300	Senegal	80
Eritrea	11	Sierra Leone	84
Ethiopia	63	Somalia	331
Gabon	53	South Africa	801
Gambia	11	Sudan	226
Ghana	74	Swaziland	57
Guinea	62	Tanzania	77
Guinea-Bissau	49	Togo	72
Kenya	307	Tunisia	29
Lesotho	54	Uganda	68
Liberia	89	Zambia	117
Libya	50	Zimbabwe	336
Madagascar	62		

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Come rain or shine: An analysis of conflict and climate variability in East Africa

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Abstract

Previous research on environment and security has contested the existence, nature and significance of a climate driver of conflict. In this study, we have focused on small-scale conflict over East Africa where the link between resource availability and conflict is assumed to be more immediate and direct. Using the parameter of rainfall variability to explore the marginal influence of the climate on conflict, the article shows that in locations that experience rebel or communal conflict events, the frequency of these events increases in periods of extreme rainfall variation, irrespective of the sign of the rainfall change. Further, these results lend support to both a 'zero-sum' narrative, where conflicting groups use force and violence to compete for ever-scarcer resources, and an 'abundance' narrative, where resources spur rent-seeking/wealth-seeking and recruitment of people to participate in violence. Within the context of current uncertainty regarding the future direction of rainfall change over much of Africa, these results imply that small-scale conflict is likely to be exacerbated with increases in rainfall variability if the mean climate remains largely unchanged; preferentially higher rates of rebel conflict will be exhibited in anomalously dry conditions, while higher rates of communal conflict are expected in increasingly anomalous wet conditions.

Keywords

civil war, communal violence, East Africa, environment, rainfall

Introduction

Recent research has speculated that future climate-related shocks might spark violent conflict in a number of regions in the world (Swart, 1996; Sachs, 2005; Homer-Dixon, 2007; Stern, 2007). The fears that violent conflict will increase in the future are largely based on the reasoning that resource scarcity has historically been conceptualized as a driver for large-scale violence and because climate change is widely predicted to have a detrimental impact on resource availability. An oft-cited example of a recent climate-related violent conflict is the Darfur crisis (e.g. former UN Under-Secretary-General for Humanitarian Affairs Jan Egeland, cited in Nordås & Gleditsch, 2007; United Nations Secretary-General Ban Ki-moon cited in Salehyan, 2008).

This view of resource scarcity as a cause of the Darfur crisis, however, has been challenged by a number of authors (e.g. Butler, 2007; Kevane & Gray, 2008) who support a wider narrative in the conflict literature that refutes a climate change–civil war relationship. For example, a recent debate in the *PNAS* began with an assertion by Burke et al. (2009) that increases in

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temperature were likely to cause unprecedented levels of violence in Africa in the near future. This was immediately countered by several academics, including Buhaug (2010) who noted that these results were based on analysis of recent large-scale conflict that selected only years and conflicts that fitted their environmental security narrative. Support for such counter-arguments also come from civil war model based studies which have shown in a number of situations that when standard political and economic variables are included in analyses of conflict, the importance of traditional 'environment' or 'climate change' variables are rarely significant (Nordås & Gleditsch, 2007; Raleigh & Urdal, 2007). Further, several additional studies have discounted degraded areas as being more likely to experience violence, international or national level water scarcity as underscoring conflict (Wolf, 1998, 2000), and natural disasters as likely to lead to leadership change as a function of government ability to respond (Nel & Righarts, 2008).

At the heart of the debate over the role of climate in conflict lies the desire to provide scenarios of future conflict patterns in a changing climate. In this context, the contestation over the linkage between conflict and the climate is set against a backdrop of significant uncertainty about climate change projections, as shown in the most recent report of the IPCC (2007). This scientific uncertainty is most pronounced for the parameter of rainfall, rather than temperature (Meehl et al., 2007). Given the relatively strong relationship between rainfall and economic resources in many of the world's agriculturally based countries, a large uncertainty exists in predicting any potential for climate change-related conflicts.

One of the past problems in isolating the possible role of climate in violent conflict has been the focus on large-scale conflict. The occurrence and characteristics of large conflicts involve a complex interplay of numerous factors on several scales. In such scenarios, 'climate' and 'climate change' are often measured in long-term trends or annual variations. These measures are largely too static to display significant effects on annual conflict patterns. In this study, we focus on the relationship between subnational conflict and variations in past rainfall conditions to further understand the climate–conflict nexus. Furthermore, we explore the relationship between rainfall conditions and different types of conflict. The rationale for looking at different types of conflict rests in the premise that climate is never the only determinant of political violence. Climate's influence is mediated via other drivers of conflict such as resource availability, political unrest and economic pressures. Different types of conflicts have alternate sets of instability determinants and, hence, will have distinct relationships (if any) with climate variability and change. In particular this study uses disaggregated information on recent violence in East Africa to test whether, controlling for other conflict correlates, climate variability influences the propensity of a location to experience different levels and types of violence. East Africa is chosen for several reasons: this region has a history of various conflicts, so the assumption that core sociopolitical factors of instability exist is met. Conflict data for this region are comprehensive, and there is relatively strong agreement between different climate models over climate change in East Africa, despite widespread uncertainty over rainfall changes in the future in the low latitudes.

In the first section of the article, we outline the theoretical rationale for the different linkages between climate and conflict as mediated by rainfall variability. We present four scenarios through which climate may influence the propensity for political violence. These scenarios rest on the assumption that it is not necessarily the sign but the magnitude of the physical change that connects rainfall variability and conflict. We then assess evidence for these scenarios through a series of locational and time-specific measures of rainfall variation and political conflict event frequencies in East Africa for the period 1997–2009. We investigate the data through a regression analysis and supplement this with an epoch superposition analysis. Finally, we conclude with an argument relating to how extreme variability in climate is associated with increased frequencies of conflict.

Potential conflict types

Political conflict varies in participants, actors, victims, political strategy, goals, spatial signature and reliance upon physical geographies. Past studies of local-scale conflict and climate have come to different conclusions on the relationship between the two (Barnett, 2000; Nordås & Gleditsch, 2007; Raleigh & Urdal, 2007; Witsenburg & Adano, 2007; Theisen, 2008; Raleigh, 2010). In part, this results from a failure to separate conflicts into different groupings according to the structure, goals and participants of the conflict.

Violence perpetrated by different actors can be separated based on (1) the formality and characteristics of groups, (2) the actions and strategic goals of groups, (3) the contexts in which groups emerge, and (4) the relationships with other forms of violence. For the purposes of this article, we have distinguished between violent events involving formally established *rebels* as one side of a civil war, and *communal violence* involving informal, often ethnically based, small rural bands engaged in violent contest.

Rebel conflict

Rebels form an official military organization for the purposes of fighting the established military power of the state. Such groups are motivated by the acquisition of formal, internationally recognized power over a state's territory. Membership in rebel groups is defined for the period in which that group operates. Recognized rebel organizations may be associated with a group or region identity, but not all members of that group or region may belong or support violent actions. Rebels often seek to control territorial bases within a state and engage in battles with military forces or violence against civilians (see Raleigh & Hegre, 2009). Geographically, these groups seek control of the power centres of the state, including the capital, regional centres, garrison towns and infrastructure of the state (Herbst, 2000; Buhaug & Rød, 2006). During a civil war, activities involving rebel groups typically result in significant deaths and destruction. For the purposes of this article, any reference to civil wars or rebels is interchangeable.

Communal violence

Very few cross-group studies have been conducted on communal violence, yet the limited sample indicates that localized ethnic conflicts differ in form, intensity and frequency from other forms of internal violence. Communal conflict is broadly defined as a form of organized violence conducted between formalized militias, where the participants are civilians instead of professional or formal soldiers. Such conflict is limited to any politically motivated, low-intensity, local contest fought between group militias associated with ethnic, regional or religious identities. Membership in a self-identified group organization is based on local ethnic affiliation and the participants are typically young males. The collective use of violence is directed towards achieving local or regional control over territory or resources for a larger group (e.g. a religious militia). The majority of communal events involve clashes between militias, which serve as self-identified policing or security units for peripheral groups, who often have a history of connected acts. Conflict between communities is typically 'traditional' in that it has occurred for several generations and often at pre-defined times during the year. It is apparent from individual communal violence cases that communal violence actors often interact with the state through police or military clashes. But critically, the motivation for this violence differs significantly from more formally organized rebel groups, whose stated aim is to replace the regime in power. No such aim exists across communal violent groups.

Communal violence is frequently conflated with 'pastoralist violence' or 'farmer–herder' violence. This is a simplification of the social categories present across East African and Sahel states. Pastoralists are present in over 21 African states and typically live in arid and semi-arid lands. Pastoralism is the livelihood of several nomadic or semi-settled ethno-regional groups. This is generally regarded as a livelihood type that is violent, with particular emphasis on resource competition. This highly organized and strategic violence is considered both a traditional and 'normal' occurrence between groups of pastoralists/herders/farmers. Cattle-raiding is the dominant form of organized violence involving a group invasion or attack by an outside group with the main objective of stealing cattle (Mulugeta & Hagmann, 2008). Raiding livestock of one's traditional enemies is a means to expand rangelands, restock herds and improve social status.

Previous researchers have noted that communal violence revolves around environmental and livelihood issues (livestock, grazing land, water access). Turner (2004: 865–870) finds that in most poor rural communities, conflicts can be interpreted as resource-related, but 'conflicts over resources' are produced from a set of broader processes of change that vary within specific historical contexts. Therefore, the focus on resources is superficial, as these struggles reflect broader social tensions (with ethnic dimensions) between and within social groups. Attacks invite retaliation and many of the ethnic disputes appear to be cyclical (Krätli & Swift, 1999). These conflicts, and the migrants they create, are often invisible to governments and conflict researchers.

These definitions differ from the standard classification as they are based on events and participants and not aggregate categories of conflict type. The rebel and communal definitions are applicable to contexts outside of East Africa. Each type may be rare, intermittent or chronic in different environments and exhibit spatial and temporal patterns that are unique to the group and contexts in which it operates.

Table I. Hypotheses

	Variation				Direction
Hypotheses	*Zero sum*	*No gain*	*Abundance*	*Equal access*	*Wet/dry*
Overall conflict	+	–	+	–	
Rebel	Increases	Stable/decreases	Increases	Stable/decreases	Dry
Communal	Increases	Decreases	Increases	Decreases	Wet

Climate–conflict relationships

The climate–conflict literature suffers from a lack of theoretical connections between its main driver (climate) and its possible consequence (conflict). As noted above, rainfall is a key climate variable in terms of its impact on society. This impact is particularly pronounced in Africa where the majority of the population relies on rain-fed agriculture and pastures as the basis for their livelihoods. Four possible relationships can link rainfall variability (hereinafter used to act as a proxy of both climate variability and change) to political conflict: the first is mentioned above with respect to 'scarcity': (1) Increased conflict is likely to follow periods of above average decreases in rainfall. This is the standard, direct, 'climatic' argument that contends groups will use force and violence to compete for ever-scarcer resources. This is a 'zero-sum' narrative. However, it is equally plausible that (2) decreases in conflict are likely to be correlated to decreased rainfall as there is little to fight for. This is a 'no-gain' argument, which contends that relative gains from conflict during a drier period are too low to justify the labour of conflict. Conversely, it is plausible that (3) increases in political violence will directly follow periods of higher than average rainfall. This hypothesis largely rests on the notion that abundance will spur rent-seeking/wealth-seeking and recruitment of people to participate in violence. Finally, this is counter to scenarios like (4) where there may be a decreased frequency in political violence following increases in rainfall as individuals and groups are self-sufficient and unlikely to motivate participants during these times.

In addition to variability as a driver of local violence, it is evident that conflict incidence patterns and types could be strongly associated with the sign of change. On the subnational level, some types of violence favour a particular environment. For example, rebel violence may be more prevalent during anomalously dry years, possibly due to the ease of movement or part-time recruitment of otherwise employed agricultural labour. Conflict logistics require less effort during dry seasons as there are fewer diseases, the harvest period allows for subsistence, and high value areas are accessible. Indeed, past accounts of interstate and civil wars referred to wet and dry seasons as determinants of strategy (see Kimble & O'Sullivan, 2002; Ziemke, 2008).

Other possibilities include that communal violence may be correlated with variation, but also favour wet periods when the result of raiding may be more successful (see Meier, Bond & Bond, 2007). Several studies have reiterated that pastoralist raiders 'like to attack during wet years because of the high grass, strong animals, dense bush to hide and availability of surface water, which makes it easier to trek with the animals' (Adano & Witsenburg, 2005: 723). During drought years, cattle raiding attacks decrease as additional burdens to pastoralist groups are avoided. These findings support Turner's (2004: 877) analysis that the high variability in the productive resources leads to strong variation in the competition over such resources and, relatedly, that conflicts resemble strategic contests to preserve or gain access over the long term. Cultural practices also dictate raid timing: persistent revenge attacks correspond to lunar cycles and attacks are designed to maximize surprise, celebrate significant events within warrior lives and limit the burden during drought years. Consequently, immediate climate variability can affect conflict both indirectly through the impact on resources and directly through mobility.

Non-physical drivers on the local scale and above create contexts in which local environmental change can affect stability. Many studies of civil war and environmental factors reiterate that the 'political and economic characteristics' of countries are the strongest indicators of civil war risk and that environmental change might be best analyzed for its marginal influences (see Raleigh & Urdal, 2007 for a review).

To summarize, variation in rainfall – as a proxy for overall climate change – is related to overall increases or decreases in conflict risk. Comparing the motivations and reactions of rebel and communal groups to environmental variation tests whether conflict type is the most salient missing consideration of the environment–security

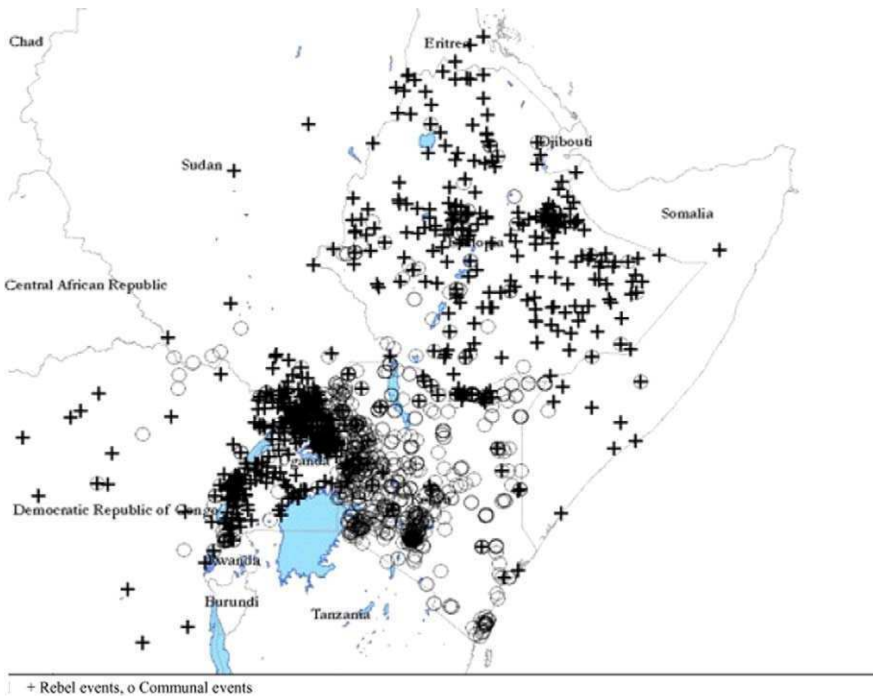

Figure 1. Map of study area

narrative. Table I summarizes the hypotheses. In addition to variation, absolute environmental characteristics, such as wet or dry seasons, may encourage or hinder rebel or communal violence. The final test is whether the relationship between environmental change and conflict is dependent upon the mediating conditions of demography, poverty and state capacity.

Data and methods

This study differs from others in three significant ways: conflict data for Uganda, Kenya and Ethiopia are disaggregated by type, date and location (e.g. town/village). Only those locations in which conflict did occur are used in the analysis. Using only those locations and times in which conflict occurred is a stricter test of the hypotheses that variations in environmental conditions significantly influence conflict patterns within countries. The arguments put forth by environmental security scholars indicate that increases of violence are a response to ecological change. A non-event cannot have variation, nor can a level of rainfall be associated with a likelihood of violence. As conflict is widespread throughout the sample area regardless of ecological variations, a test of increased or decreased frequency as a response to variation and climate conditions is most appropriate. Figure 1 displays the rebel and communal violence patterns across all three states; rebel violence is most extensive in both Ethiopia and Uganda, while communal violence is present across all three main states.

The use of disaggregated conflict data presents both theoretical and empirical opportunities and issues. Such fine-level data create possibilities for ecological inferences about local areas and individual actions. Empirically, conflict data are at a lower level of spatial and temporal disaggregation than most available independent variables. Compromises must be made to fit data together in a unit that is both theoretically and empirically defensible: it is exceedingly difficult to argue that a location, in and of itself, is an appropriate unit given the networks and movement of conflict over time. To rectify the impression that only location characteristics are considered in this analysis, these conflict data are combined with rainfall data for 1997–2009.

Conflict data

The geo-referenced Armed Conflict Location and Event dataset (ACLED) codes the specific date, location, actors and type of conflict activity across over 50 unstable states from 1997–2010 (Raleigh et al., 2010). For this study, data from Uganda, Ethiopia and Kenya for 1997–2010 are aggregated by the number of events by month-year

Table II. Conflict summary

	Total	*Kenya*	*Ethiopia*	*Uganda*
Total conflict count (1997–2009)	Events: 5,187 Units: 3,585 Locations: 1,067 Range: 1–26 Months: 151	Events: 1,661 Units: 1,092 Locations: 381 Range: 1–26	Events: 981 Units: 682 Locations: 283 Range: 1–15	Events: 2,545 Units: 1,811 Locations: 441 Range: 1–15
Rebel action	Events: 2,978 Units: 2,140 Locations: 631 Range: 1–15	Events: 53 Units: 44 Locations: 29 Range: 1–4	Events: 826 Units: 597 Locations: 256 Range: 1–14	Events: 2,099 Units: 1,499 Locations: 346 Range: 1–15
Communal violence	Events: 2,209 Units: 1,445 Locations: 575 Range: 1.26	Events: 1,608 Units: 1,048 Locations: 370 Range: 1–26	Events: 155 Units: 85 Locations: 51 Range: 1–15	Events: 446 Units: 312 Locations: 154 Range: 1–19

that occurred in specific locations, resulting in a rebel dataset of conflict event tallies by location date (aggregated to month) and a matching communal violence dataset of location date. Table II reviews the details of conflict frequency, location-month aggregate units, locations and types of violence. The exact number of incidents per month-year-location of conflict is collected for statistical analysis. Figure 2 displays the general relationship of conflict frequency and rainfall seasonality over space; there is clear variation in the total amount of violence experienced over the course of a year.

There are mean rates of chronic conflict in communal areas that can be largely ascribed to seasonal variation. There is a largely stable amount of conflict for most of the year, but the rate rises during the short rains and dips sharply during the January dry spell. Following this brief dry spell, conflict patterns increase before the long rainy season. The 'hungry season' at the end of the wet season is not associated with higher rates of communal conflict, but the summer months experience a more active rebel campaign over the dry season.

Rainfall data

Satellite-based rainfall data are used from the National Oceanic Atmospheric Agency (NOAA) Climate Prediction Centre (CPC) Merged Analysis of Precipitation ('CMAP') technique (hereafter referred to as CMAP data). These data are available along with monthly time scales for the whole of the globe.[1] The CMAP technique consists of merging observations from rain gauges with precipitation estimates from several satellite-based algorithms (Xie & Arkin, 1996). For the purposes of this research we use monthly data. The rainfall data are available on a 2.5 x 2.5 degree latitude/longitude grid and extend back to 1979. Rainfall averages for each month of the year were determined from 1997 to 2009. Positive or negative deviations were derived by month and were associated with the corresponding locations in which conflict occurred. Seasonal differences are not relevant as deviations from typical rainfall levels were used.

The resolution of the rainfall data is significantly poorer than that of the conflict data. The spatial discrepancy can be partially justified on the grounds that there is no reason to expect that parties will fight on the exact location of rainfall aberrations. However, it is recognized that smaller-scale rainfall data would have been preferential, if available.

For the regression analysis, rainfall data are manipulated to create two sets of measures. The first set includes dummies of no change, negative and positive rainfall. The second are a positive variation variable of values over zero and a negative variation variable to record all values where the deviations are below zero mm. For ease of interpretation, the positive and negative variation variables were transformed into standard deviations from zero. Similar rainfall variables for one and two months prior are also created. The correlation between positive rainfall anomalies for month 0 and month 1 is 29%, month 0 and month 2, 19% and month 1 to month 2, 26%. Slight differences are noted in the correlations between months with negative anomalies; month 0 is 36% correlated with negative values for month 1, whereas the correlation between month 0 and month 2 is 20% and month 1 to month 2 is 26%.

[1] Data from the CPC FTP server (ftp://ftp.cpc.ncep.noaa.gov/precip/cmap/).

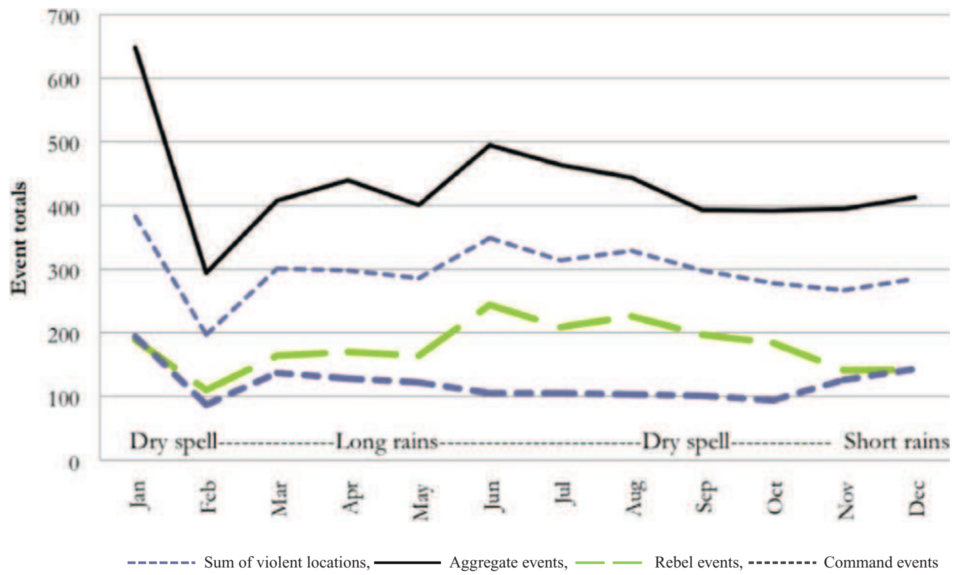

Figure 2. Monthly conflict

Controls

Several controls for violence frequencies are included in the analyses. Unfortunately, many controls are not disaggregated to the level at which conflict occurs, nor are they time varying. These controls include measures of population in conflict locations for the year 2000 (from CIESIN, 2005a), relative poverty in conflict location as proxied by the percentage of children under five who are underweight (CIESIN, 2005b,c) and finally the distance (in degrees) of the location to the nearest urban centre (population larger than 50,000) (UNEP, 2006). Each of these controls is used to assess the marginal effects of rainfall variation on violence within local contexts. Raleigh & Hegre (2009) found that local population and distance measures were critical in explaining the geography of conflict in Central Africa, while several studies have confirmed the importance of population on the national level. In addition, Hegre, Østby & Raleigh (2009) reviewed how local poverty indices explain the patterns of conflict during the Liberian civil war. As low and variable GDP is one of the strongest indicators of civil war risk on the national level, it is equally likely that poverty creates grievance and opportunity-seeking on the local level. However, the poverty indicator is set at 2.5 degrees (250 km^2) in 1995 terms and therefore can only act as a basic proxy for relative poverty in the region. To account for relative poverty, the control variable is the deviation level of each location from the national mean of underweight children.

The impact of spatial and temporal autocorrelation of conflict levels is assessed by incorporating the previous conflict events by month and months one year previous by locations. Conflicts are also clustered by a locator variable, in subregions and in ethnic group homelands. Areas with violence proximate to each other are likely to be contained in the same rainfall unit, so controlling for neighbouring lags is unnecessary. Further, when compiling datasets for large numbers of events, the controls and surrounding locations cancel the need for additional lagged variables as it is assumed such dependence is incorporated into the event occurrence rates.

Two basic methods were used to examine the relationship between rainfall variability and conflict. The first is negative binomial count regression of conflict frequency in location-date units. Regression models were created separately for different conflict types, using dummies to control for countries. Frequencies of conflict are examined in relation to positive or negative deviations from the mean expected rainfall in locations and month of conflict (and one and two months prior) for the entire sample.

The second method of analysis is composite analysis (or ‘epoch superposition’) methodology in which the conflict data are sorted in terms of the number of incidences of violence across the region per month, and rainfall collated from each location where violence occurred during the month for an aggregated monthly total (Todd & Kniveton, 2001). The monthly totals of conflict are then sorted from high to low, and from this sorted list, two samples are taken of the 20% lowest and highest numbers of conflicts per month and the rainfall anomalies compared. This simple methodology thus focuses on comparing rainfall conditions for extreme conflict situations and hence not all conflicts as in the regression analysis. Also, such an approach does not make any assumptions about the distribution of the conflict data. The months of December 2007 and January 2008 for Nairobi, Kenya were excluded from this analysis due to the election-related conflict. Mann Whitney tests and t-tests were then used to assess the significance of differences between rainfalls for high conflict months and low conflict months. Critical t-test and Mann Whitney test thresholds at 90% significance levels were calculated using a Monte Carlo simulation method using 1,000 iterations of randomly selected samples of rainfall to account for temporal autocorrelation in the rainfall data.

Results

The regression results are reported in two stages to distinguish between dummy variable and variation results. Each type of model is further distinguished by whether it means to explain rebel and communal conflict events. Dummy variable models (not shown) for positive or negative monthly deviations from average climate averages compared to no changes in climate report higher rates of conflict in both wetter and drier periods. While wetter and drier results are of equivalent strength in the 'rebel' sample, for the 'communal' sample, wetter periods are more conflict prone compared to drier and no-change periods. In addition, for communal violence, while both positive and negative deviations are significantly related to conflict, one-month prior positive rainfall deviations are correlated with higher rates of communal conflict. This conclusion is largely in line with Meier, Bond & Bond (2007) who note that communal raiders frequently rely on vegetation for strategic advantage.

Table III presents the positive and negative variation models for rebel violence. The model largely supports the conclusions of the blunter dummy variables, but with important exceptions. Climatic triggers at the extremes of positive and negative scales are both related to violence, and the number of predicted incidences is strongly orientated towards smaller vacillations in positive deviations. The proportion of violence explained remains relatively low, which reflects the lack of significant political and social dynamics in the model and the marginal role of climate in conflict variability.

The communal models in Table IV return slightly less positive rainfall variation coefficients than the negative variation counterparts. This indicates that negative shifts may have a stronger effect on the location and frequency of violence. Yet, the predicted values in Figure 3 display that the vast majority of conflict events occur in periods with minimal to no deviations, which again supports the notion that climate variability is of marginal significance.

The control variables are largely insignificant for the rebel study. For the communal conflict's dummy and variation models, poverty, the conflict at the location in previous months, and distance to urban areas are highly significant. The control coefficient for mean poverty rate (measured as percentage of underweight children) indicates that areas that experience communal violence are among the poorest in the state. In addition, these areas are remote and suffer from chronic violence in that it repeats over time and space. This is significant as locations in which rebel and communal violence occur do not overlap significantly (approximately 10% of locations in the model have experienced both types of conflict). Hence, although the weather and environment have some relationship to both types of violence, the contexts in which that effect is present differ significantly for a rebel versus a communal fighter. Poor rural locations have a higher instance of communal violence, which is exacerbated by higher climatic variation. The intersection would imply that environmental scarcity and abundance is dependent upon pre-conditions including livelihoods and wealth.

In the rebel sample, it is more plausible that the environment functions largely as a tactical consideration, as the locations in which rebel violence occurs are far more widespread with fewer repeated events and no correlation to poverty, attacks on primarily urban centres or population places.

Whether we take the data and separate into wet (positive) or dry (negative) models, or designate positive and negative variation models, the strongest signals suggest that the zero sum and abundance arguments can be moderately accepted. There are stronger positive variation drivers in the rebel sample and slightly stronger negative deviations and conflict in the communal cases. The zero-sum behaviour appears to be conditionally true in cases of extremes – in poorer, communal areas these arguments may largely conform to typical raiding behaviour. The no-gain argument can be rejected as both types of violence are found at a stable rate regardless of small rainfall deviations, and both types of violence increase at extreme climatic deviations. The fourth equal-access argument also does not hold as there is increased conflict following increased rainfall deviations.

The number of conflict events occurring at a location strongly influences the regression results, which largely find that deviations are not necessary for explaining a standard rate of conflict: most conflicts occur in areas which have not experienced strong variation. Finally, there are clear and sharp differences between the

Table III. Rebel event variation models

	Rebel			
	Month (pos.)	*Month (neg.)*	*All (pos.)*	*All (neg.)*
Positive rainfall variation	.176***		.105***	
	(.013)		(.014)	
Positive rainfall variation (month prior)			.074***	
			(.009)	
Positive rainfall variation (2 months prior)			.115***	
			(.010)	
Negative rainfall variation		−.130***		−.088***
		(.011)		(.134)
Negative rainfall variation (month prior)				−.078***
				(.017)
Negative rainfall variation (2 months prior)				−.115***
				(.015)
No change	.008	.010	−.003	.044
	(.048)	(.048)	(.048)	(.048)
Population location	.013	.013	.006	.001
	(.013)	(.013)	(.013)	(.013)
Urban distance	.005	.009	.014	.003
	(.015)	(.015)	(.015)	(.015)
Border distance	−.029**	−.006	−.022	.003
	(.015)	(.015)	(.015)	(.015)
Regional poverty measure	.002	.000	.000	.002
	(.004)	(.004)	(.004)	(.004)
Country dummy Ethiopia	.118	.100	.177	.129
	(.127)	(.127)	(.127)	(.127)
Country dummy Uganda	.045	.029	.054	.019
	(.126)	(.126)	(.126)	(.126)
Country dummy other	.086	.0917	.111	.086
	(.139)	(.139)	(.139)	(.139)
Location conflict count prior month	.001	.039	.001	.044
	(.047)	(.047)	(.047)	(.047)
Location conflict count previous year (at month)	.280	.294	.229	.163
	(.303)	(.303)	(.303)	(.303)
Constant	.445	.204	.323	.059
	(.200)	(.206)	(.203)	(.207)
R^2	2.5%	2%	6%	4%
LL	−2775	−2790	−2679	−2746

Units: 3,588; Rebel count: 2,978

communal and rebel conflict patterns across the study area and the overall dispersion of events: poorer and more peripheral areas see higher levels of communal conflict, while the areas that experience rebel events are more scattered and distributed across a range of socio-economic and geographic regions.

Epoch results

Unlike the regression results, the epoch superposition analyses were aimed at determining whether periods of very high levels of conflict compared to periods of very low conflict differ in anomalous rainfall conditions and the temporal emergence of any rainfall signal. In essence this provides a distribution free test of the conflict–rainfall relationship. In Figure 4, the variation in normalized rainfall for months with low and high levels of conflict for rebel conflict and communal violence are displayed when the data is aggregated for all three countries. Conflict occurs at month zero and negative and positive months refer to the aggregate rainfall conditions for all high and low

Table IV. Communal conflict event models

	Communal			
	Month (pos.)	*Month (neg.)*	*All (pos.)*	*All (neg.)*
Positive rainfall variation	.089***		.041***	
	(.009)		(.011)	
Positive rainfall variation (month prior)			.080***	
			(.011)	
Positive rainfall variation (2 months prior)			.049***	
			(.009)	
Negative rainfall variation		−.153***		−.078***
		(.015)		(.016)
Negative rainfall variation (month prior)				−.044**
				(.018)
Negative rainfall variation (2 months prior)				−.161***
				(.015)
No change	−.020	−.039	−.000	−.039
	(.063)	(.064)	(.062)	(.063)
Population location	.013	.011	.019	.002
	(.013)	(.013)	(.013)	(.012)
Urban distance	−.038**	−.038**	−.024*	−.050***
	(.014)	(.014)	(.015)	(.014)
Border distance	.000	.013	.004	−.000
	(.014)	(.014)	(.014)	(.014)
Regional poverty measure	.011**	.009**	.009**	.008*
	(.004)	(.004)	(.004)	(.004)
Country dummy Ethiopia	.160	.119	.197	.166*
	(.089)	(.089)	(.089)	(.088)
Country dummy Uganda	−.81	−.060	−.063	−.046
	(.071)	(.071)	(.075)	(.070)
Country dummy - other	−.327	−.156	−.210	−.175
	(.182)	(.181)	(.181)	(.180)
Location conflict count prior month	.201***	.146	.234***	.172**
	(.062)	(.063)	(.062)	(.062)
Location conflict count previous year (at month)	.082	.085	.121	.103
	(.232)	(.231)	(.231)	(.228)
Constant	.205	.043	.078	.130
	(.173)	(.173)	(.175)	(.172)
R^2	3%	3%	5%	6%
LL	−1953	−1944	−1906	−1884

Units: 3,588; Communal count: 2,209

conflict samples at different times, before and after the conflict occurs. These results show that in periods of high rebel conflict, the conditions are statistically (significant at the 90% significance level) anomalously dry for the three months prior to the conflict, compared to periods of low rebel conflict; this difference in rainfall conditions starts to emerge at three months prior to the conflict. For communal violence the relationship is reversed: periods of high communal violence are statistically more likely to be wetter for the three months prior to violence than periods of low communal violence. This difference is greatest at 2 months prior to the violence where the rainfall variations for this month and the previous three months are statistically (significant at the 90% significance level) higher for high rather than low conflict levels.

Conclusions

Previous studies have contested climate as a significant driver of conflict. In part this disagreement has arisen because of a concentration on large-scale conflict. In this

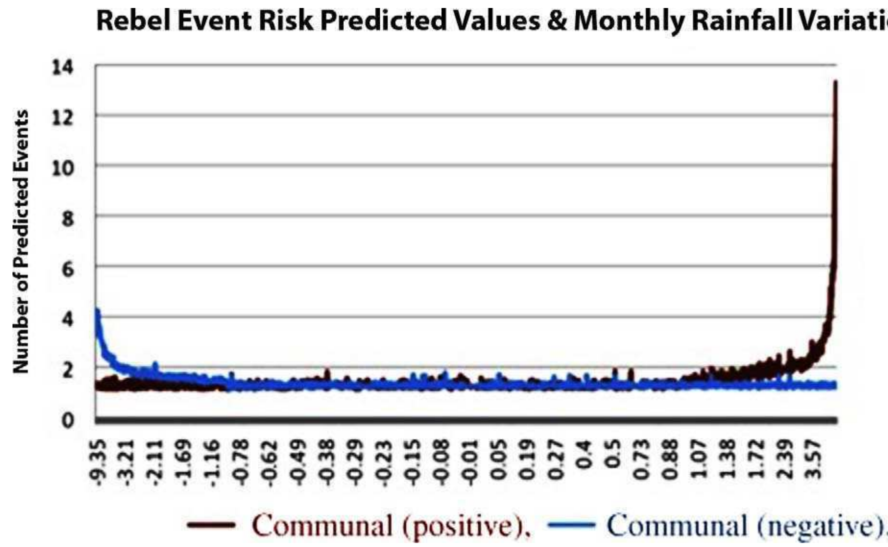

Figure 3. Communal violence: Predicted events over rainfall deviations

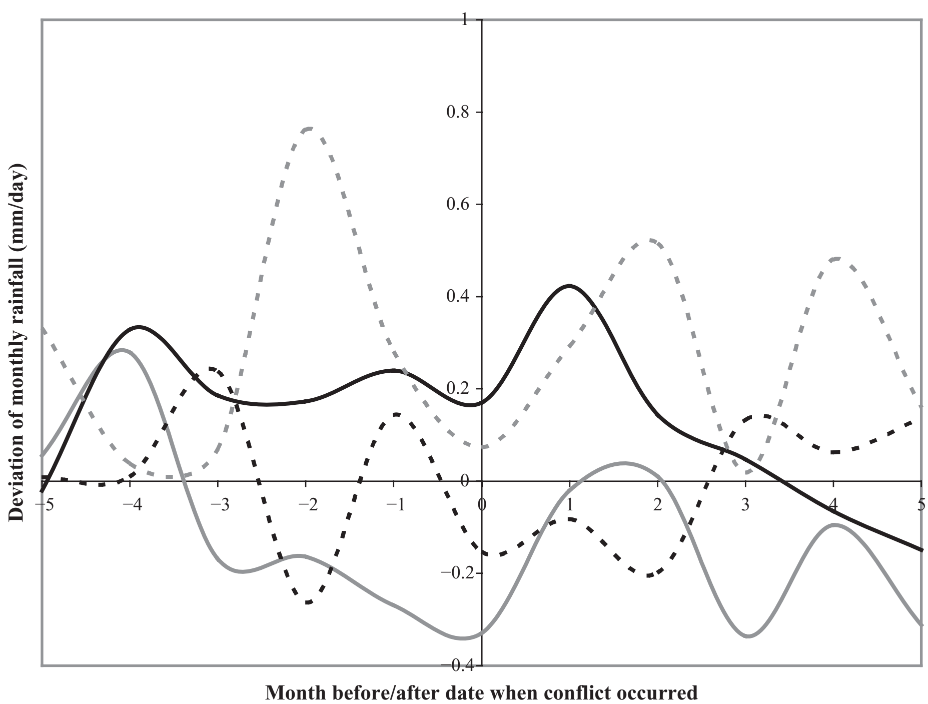

Figure 4. Variation in normalized rainfall for months with low and high levels of rebel and communal conflict in Kenya, Uganda and Ethiopia

Rainfall for events with high (low) rebel conflict are shown in solid grey (black) while for high (low) communal violence these are shown in dashed grey (black)

article, we analyze disaggregated conflict events where, while still politically determined, the linkages with the physical environment are considered to be more immediate and direct. In particular, the article looks at the influence of one climate parameter, rainfall, and uses the analogy of rainfall variability (e.g. monthly and seasonal changes) to assess the climate–conflict nexus. The results of this analysis for conflict over East Africa support a theoretical linkage between the climate and conflict that focuses rainfall variability as a marginal driver of conflict frequencies. The results show that disaggregated conflict frequencies are exacerbated by both extreme wet and dry conditions. In the setting of East Africa, rainfall provides an indicator of resource availability through its impact on natural and agricultural resources. Therefore, these findings moderately support both a 'zero-sum' narrative, where conflicting groups use force and violence to compete for ever-scarcer resources, and an 'abundance' narrative, where an abundance of resources spur rent-seeking/wealth-seeking and recruitment of people to participate in violence. In both cases, there is clearly a prerequisite of economic and political instabilities for such narratives to be played out. Key to the discovery of this climate–conflict link is the separation of conflict into rebel and communal types. Within this general framework, anomalous rainfall conditions, irrespective of sign, are likely to enhance the probability of conflict. However, when looking in more detail, the highest incidence of rebel conflict appears to occur in extreme dry rather than wet conditions. By contrast, it is shown that the highest incidences of communal violence appear to occur in extreme wet rather than dry conditions.

Given the geographic focus of the study, the conclusions of this work are applicable mainly in East Africa. However, they are arguably generalizable to other countries across the Sahel belt where high rates of communal and rebel violence occur in arid and semi-arid lands (ASAL). The primary rebel group in this study is the Lord's Resistance Army, which has a unique spatial signature compared to other rebel groups, in that the LRA has significant operations in and around Uganda and has more diffusive campaigns. However, the results from both Ethiopia and Uganda are applicable to other rebel contexts and complement a growing recognition of how rebels use the environments in which they operate for resources, tactical manoeuvring and possibly recruitment. The differences in control variables coefficients for the communal and rebel sample indicate a critically understudied aspect of the environmental security literature: the locations, which have both extreme climate variability and very high rates of communal conflict, are poorer relative to the remainder of the state. This conclusion supports a wider case-based literature on communal and pastoral violence in the Sahel belt which suggests that conflict is a competition for power and access to resources in areas of government absence and a dearth of public goods. Due to the narrow margin of sustainability for the livelihoods across the Sahel, groups again manipulate environmental conditions in order to control territory, resources and aggregate wealth through raiding behaviour.

The implications of this work are that conflicts do not occur in a political vacuum. There is a lack of attention to how the politically marginal become highly vulnerable to ecological variation. The people living in ASAL are frequently victims of poverty and political manoeuvring including elites who encourage groups to 'ethnicize' land claims, leading to contests over access and occupation of communal lands, water and migration rights (see Hagmann & Mulugeta, 2008). The changing economic landscapes in African states – including the gradual incorporation of land for agricultural activities – create contests over livelihoods. This is frequently the basis for blunt assumptions of farmer–herder contests. However, this is a larger issue about 'pastoralist spaces' and their continued existence within modern states (Mulugeta & Hagmann, 2008).

The policy implications of these findings are that greater attention should be paid to communal conflict management, particularly in periods of high rainfall variability. This fits well with current climate change projections which are largely uncertain in terms of the sign of change in mean rainfall for large parts of the tropics but agree that the magnitude of rainfall variability is likely to increase with human-induced climate change. However it should be noted that the assumption of increased conflict with increased rainfall variability has not been shown in this study to be independent of changes in mean rainfall conditions.

Replication data

Replication files for this article are found at www.prio.no/jpr/datasets. All data are publically available and collected from a range of secondary sources at www.acleddata.com. Data on nonviolent events (approximately 7% of the total data) are not included in the analysis conducted here.

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Climate change, violent conflict and local institutions in Kenya's drylands

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Abstract

Many regions that are endowed with scarce natural resources such as arable land and water, and which are remote from a central government, suffer from violence and ethnic strife. A number of studies have looked at the convergence of economic, political and ecological marginality in several African countries. However, there is limited empirical study on the role of violence in pastoral livelihoods across ecological and geographical locations. Yet, case studies focusing on livelihood and poverty issues could inform us about violent behaviour as collective action or as individual decisions, and to what extent such decisions are informed or explained by specific climatic conditions. Several case studies point out that violence is indeed an enacted behaviour, rooted in culture and an accepted form of interaction. This article critically discusses the relevance of geographical and climatic parameters in explaining the connection between poverty and violent conflicts in Kenya's pastoral areas. These issues are considered vis-à-vis the role institutional arrangements play in preventing violent conflict over natural resources from occurring or getting out of hand. The article uses long-term historical data, archival information and a number of fieldwork sources. The results indicate that the context of violence does not deny its agency in explanation of conflicts, but the institutional set-up may ultimately explain the occurrence of the resource curse.

Keywords

climate change, Kenya's drylands, local institutions, resource curse, resource scarcity, violent conflict

Natural resource wealth, climate change and violent conflict

This article looks at the possible links between environmental factors and collective behaviour. A direct causal link between society and the physical environment has long been dismissed as physical determinism (Cole, 1996), because there is no direct relationship between, for instance, economic performance and the natural resource base. Yet, others have alluded to a strong relationship between the supply of environmental resources and the occurrence of violent conflict (Homer-Dixon, 1999; Kahl, 2006). These divergent views about the connection between scarcity and conflict indicate the complex issues that have continued to draw out academic debate (Collier & Hoeffler, 1998;

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de Soysa, 2002; Gleditsch, 1998; Homer-Dixon, 1999). Until now the mainstream thinking has been that scarcity of resources creates war and conflict (Kaplan, 1994; Homer-Dixon, 1999). However, resource scarcity might actually foster cooperation over resources rather than trigger conflict (see also Buhaug, Gleditsch & Theisen, 2008).

The *Human Development Report 2007/2008* most prominently emphasized the consequences of climate change for human security (UNDP, 2007; IPCC, 2007) rather than just being an environmental issue. Africa is termed a continent with climate-dependent economic sectors at risk of violent ethnic conflict. Climate-change predictions for Africa suggest increasing scarce water resources associated with a high risk of violent conflict, and declining and failing agricultural yields in the Horn of Africa (Carius, 2009; OECD, 2008). Burke et al. (2009) found correlations between changes in temperature or high levels of variability in rainfall and the likelihood of violent conflict events in Africa. The question arises, therefore, whether Kenya, which is experiencing the drying up of lakes and rivers, dwindling water supplies, and serious food shortages, is facing a typical situation with conflict induced by environmental scarcity.

The changes in rainfall patterns and frequent droughts make the survivability of pastoralists in the arid environments particularly difficult (Boko et al., 2007). Cyclical droughts are increasing in frequency, with the drought cycle, on average, increasing from one in eight years to one every three years. Interannual and interseasonal variations in rainfall patterns determine pastoral mobility and the use of fall-back grazing areas, intercommunity relations and altered land tenure arrangements, and conflict to the detrimental use of the rangelands. The availability of common-pool resources across border areas leads to periodic conflicts in the drylands. Conflicts between pastoral communities in the arid borderlands of northern Kenya, southern Sudan and southern Ethiopia are said to be over access to pasture and water, livestock raiding and the heavy presence of small arms (Leff, 2009). The fighting between pastoralists and farmers in the Oromia and Ogaden regions of Ethiopia, and interclan fighting in Somalia all seem to indicate the links between the human impacts of climate change and the threats of violent conflicts (*Human Impact Report*, 2009).

Lobell et al. (2008) predict a 54% increase in armed conflicts in sub-Saharan Africa by 2030 compared to the 1980 to 2000 period, *if* future wars are as deadly as recent wars. Burke et al. (2009) report strong historical linkages between civil war and temperature increase in Africa. These claims were later refuted by Buhaug (2010a,b), who shows that, using a more accurate method of investigation and by making use of a more complete armed conflict dataset, there is no causal relationship.

The risk of increased conflict trends in Africa are likely a result of many complex reasons, including inadequate governance, rampant corruption, heavy dependence on natural resources and ongoing cycles of violent conflict (Halden, 2007; Olsson, Eklundh & Ardö, 2005). Buhaug, Gleditsch & Theisen (2008) give an overview of multiple factors that may play a role in the evolution of climate change-related violence, yet emphasize that there is no up-to-date empirical statistical evidence of violence directly related to climate change and environmental scarcities. Natural resources usually seem like the obvious cause, but conflict may be triggered by the absence of good institutions and external interference. A study of Northern Kenya found that it is not drought, but the coming of the rains that is associated with greater conflict casualties (Witsenburg & Adano, 2009). Pastoralists do not fight during a time of scarcity but during periods of plenty, and the disruption of livelihoods remains a major concern for security policies. In combination with economic, social and political uncertainties, climate change *might* increase the risks of conflict and instability, especially under conditions of poor governance.

The actual impacts of climate change remain controversial and speculative. According to Ostrom (1990) and Young (2011) natural resources, including common-pool resources such as forests, grazing pastures and fisheries, are at times better managed collectively. Ostrom (1990) explains that self-governing institutions under common property rights are able to regulate many resources for collective benefits, as people learn to cooperate when presented with a resource problem. In this regard, institutions become a decisive variable in shaping human–environment interaction, and in preventing competition over resources turning into a violent conflict (Ostrom, 2007; Young, 2011). We do not argue that resource scarcity or abundance bring about (violent) conflict by themselves, but aim to provide evidence of how and under what conditions natural resources contribute to cooperation or violent conflict. This article shows the outcome of an enquiry into the relationship between climate change, natural resources availability and marginality (ecological and political) and social interactions between ethnic groups. The article seeks to answer the question whether we can develop an approach that combines the physical environment and human agency mediated by social institutions in explaining why natural resources and violence are not always directly related. The examples come from Kenya, where in the last couple of years violent incidents attracted much attention.

This work links up with the current debate on the demographic and social consequences of climate change in particular by linking ethnic violence and natural resource availability. Violent killing and raiding take place in a social context that may be motivated by considerations other than climate. In the first case of northern Kenya, cooperation increases in the dry season as natural resources become scarcer, and violence increases during the wet season. Against this background, the issues of governance and cooperation turn out to be relevant for our inquiry into the role of resource scarcity in low-productivity arid areas. In the second case of southern Kenya, the Loita forest as a contested resource also turned out not to be a resource curse[1] because of the management regime and an ingenious use of old and new institutions that prevented the loss of the forest to a private 'developer'. The benefits from the communally used forest remained well distributed among the local inhabitants.

The article draws a parallel between the conventional notions of resource scarcity inducing violent conflict, on the one hand, and the resource curse as it relates to abundant endowments of natural resources, on the other. We use these concepts to investigate the importance of the local institutions in access to and use of environmental resources. Natural resource regulations and governance arrangements play an important role in handling potential conflicts over scarce water resources in the drylands and in community-shared forest resources, even when climate change seems evident. For instance, while Africa generally is expected to get hotter and drier, climate change will bring different changes to different areas and, in particular, Marsabit and Loita are expected to get more rain coupled with more variability.

Resource curse and violent conflict in poor countries

The resource curse, or the paradox of plenty, generally refers to the observation that countries harbouring abundant natural resources often lag behind in their economic performance relative to countries with limited natural resources. The explanation of this phenomenon varies widely across disciplines, and singling out a few causative variables has therefore been a very difficult exercise in a large number of studies (Brunnschweiler & Bulte, 2009; Collier & Hoeffler, 1998; de Soysa, 2002; Sachs & Warner, 1997, 2001).

Even in wealthy, democratic countries, the 'paradox of plenty' can be observed when state revenues from natural resources have paralysing effects on manufacturing and economic productivity (see, for instance, Krugman, 1987). In countries with a low GDP per capita and slow growth, poverty and scarcity of natural resources are assumed to be related to violent conflict (Brunnschweiler & Bulte, 2009). A large number of studies have been carried out to establish whether resource depletion leads to social unrest and eventually ethnic wars (Kaplan, 1994; Homer-Dixon, 1999). Especially in regions where people depend on the natural environment in production systems that rather produce for self-sufficiency than for the market, a link between poverty and violence is easily suggested (see Peluso & Watts, 2001 for a critical review).

The resource-curse paradigm seems to be especially relevant to countries whose GDP largely consists of revenues from primary commodity exports (Collier, Hoeffler & Rohner, 2009). When governments are unable to ensure fair distribution of returns from resources and provide basic public goods such as security, education and health financed through resource revenue, resource abundance stimulates violence, grievances, theft and looting caused by rebel groups, and even civil war (Mehlum, Moene & Torvik, 2006). Different economic growth rates among resource-rich countries are primarily explained by how resource revenues are distributed via the institutional arrangement and fair systems of democratic governance. Their study confirms that when individuals 'colonize' the opportunities of power and resource profit offered by the state to influential leaders or politicians, natural resources push the aggregate incomes down when institutions are 'grabber-friendly'. This means that a large share of revenues earned from natural resources end up benefiting only a few individuals at the expense of the general public, usually the poor. This hints at the importance of governance and institutions in regulating the use of revenues accruing from natural resources at the national level. In the following sections we present two case studies that indicate that resource conflicts can be settled when institutional arrangements do not always lead to unlimited resource grabbing. This assumed link between scarcity

[1] Popularly, resource curse refers to a phenomenon where countries, regions or areas with an abundance of natural resources tend to show less economic growth and worse development outcomes than countries with fewer natural resources (Collier & Hoeffler, 1998; Sachs & Warner, 2001). In this article it refers to a situation where resource-rich areas show a high chance of (violent) conflicts.

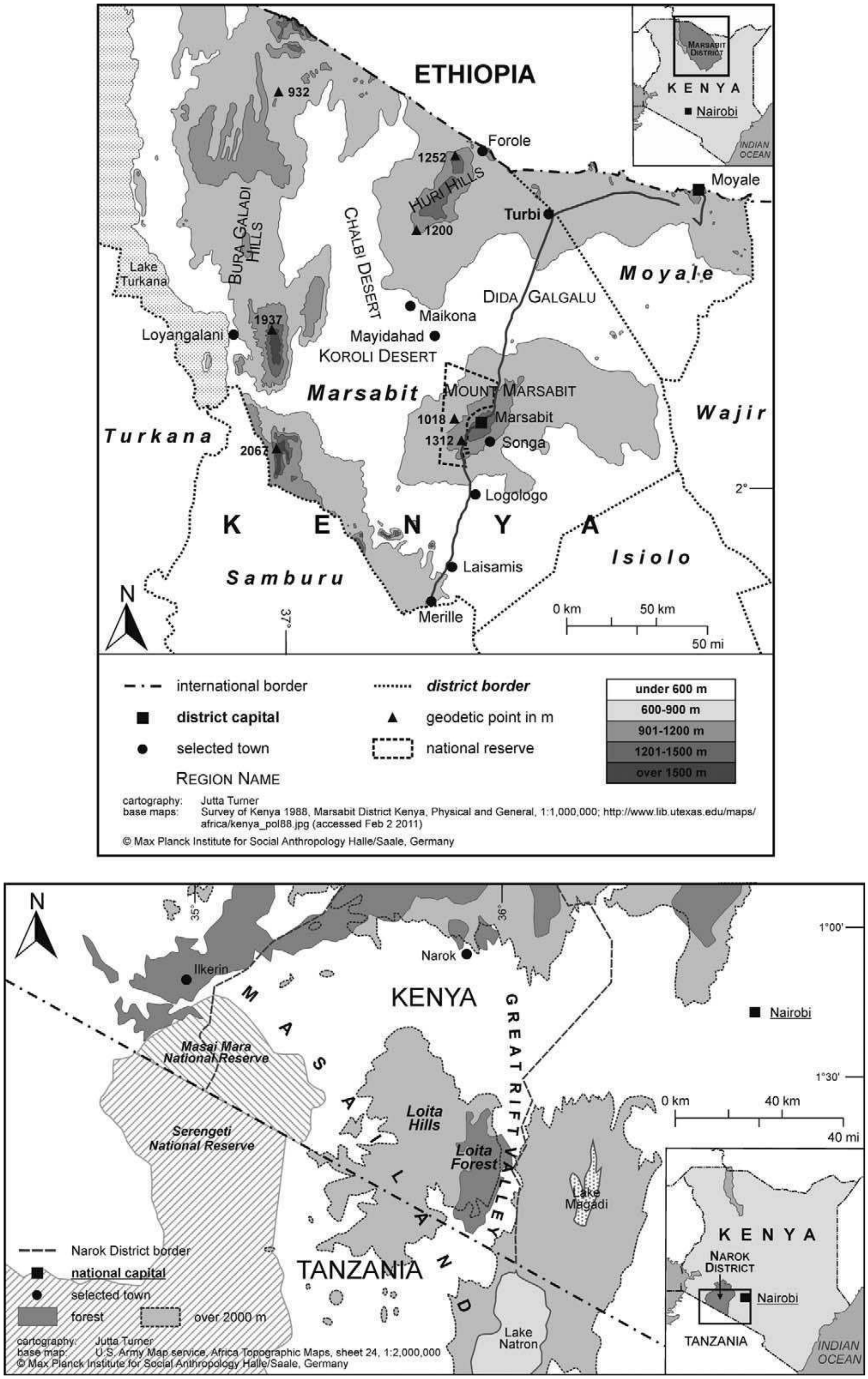

Figure 1. Location of Marsabit and Narok Districts in Kenya

of natural resources and conflict is tested and falsified in the first case study from northern Kenya, and the other from southern Kenya (Figure 1).

In the northern Kenya drylands, where livestock raiding is a widespread practice among pastoralists, the use of violence is common and part of the group-specific accepted codes of conduct and cultural institutions. Yet during times of drought, warring parties patch up their differences and reconcile to use scarce water resources together from limited water holes. While water is generally scarce in drylands, water abundance is extremely localized in northern Kenya, like in the other drylands. Thus, the 'value' of water as a resource in those few places increases.

The second case study deals with the paradox of plenty in a different way. In southern Kenya, pastoralists had a conflict over forest management and accessibility. Using a mix of indigenous and formal institutions, subsections of Maasai pastoralists were able to secure their access rights through a largely nonviolent settlement in court, whereby the individual resource grabbers had to withdraw their case to allow local communities to share the forest and its associated benefits according to the terms of local institutions governing natural resources. The Maasai case brings to light a pluralistic (i.e. use of traditional and 'official') form of resource regulation and access rights through collective organization of the Maasai subgroups. These groups make ingenious use of common-pool resource institutions and the provisions of the legal courts to peacefully settle differences over common property resources, despite increasing pressure on these resources due to changing climatic conditions. This result links up with other studies (Ostrom, 1990; Anderies, Janssen & Ostrom, 2004) that find the role of local institutions crucial to resource management, avoiding a potential resource curse and instead turning it into a blessing. Thus, the example from northern Kenya is about the environmental context and the use of the institutional structures (raiding as a traditional social institution) to cope with violence. A change in environmental context such as drought activates traditional institutional structures (coping mechanism) that in turn mediate behaviour of raiders (social institution) toward cooperation. The Loita case demonstrates how non-state actors can react to social threat to a portion of their resource base (i.e. the Loita Forest as a dry season fall-back area for Maasai herders in the lowlands) in order to protect their interest without violence. While the Marsabit case is mainly about the use and outcome of social institutions of raiding, the Maasai case is about particular social institutions of age groups, Laibon and the local NGO. Both case studies show that valuable natural resources are protected and shared through peaceful collective action during periods of stress (drought, or resource capture by the state) rather through violent action. People are probably more inclined to cooperate and share resources when wealth benefits them all.

Example of violent conflict from northern Kenya[2]

Northern Kenya is an economically poor and marginal region, where water, arable land and pasture are scarce resources. Their availability is highly variable, but nevertheless of vital importance to the local population. Most people here such as the Borana, Rendille, Gabra, Samburu and Dassanetch are pastoralists who fully depend on the environmental resources for their survival. Low and unreliable, rainfall determines the availability of water, pasture, crop yields and livestock production including milk and meat. Dry months typically cause stress, because all the resources that people depend on become scarcer. When the pressure on resources increases, it seems more likely that people will fight over access to these resources. Northern Kenya therefore provides a test case of climatic variability and social responses (Adano & Witsenburg, 2004). In this context, research has been carried out on the availability of water resources and violent conflicts over several years to investigate whether there is a link between water scarcity and violence. We examined the number of violent deaths in dry and wet years in Marsabit District (including Moyale) over more than 30 years, using archival records and annual reports of government ministries. There was no evidence that drought years were more violent than wet years (Figure 2). On the contrary, there was more violence in years of high rainfall. Twice as many people (50 vs. 23) were killed in wet years as in drought years.[3]

We could think of a situation in which people might postpone violence until the first wet year after a drought year. But wet or average years following a drought did not show more conflict incidents and killings. In fact, fewer people were killed in wet years following droughts than in wet years in general, although the standard deviation is so high that the difference is not significant. The violence occurring in Marsabit District cannot be attributed to drought-induced scarcity of resources (Adano & Witsenburg, 2008).

Another set of data from the same areas on seasonality and the number of killings shows yearly seasonal fluctuations in the type of violence and the number

[2] This section draws heavily on work in Northern Kenya, as described in Adano & Witsenburg (2004, 2008) and Witsenburg & Adano (2007, 2009).

[3] A 'drought year' is defined as a year when the annual rainfall is 700 mm or less. The rainfall was measured on Marsabit Mountain, which receives a higher amount of rainfall than the surrounding lowlands (Adano & Witsenburg, 2008: 229, 1161–66).

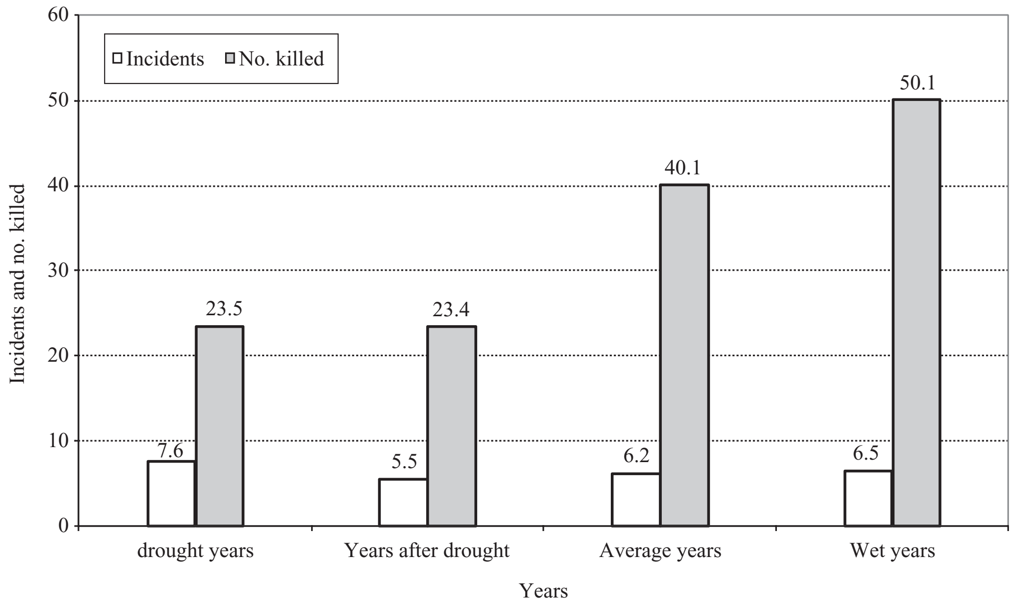

Figure 2. Average number of conflict incidents and killings in dry, average or wet years, 1929–99
'Drought year' is rainfall ≤ 700 mm; 'year after drought' is rainfall < 700 mm; 'average years' is rainfall 701–850 mm; 'wet years' is ≥ 851 mm rain.

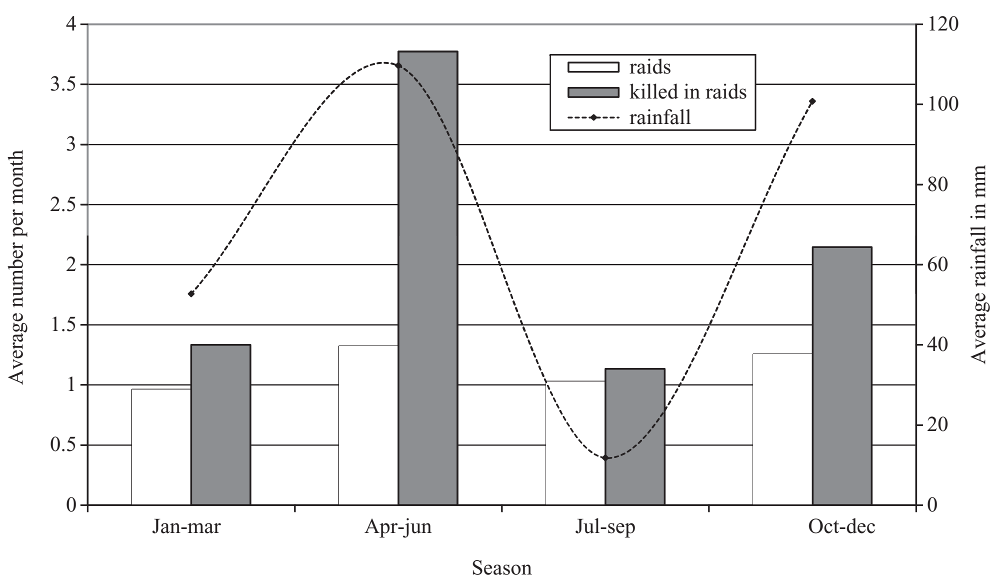

Figure 3. Seasonal fluctuations in killings and rainfall, combined averages per season, 1950–94
Source: Witsenburg & Adano (2009: 525).

of killings. Figure 3 shows the relationships between seasonal human killings and rainfall patterns based on information from archival records of the Security Committee. We only took years for which we had 12 months of both rainfall data and the number of killings. We divided the year into four seasons based on a bimodal rainfall pattern (long rain March–May and short rain October–December), with two dry seasons, in northern Kenya. Figure 3 also shows the sum of all people killed and those killed in raids, per month, combined in three-month seasons. The data only include interethnic violence. Intragroup killings are excluded from these figures because data are not available from the records.

In January–March relatively few people are killed in raids. The number of violent raids shoots up in the wet season of April–June, but then decreases during the dry period in July–September. Raid-related violence again goes up in the wet season of October–December. Generally, most violent killings in this region occur during livestock raids. Only one person per month on average is killed in other fights. This figure remains stable over the year, except for the dry season of July–September when other violent killings shoot up. During the July–September season there still is a very high murder rate that is not livestock-related. A closer look reveals that these months were particularly violent in the years 1963 (46 killings), 1992 (24 killings) and 1994 (49 killings). In 1963, Kenya achieved independence and the secessionist Shifta War started, so this was a very violent year in the whole of the northern region. 1992, when multiparty democracy was introduced, was a very violent year all over the country. In 1994, there was a violent ethnic conflict on Marsabit Mountain between the Borana and the Burji. These incidents were solely politically motivated confrontations.

Violence as enacted individual behaviour and collective choice

The finding that more people are killed in raids during the wet season may seem strange to outside observers, but to the local people involved it was simply explained by their notion of rational behaviour. In northern Kenya people do not necessarily engage in violent conflict in general, and more specifically not over water resources. Especially during droughts people are more inclined to keep the peace, to cooperate and to use wells together. Even though wells can be individually owned or owned by a specific clan, the water inside is a common property resource and carefully managed by a number of people. When a drought is expected, warring pastoralists usually reconcile in order to use water and pasture together. Violent livestock raiding is mostly carried out during the wet season. The animals are stronger and fatter then, and the vegetation and surface water are more readily available, which is necessary during a long trek away from the area where the raid took place. The vegetation is also thicker, which makes it easier to hide after an attack. Raiders usually have to trek long distances, for which the animals should be fit and strong. Raiding is especially common during the rainy season because rain washes away tracks, which increases the chance of escaping with the raided livestock. Rainy seasons in pastoral areas are usually times of relative abundance, not only of pasture, water or milk. There is also a labour surplus, which makes it easy for young men to engage in raiding.

As Peristiany (1939) notes in the 1930s for the Kipsigis, raids are carried out under enduring hardship in the bush and using every tactic of enemy engagement such as sending out spies, occupying all the strategic positions to ward off any forthcoming help for those attacked and attack before daybreak. In 2008, one informant narrated how raids are normally organized. The people who participate in the raid come from all clans to avoid the risk that one clan is decimated when the attack fails. Most age groups are also represented. Raiders who are too eager to attack because of anxiety and lack of sleep might be advised not to join the group at the place of the enemy on the actual day of attack. The party needs some calm and experienced men who do not make disastrous errors during the attack. Before the actual raiding day, the group decides which animals to take and also obtain tags such as white bark of a tree to differentiate themselves from the enemies (Wosori Damballa,[4] Marsabit, July 2008). Otherwise the group may end up killing each other in the commotion, especially in the dark when it is difficult to differentiate people.

The same informant stated that such big raids are rare nowadays, as Peristiany (1939) also observed in the 1930s among the Kipsigis community in western Kenya. According to the informant it is hard for such a large group of men to leave the herds for so long a period. In times of hardship such as dry seasons or during droughts there is no labour surplus as heavy manpower is required by the herding families. This narrative clearly confirms the notion of both individual or collective action in violence as rational behaviour, and the phenomenon of cooperation to overcome climatic stress rather than to indulgence in violent behaviour.

A number of other interesting descriptions explain the practice of violent livestock raiding in a similar way. For example, Mieth (2006), Eaton (2008) and de Vries (2007) have independently surveyed cattle raiders in the western Pokot area for their motives and raiding practices and their perceptions of insecurity. Like-minded small groups organize raids of which the whole ethnic group is not necessarily always informed (Peristiany, 1939; Almagor, 1979). Approval of elders was often not sought. A raid should therefore not simply be called ‘ethnic warfare’ or ‘ethnic clash’, since it is not the ethnic group as a whole or its leaders that is involved in

[4] The names have been changed in order to maintain the anonymity of the interview participant.

violence. In addition, raiding parties consist of a small selection of warriors who strive to achieve social standing in the pastoral society. They are often young, strong and certainly not among the poorest. They value group respect, bravery and earning a name among peer groups, and defend or protect their own group's territorial grazing areas. To be seen as a hero, and gaining the image of a fierce cattle raider, is of immense importance to the warriors. According to Pokot informants (Mieth, 2006) a raider goes to the war front for appreciation of others, to prove he is a hero and to earn praise for killing an enemy. A warrior who proves to have poor raiding skills is teased without mercy. A raider who goes to raid and then runs away from the raided party is called a coward and people will compose and sing songs to humiliate him and his family.

In Pokot, like in other drylands, situations of insecurity and keeping a region unsafe serve the raiders well. The raiders do not necessarily have the same interests as those who prefer a secure environment and a peaceful community. Raiding is training for survival in insecure areas. Understandably, finding a partner who is able to face up to a fight is a matter of securing the basic survival for girls. Indeed, spaces of insecurity have for a long time served such communities in their struggle against government control, as the following incident from the colonial records shows. The colonial administrator from 1963 in northern Kenya describes an incident on the 15 June, when a 35-strong raiding party attacked a Samburu hamlet and killed and mutilated about 24 people. Only two raiders were wounded during the attack, and the rest looted and made off with all the cattle owned by the village. One policeman killed two of the attackers later, but the remainder of the raiders made off. This raided hamlet was situated in the extreme south-west of Marsabit District, in country difficult to access. Only 24 hours later news of the incident reached Loiyangalani, so that Kenya Police and Tribal Police could be deployed in an attempt to intercept and trace the offenders.[5]

This incident depicts the livestock raiding practice as something of a ritual to humiliate and dehumanize the enemy. The raid described here took place in a very remote area, which was not only difficult to access but also made it difficult for the police to intervene. This is a typical geographical feature necessary for a successful raid. The raiding party consisted of at least 35 men, which is partly indicative of a collective action that needs organization and mobilization. The raiding party only lost two members to the police while the rest made off with their loot. The advantage of raiders over the police is that they know the landscape better and are usually better trained in trekking through rough country. The brutality of the attack, during which not only were livestock taken but the bodies of men, women and children alike were mutilated is a reminder that this event is not only about resource capture. The year 1963 (with 1,235 mm rainfall) was not a dry year, and the 1960s were not a period of drought (Adano & Witsenburg, 2004: 91); it was even one of the wettest decades in the history of recorded rainfall in the district.

On insecurity, poverty and geographical context

The number of people who were killed in interethnic violence in Marsabit and Moyale comes to an average of about 25 persons per 100,000 inhabitants per year from 1949 to 1959 (KHRC, 2000; Witsenburg & Adano, 2009) and 36 persons per 100,000 inhabitants each year from 2002 to 2008. The increase could be a result of a more efficient method of counting and reporting, and also worsening tension between ethnic groups related to the government's ardent top-down approach to the introduction of new boundaries. New administrative boundaries have cut off former natural resources for neighbouring ethnic groups, in regions where resources were shared before. With this high killing rate, the region comes close to being as insecure as urbanized areas in the world, such as Nairobi (77), Washington, DC (60), or Pretoria (43).[6]

Dryland regions generally bear the image of being unsafe. It is not a coincidence that geography and social problems converge here; remote and marginal areas are attractive environments for certain types of violence and criminal behaviour. This is in line with Fleisher (2000), who observed that in southern Kenya no effective opposition to cattle raiding exists among herding communities because of recurring clan warfare. While alluding to a similar ethnographic account in western Kenya, Anderson (1993: 865) observes that among the Kalenjin community, allegedly, the cattle-rustling activities of the *moran* (a Maasai word for warriors) are considered rather a 'sport' and not a crime. This kind of view locally legitimizes the practice of cattle raiding and

[5] Marsabit District Security Committee (DSC) Files; C. Sec. 2/1/5/IV/494 (1963: 2).

[6] 1997 figures (Barclay & Tavares, 2002). The Marsabit figures are underreported, because these only include violent deaths as a result of interethnic fights or raids (Gimode, 2001).

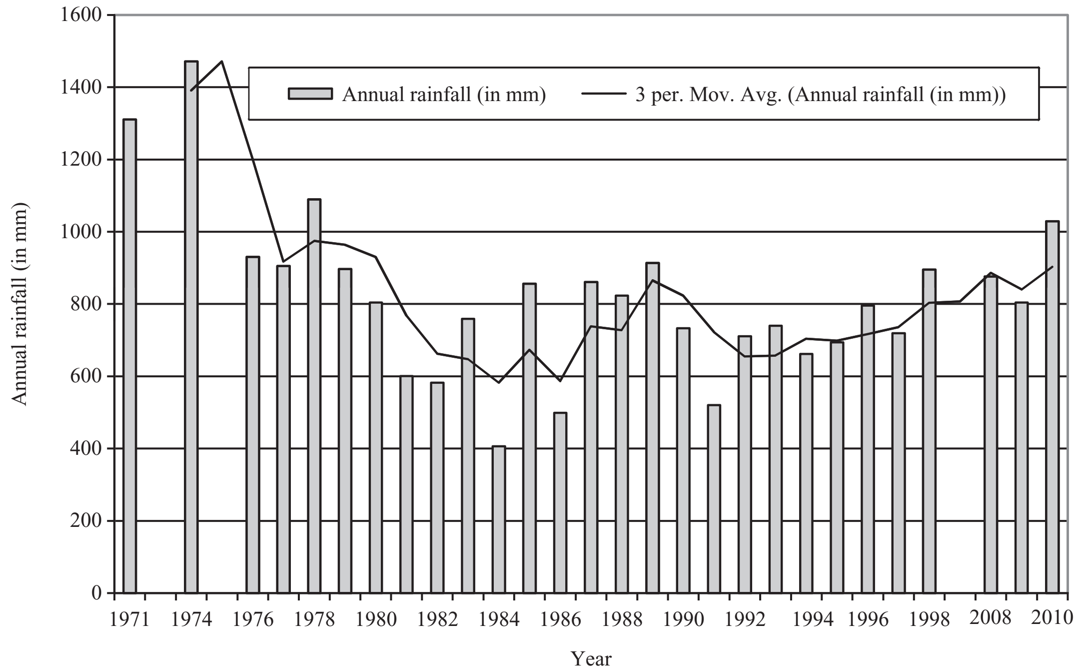

Figure 4. Rainfall trend for Narok, south western Kenya

functions as a training opportunity for young men to try out and perfect their raiding, and thus thieving skills. The culturally endorsed and socially rewarded raiding behaviour thus reinforces a climate of insecurity and lawlessness that is necessary to raid effectively, especially against certain groups in the absence of effective law enforcement. Thus it proves true that 'War is good for thieving' (Fleisher, 2000: 750) or that 'opportunity makes the thief' (Felson & Clarke, 1998).

Ingenuity in social institutions

The conflict in the Loita Maasai area of Narok District, southern Kenya, is a very illuminating one for our argument. The contested resource is the Loita Naimina Enkiyio Forest (LNEF or Loita forest hereafter), a source of water, dry-season grazing area and natural forest on the edge of the Great Rift Valley. The forest is used by the Loita Maasai, but coveted by the Purko Maasai, living to the north but still inside Narok District. In many similar cases in Kenya over the last few decades, ethnic groups or subethnic groups compete or sometimes fight over key resources for access, use of revenues or competing claims over ownership rights. Water resources and dry-season grazing in pastoral areas are the natural capitals triggering conflict when issues of access, usage rights and ownership are at stake. The Loita forest can be seen as a scarce resource, for which ethnic groups compete. However, due to its character, size and fixed location, and given the context of the Kenyan economy and political constellation, the Loita forest is also a resource for national actors. Not only the ethnic groups, but also their ministers want access for personal wealth. These two conflicts merge, and we describe the process chronologically.

The context is typical for Kenya and many other countries in Africa. The Kenyan population has increased rapidly, from 10.9 million people in 1969 to 38.6 million in 2009 (KNBS, 2010) and shows no sign of stabilizing soon. In Narok District, population growth has been even more rapid, with about a seven-fold increase over the same period. Already among the most densely populated semi-arid areas of Kenya, the pressure on land in Narok District has increased further with commercial wheat production taking large tracts of land away from use by pastoral producers.

In addition, climate change seems to have begun impacting this region too, and long-term rainfall figures show a decline in the western part of Kenya since the early 1970s, which is supported by (still scanty) data on precipitation in Narok and nearby Kajiado Districts. Droughts have become lengthier, the rainfall within the rainy season more variable. Figure 4 shows a clear increase in rainfall particularly in recent years in Narok District, but as this seems to coincide with higher temperatures and subsequent higher evapo-transpiration, the effect is a decline in the moisture balance.

The Loita forest is a fall-back area for the Loita Maasai and the neighbouring Purko alike and is therefore increasingly important for the survival of the pastoral production system. As a consequence, there is a slow migratory movement towards the forest, and the potential for conflict over future access rises. Although the previous case can be characterized as a study of short-term conflicts over seasonally scarce resources, this case provides a longer-term perspective on scarcity due to population growth, climate change and relative resource scarcity.

The Loita forest is set between the Nguruman-Magadi escarpment bordering Kajiado District to the east, the *Osupuko Oirobi* (Purko Maasai land) to the north, the border of Tanzania to the south and the rangelands towards the Maasai Mara National Game Reserve, the most famous tourist destination in Kenya, to the west. The Loita Maasai area encompasses a variety of ecosystems, of which the grasslands at lower altitudes and the Loita forest at higher altitudes form the dominant features. The forest is one of the few un-gazetted (i.e. with no legal restrictions of local access) and largely undisturbed indigenous forests in Kenya (Njogu, 2004). The Loita Hills, with the Loita forest, are the main water catchments for the surrounding lowlands. The forested highlands receive, on average, an annual rainfall of between 700 and 1,200 mm, while rainfall in the surrounding lower rangelands is at 600–700 mm. The wetland areas and, during extreme droughts, the upland semi-deciduous and mixed species forests form the ultimate fall-back grazing areas (Maundu et al., 2001; Dietz, 1996). During the extreme drought of 2005–06, almost all Loita Maasai herds were grazed within the forest.

The Loita Maasai community has an indigenous tenure system that gives use rights of natural resources to various groups in and outside the community. The Loita forest is a common-pool resource shared by many users for grazing, traditional cultural ceremonies, medicinal plants, construction materials and as a source of water. Certain resource types and uses are strictly controlled, while others are more freely accessible. For example, the forest has considerable spiritual and emotional value. Many transition rites and other important rituals and ceremonies take place in the forest, such as the age-set initiation and cleansing rituals and fertility blessings for women who are unable to give birth (Maundu et al., 2001). Because of all these usage practices, the Loita community sees the spiritual leader, the *Laibon*, who performs his ritual duties at specific sacred sites in the forest, as the custodian of the forest. He is central to forest conservation. The *Laibonok* (plural of *Laibon*) have unlimited rights and access to the forest to provide divine services to the wider Maasai society rather than for their own private gains (Karanja, Tessema & Barrow, 2002).

The Loita community shares the grazing land with the neighbouring Purko Maasai community and the Loita Maasai of Tanzania. As long as the boundaries of the territories are undisputed and resource use is mediated and regulated by customary laws, the sharing of seasonal pastures by the different Maasai sections poses no threat to any section. It is a reciprocal right used during emergencies and regulated by customary laws. In this case and depending on the season, the *Laibonok* and the herders have overlapping rights to use the forest, for cultural ceremonies and grazing, respectively (Ole Siloma & Zaal, 2005).

However, there has been a slow and continuous migration of Purko Maasai towards the Loita highlands for many decades now, starting early in the colonial period as part of early 20th-century upheavals.[7] The Purko population, being more numerous and living in slightly drier areas of Narok, had for some time been invading the forest and Loita area. The valleys leading into the forest were, and still are, slowly being occupied by Purko Maasai. This slow intrusion into Loita Maasai ancestral lands and into the forest is resented by the Loita Maasai who are frequently in conflict with the Purko migrants over illegal use of the forest, such as charcoal burning and timber production. The relationship between these two groups has been 'not cordial', to quote an interviewee. Yet, the Purko Maasai who live in those valleys maintain that as long-time residents they have the right to use the forest, especially when they claim access on the basis of belonging to similar clans that exist within both the Loita and Purko Maasai communities.

Collective rights versus rent-seeking behaviour over the Loita forest

The Loita forest is located on trustland (Maundu et al., 2001), which means it is entrusted to the local County Council of Narok and managed in accordance with the Trust Land Act (Cap. 288 of the Laws of Kenya). The

[7] The pressure on the grazing resources in Narok and Kajiado Districts had increased considerably due to the displacement in two successive moves of the Maasai community from the Central Kenya Highlands such as Laikipia, when white ranchers, supported by the colonial government, appropriated these areas. Within a decade, the population in Narok and Kajiado Districts almost doubled.

potential of the forest as a conservation area and tourist site has been a source of conflict among the different interest groups, notably the local community and the County Council. The local balance of power was further complicated when one of the most prominent leaders of the Purko Maasai, a minister in the Kenyan Cabinet, tried to generate support among local elected leaders (councillors of the Divisions of Narok District of which Loita Division is only one) to gazette the forest (i.e. restrict local access) and turn it into a forest reserve and national park. This would have expelled the present local users from the forest and would have allowed a few entrepreneurs to build lodges and generate private revenues from tourism. The Minister had a number of lodges in the neighbouring Maasai Mara District, and thus he clearly had the business experience and opportunity to take over the forest and build tourist facilities there.

The Purko minister had allied himself with a Loita Member of Parliament and a Loita councillor. The three men seemed to have agreed that the Loita forest was to be demarcated for gazettement, and the councillor drafted a letter incorrectly writing that the Loita people agreed to the gazettement decision. The intention to gazette the forest was communicated to the Minister for Environment.[8] This minister himself had benefited from a similar procedure, when a neighbouring group ranch had been demarcated and leased to him when he was still a Member of Parliament for a neighbouring constituency.

However, resistance began to build up, and the director of a regional development project, the Ilkerin Loita Integrated Development Project (ILIDP),[9] called a meeting of the Loita Council of Elders (LCE). The LCE had been installed earlier with assistance from the ILIDP project to organize the community. The LCE was constituted with the intention to have a broad representation of the population in the council. An important part of the intervention strategy of the ILIDP, this participation did ultimately lead to more relevant project work. Now, however, it also linked the population that started to resist the gazettement with the ILIDP, the senior elders, the elected councillors, the *Laibonok*, the development officers in the government, and some women and youth groups. Some of the LCE members were also on the Board of ILIDP, for example. The Narok County Council (NCC) was acknowledged at the time as being entirely justified in managing the forest and deciding on its future use, as the council kept all un-demarcated and un-gazetted land in trust for the benefit of the local population. Even so, the earlier loss of access to the Maasai Mara and Kamororo group ranch referred to above (Zaal & Ole Siloma, 2006), which was previously allowed by earlier council members and had benefited the Minister for the Environment, had made the ILIDP and LCE very concerned. Other similar cases included the destruction in previous years of the Mau forest, which is also a Narok forest area under NCC trusteeship.

The LCE resolved to organize a broad resistance movement. The Minister for Environment subsequently changed his mind and agreed to assist the Loita community. A lawyer established the Loita Naimina Enkiyio Conservation Trust (LNECT), a registered entity with the primary duty to protect and manage the forest and its associated ecosystem heritage held in trust by the local Narok County Council.

Of course this merits the question whether, as a non-legal institution informally representing the population, the LCE was in a position to organize resistance against a formal and lawful institution such as the Narok County Council, which had the responsibility by law to decide on the future of the forest.[10] However, the timing of the conflict is worth considering in the context of Kenya's history. The first truly democratic elections were to be organized in 1992, and at the present stage of the conflict, the NCC could hardly be considered truly

[8] This is according to Kenyan law. As stipulated in the Forests Act (Cap. 385), a minister has among others the powers, by notice in the Gazette, to either declare or alter the boundaries of a forest (Government of Kenya, 1982).

[9] ILIDP was started in 1968 as the initiative of a local Loita leader and a Dutch Catholic Missionary. Support came from Dutch Catholic development NGOs. The conflict coincided with a period in development thinking in general, and within this organization in particular, that promoted empowerment, advocacy and networking as strategies for development. Two decades after it was founded, ILIDP was confronted with the Loita forest conflict which a decade later was successfully solved.

[10] In a recent landmark ruling, the African Commission found the Kenyan Government guilty of violating the rights of the Endorois community living around Lake Bogoria by unlawfully evicting them from their ancestral land in order to create a protected area (CMRD, 2010). Two of the views of the African Commission in support of the ruling have relevance to the Loita example. First, the recognition that the state has a duty to ensure that indigenous sacred places, linked to cultural beliefs and practices, and ceremonial acts that are central to freedom of religion, be preserved, respected and protected. Second, the State is to apply international law concerning the protection of indigenous people's collective rights to lands and natural resources as a community, even in the absence of official title deeds to a particular territory. These aspects would support the Maasai community in defending their ownership rights to the local resources.

democratic in a representative and multi-party democratic meaning of the word. The conflict had erupted meanwhile, and protesters and those who wanted to appropriate the forest confronted each other violently. On one occasion opposite the ILIDP facilities in Narok Town, some people were killed when police started shooting prematurely (Dietz, 1996).

The Loita Naimina Enkiyio Conservation Trust (LNECT) took the matter of the appropriation of the forest to court. In this court case, many found it very difficult to choose sides. Conflicting points of view became apparent within the Loita community (groups were divided along clan lines according to their Purko or Loita background, and old and young also often disagreed).

So far, traditional institutions (age groups, *Laibonok*) and modern organizations (the ILIDP, LCE and LNECT) had joined forces to fight against the Purko and their Minister for control over the Loita forest. The national elections gave the opportunity for both factions to present their views and drum up support. Within the Loita community, councillors supported by the ILIDP faction were better positioned to win this election. One item that came up for public scrutiny was the letter that the Loita councillor had written stating that the Loita people were supportive of the gazettement. This and many other issues ultimately led to the political demise of the councillor who lost the election. A new Loita councillor took charge, split his constituency[11] and had four other Loita councillors elected. This considerably increased the representation of Loitans on the Narok County Council, and when a Loitan was elected as chairman of the NCC, the political clout of the Loita community in the NCC had improved. The power balance had shifted between the national elections of 1992 and the last years of the 1990s. The earlier councillor and the minister lost control in Narok District. On the instigation of the new Loita councillors and the chairman of the NCC, the case was withdrawn from court. The Loita forest did not gain the status of national park, but remained open for use by the Loita community. A decade-long conflict had ended.

The Loita forest case shows that individual actors can be quite influential in how conflicts start and develop, but the actual course that conflicts take and play out is ultimately determined by larger forces. The underlying tension between Purko and Loita Maasai, dating back to well before the colonial period but strengthened by colonial policies of population displacement and boundary establishment of the Districts in which they lived, proved to be a fertile ground both for Purko players to gain control and for Loita players to resist this usurpation. More modern sets of legal entities, both elected and non-elected, have been added to this sphere of conflict. The present status quo could not have been reached without a modern judicial institution, used successfully by the Loita Maasai through legally authentic institutions such as development projects and a re-established informal Council of Elders. This fascinating case shows that old ethnic and subethnic conflicts between Maasai groups over a key resource can be peacefully contained through complex and unexpected alliances.

The Loita forest case shows that with increasing pressure on resources due to population growth and drought impacts of climate change, there are opportunities for moderation of potential conflicts. This evidence offers an important starting point for recognizing the importance of local knowledge and norms in crafting cooperative, nonviolent solutions in collective actions. This case also shows that old institutional arrangements can link up with new institutions and organizations to achieve this moderation. Within a changing and interconnected world, new threats in the form of commercial interests arise. To counter this, new local-level alliances are formed to deal with potential conflict over a common-pool resource, turning resource abundance into a blessing.

Spaces of violence

Violence itself creates a space of insecurity and lawlessness. It attracts individuals who thrive in insecure environments where there is little or no effective state control (Schlee, 2002, 2008; Salih, 1999). Insecurity also prevents the entry of peaceful individuals, firms and organizations to settle or invest locally. In addition, flows of people, goods, information, money and weapons involved in violence either directly or indirectly are generated. Insecurity transcends the region and makes situations conducive for thieving and other predatory forms of involvement of outsiders (Felson & Clarke, 1998).

Borders play a role in this process. In a raid, tracing raided livestock is more difficult once it has crossed a border. In a globalized world, rebel or guerrilla movements with international support networks look for sparsely populated areas for their training camps and their trekking routes. They also provide recruitment grounds for unemployed youths whose bravery and courage can

[11] This was implemented after discussions with the relevant authorities in Kenya at national level. Support was sought from the Office of the President which influenced this decision.

be exploited and cultivated in places far from the centre. In addition, violence and insecurity reduce people's capacity to cope with drought, to educate their children properly, to market their goods and to use land intensively and effectively. As a result, insecurity and violence deny components of economic and other forms of development and the opportunity to respond to peoples' needs, thus preserving the state of poverty. Insecurity and conflict in drylands have hampered provision of and access to basic public services such as health care and education. In the words of Sen (1999), these issues obstruct the development of people's capabilities. The negative economic consequences therefore have wider spillover effects, and the relationship between violence and poverty centred on exactly these issues. It is not that poor people are more likely to use violence. But, a situation of insecurity denies new and innovative ideas the chance to develop, which in turn leads to loss of opportunities for economic growth.

A study of violent relationships between growing numbers of humans and their struggle for access to natural resources influenced by climate change should not *a priori* have a structural or an agency approach. A structural approach tends to ignore all the personal decisions and the opportunistic behaviour of individual actors, while an agency approach does not take pathway-dependent structural variables into account. As the case studies described above clearly show, there is a need to combine both aspects.

Our conclusion is that the wetter the season, the more people are likely to die in violent livestock raiding. In other words, more conflicts and killings take place in wet season times of relative abundance, and less in dry season times of relative scarcity, when people reconcile their differences and cooperate. During drought periods, pastoralists in northern Kenya deploy social institutions that mediate agency toward cooperation and guarantee access rights to resources (water) for all, thereby reducing violent conflicts. Remoteness and inaccessibility of the terrain weaken government initiatives to provide adequate security, but local arrangements moderate conflicts when scarcity peaks. The absence of overt violent conflict in Marsabit is clearly not due to lack of scarcity, which is a common feature of marginal and deteriorating environmental conditions.

In the Loita forest case, a fast-growing pastoral population mobilized against neighbouring ethnic groups with high-level linkages to the national government in order to secure access to a typical common property resource that was of vital importance to their livelihood. Individual and group actors made clever use of institutions to win a conflict over resources nonviolently. The Loita forest did not become a resource curse, because a mixture of old and new institutional arrangements prevented it from being grabbed by a collusion of competing pastoralists and a few rent-seekers. The range of benefits from the forest's functions and financial revenues are now used and shared by a large number of producers. The results reveal a rare insight into the importance of hybrid customary-cum-legal institutions and ingenuity as to whether or not a common-pool resource becomes a curse. Therefore, human agency ultimately determines whether natural resources turn into a curse, but we need the historical contextual analysis of institutional structures to inform us about the potential threats and opportunities. Equally, in a scenario of climate change when the potential threats to the environment are known, coping largely depends on the institutional devices invoked by local actors. When northern Kenya indeed receives more rain in the coming century, as predicted by the IPCC report, we may expect more violence in the short term. However, we may also expect the technological and institutional change and flourishing ingenuity that usually ensue from higher population numbers and increased scarcity. When south-western Kenya indeed becomes dryer, we may expect increased competition for forest resources. Yet, institutional development may address the need for conflict resolution. Inaccessibility, remoteness and marginality may be reduced under such a scenario, and this will make the environment a less attractive place for violent behaviour.

From each of the two case studies emerges the significant role of institutions, be they traditional or 'official', in preventing avoidable conflicts and allowing reconciliatory situations to prevail within competing interest groups and between rivalry communities in Loita and Marsabit. The turning of natural resources into either a blessing or a curse depends on the community shaping and using its own institutional apparatus, and doing this within its historic institutional context. Thus, in areas where certain key resources are either scarce or abundant and climate is changing, the local institutional arrangements can be instrumental in moderating resource-related conflicts.

Replication data

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Climate clashes? Weather variability, land pressure, and organized violence in Kenya, 1989–2004

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Abstract

The evidence of coming climate change has generated catastrophe-like statements of a future where a warmer, wetter, and wilder climate leads to a surge in migrant streams and gives rise to new wars. Although highly popular in policy circles, few of these claims are based on systematic evidence. Using a most-likely case design on Kenya 1989–2004, with new geographically disaggregated data on armed conflicts below the common civil conflict level, this study finds that climatic factors do influence the risk of conflicts and violent events. The effect is opposite to what should be expected from much of the international relations literature; rather, it supports the observations made by recent anthropological studies. Years with below average rainfall tend to have a peaceful effect on the following year and less robustly so for the current year as well. Little support is found for the notion that scarcity of farmland fuels violence in itself or in election years. More densely populated areas – not areas with a low land per capita ratio – run a higher risk of conflict. Election years systematically see more violence, however. The findings therefore support the notion that large-scale intergroup violence is driven by calculation and political gain rather than desperate scrambles for scarce land, pasture, and water resources.

Keywords

climate change, elections, Kenya, land, resource scarcity, violence

Introduction

> There is one issue I want to raise, general to all. Water. Water for livestock, water for people. They go into conflict because water is not available. If we had water we could start sorting out the conflict. A lot of fighting is over water availability. (Elder from the Jie group in Uganda, cited in Mkutu, 2008: 14)
>
> The threat from climate change is serious . . . more frequent drought and crop failures breed hunger and conflict. (Obama, 2009)

The two statements above, one from a person of a marginalized group, the other from arguably the most powerful person in the world, both posit a clear link between resource scarcity and conflict. They also fit nicely into the popular narrative on sub-Saharan Africa as a desperately poor continent without sufficient food, water, or livelihoods for its growing population. In a nightmarish account of Africa, Kaplan (1994) pointed to high rates of population growth and allegedly unsustainable resource utilization as two main factors behind the development failure of several African states. This so-called 'crisis-narrative' (Roe, 1995) has also been used to explain why civil or intergroup violence breaks out and why civil violence is more prevalent in less developed countries. Add to this the recent debate on the future consequences of climate change, and this neo-Malthusian explanation should be as relevant as ever. For instance, a recent report by Safeworld (2009: i) argues that in the 2009 drought in East Africa:

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> There seemed a clear correlation between the scarcity of natural resources resulting from the drought, and violent conflict. In the context of growing awareness and concern about global warming, this inevitably prompts the question as to whether Kenya's prolonged drought was a consequence of climate change – and to what extent therefore climate change will lead to an increase in violent resource-based conflicts.

Several scholars also attribute intergroup violence in Kenya to scarce renewable resources. Dietz (1987) and Mkutu (2008) claim a strong link between drought and pastoral violence, whereas Kahl (2006) suggests that violence in the central parts of Kenya in election periods is heavily influenced by competition over scarce farmland. However, the link between scarce resources and conflict is contested in general (Peluso & Watts, 2001; de Soysa, 2002), as well as in the particular case of Kenya (Witsenburg & Adano, 2009).

In the following I will first demonstrate why Kenya is a critical case in analyzing the potential links between scarce renewable resources and violent conflict. Thereafter, I review the existing research on resource scarcity and armed conflict in general and on Kenya in particular. Subsequently, I outline my research design before I present and discuss my findings. My findings indicate that relatively dry years tend to have a peaceful effect on the following year. Little support is found for the notion that scarcity of farmland fuels violence in itself or in election years, but an election by itself increases risk. More densely populated areas run a higher risk of conflict, but this is not due to pressure on cropland; rather, it is likely to be driven by other mechanisms that put densely populated areas at risk.

Why study Kenya?

In a region where four out of five neighboring countries have experienced some of the longest and bloodiest civil conflicts in Africa, Kenya's civil peace offers at first glance a peaceful contrast. Except for the brief violence associated with the failed 1982 coup attempt and the irredentist Shifta war in the North-Eastern Province immediately following independence, Kenya's post-independence period has been free of insurgent movements. However, the country has seen several quite bloody episodes of interethnic conflicts and state repression, the latter mostly taking the form of groups supporting the incumbent attacking civilians suspected of supporting the opposition. The lack of a large-scale civil war in Kenya eliminates the possibility that interethnic violence is simply a spillover from a civil war, for instance as a power-struggle along ethnic lines within a rebel movement. Other factors not directly related to civil war dynamics are likely to be at center stage. Of course, this does not mean that civil conflict dynamics are absent, since conflicts in its neighboring countries are frequently seen as influencing violence in Kenya (Mkutu, 2008). This lack of an insurgent movement is the first reason for using Kenya as a suitable case when studying the links between scarce resources and conflict.

Kenya's sluggish economic growth has been partly blamed on its population growth rate and the lack of available farmland to occupy the growing population (Markakis, 1998: 95). Whereas the economically most productive regions were peaceful until 1991, the northern and eastern districts have seen persistent intergroup conflicts since the pre-colonial era (Kimenyi & Ndung'u, 2005). Most of the time this has taken the form of one group fighting another with the occasional involvement of state forces.[1] With the announcement of multi-party elections upcoming in 1992, this pattern changed as interethnic violence flared up in Bungoma and Trans-Nzoia districts in late 1991. Unrest spread across Rift Valley Province as prominent politicians within the regime incited, trained, and paid KANU supporters to attack opposition supporters and claim the land as theirs (Roessler, 2005). The violence subsided slowly from 1993 to 1995, only to resurface on a smaller scale on the coast before the 1997 elections. While the 2002 elections were calm, the period leading up to and immediately following the 2007 elections saw renewed bloodshed in central parts of Kenya. Politicized land conflicts, allegedly over disputed land-resettlement schemes in Mt Elgon district, led to the formation of the Sabaot Land Defense Force, which committed several atrocities in the 2006–08 period (Simiyu, 2008). Thus, it has been argued that much interethnic violence is driven partly by land scarcity, as Kenya's economy and growing population is highly dependent on agricultural produce.

The violence in Kenya's drylands is also frequently explained as stemming from conflicts over other scarce resources, such as pasture and water sources, an explanation refueled by the debate on climate changes. Several anthropologists and economists claim a strong link between drought and conflict (e.g. Burke et al., 2009;

[1] In the notable cases of the 1980 Bulla Kartasi Estate massacre (Garissa) and the 1984 Wagalla massacre in which several hundred Degodia Somalis are said to have been slain on Moi's order, and the violence associated with the de-facto annexation of the Ilemi triangle (now Kibish division in Turkana) in 1988, the state was the main agent of the violence and killed a large number of civilians.

Dietz, 1987; Miguel, Satyanath & Sergenti, 2004; Mkutu, 2008). The arguments relating land scarcity to the election violence (Kahl, 2006) and about pastoralist conflict during and after drought and in the dry season make the country a very well-suited case for a study of the relationship between resource scarcity and conflict. Some have argued that resource scarcity is a more plausible driver of smaller conflicts than of full-blown civil wars (Barnett, 2001; Suliman, 1999). Since Kenya has experienced several intergroup conflicts, it is an excellent test case. Moreover, many of the hypotheses in the environmental security literature are based on cases from Kenya (e.g. Kahl, 2006; Mkutu, 2008). Studying one country also implies that country-specific factors do not affect the observations differently. Among the large number of suggested factors linking resource scarcities conditionally to conflict in the environmental security literature (Homer-Dixon, 1999; Kahl, 2006), Kenya exhibits several, such as a low degree of economic development, high ethnic barriers, societal inequalities, an unstable neighborhood, and contested elections. Even though it is impossible to generalize from a single case, testing a case where the theory should apply best could tell us more about the applicability of the theory in general. This is what Lijphardt (1971) refers to as a 'fitting' case study.

Theory and hypotheses

Scarce renewable resources and armed conflict

As already noted, politicians and NGOs have repeatedly claimed a strong link between climate change and violent conflict, but rarely with reference to existing scholarly work. Environmental security scholars such as Homer-Dixon (1999) and Kahl (2006) arguably form the scholarly tradition that most generally links scarcity of renewable resources to armed violent conflict. They argue that social consequences of environmentally-induced migration, soil degradation, droughts, floods, and other natural disasters, as well as more slow-moving processes such as decreased land productivity due to population pressure, can cause social processes that again can lead to violent conflict.

Homer-Dixon's (1999) tripartite concept of *environmental scarcity* relates to the supply, demand, and distribution of a resource. When *environmental scarcity* is sufficiently acute it can lead to chronic poverty which, in turn, can lead to violence. Homer-Dixon emphasizes that environmental degradation and absolute scarcity are, to a large extent, exogenous to social processes, and that economic, cultural, and political institutions are partly endogenous to scarcity. It is therefore appropriate to treat demographic and environmental factors as independent variables, and social variables such as migration and conflict as dependent variables. Although Homer-Dixon's model refers to renewable resource scarcity in general, he claims that the importance of climate induced scarcities will become more pronounced in the future.

During the last five to ten years, a number of large-N analyses have tested relationships between inter-year climatological variability and violence. Miguel, Satyanath & Sergenti (2004) as well as Hendrix & Glaser (2007) find that negative rainfall shocks either directly – or via economic shocks – increase the risk of civil armed conflict. Jensen & Gleditsch (2009) criticize Miguel et al.'s (2004) operationalizations. However, they find a significant although weaker and less robust effect of rainfall. Furthermore, Ciccone (2011) shows that earlier findings on rainfall and conflict, using percentage change from one year to the next as the measure of drought, are sensitive to changes from a relatively wet year to a normal year. What might appear to be a drought could simply be a regression towards the mean. Thus, to date there is little robust statistical evidence linking lower rainfall to civil armed conflict. In a recent study, Burke et al. (2009) find that sub-Saharan countries run a significantly and substantially higher risk of experiencing civil conflict onsets in warmer years. However, Buhaug (2010) shows that their findings are quite fragile. Accounting for the importance of local geographic, climatic, and socio-political factors, Theisen, Holtermann & Buhaug (2011-12) use data on subnational units for Africa and find no relationship between drought and civil conflict onset. The lack of robust findings on the relationship between climatic factors and conflict can be due to the fact that almost all studies to date have looked at civil conflict, that is, insurgencies against the state. As argued above, several scholars argue that scarce resources should be more relevant in generating smaller more local conflicts than civil or intrastate wars (Barnett, 2001; Suliman, 1999).

A few studies have systematically analyzed whether drought influences the risk of pastoral conflict. Meier et al. (2007), studying the border areas between Uganda, Kenya, Sudan, and Ethiopia over two years, find that periods with more abundant vegetation experience a higher incidence of raids and no link between rainfall deficiency and violence. Taking a longer-term perspective, Witsenburg & Adano (2009) analyze the Marsabit district in Kenya and find that wetter years see on average more than twice as many killed than do drier years.

Thus, empirical studies on local violence so far have lent little support to the notion that droughts fuel violence.

Like the cross-national analyses on the climate–conflict nexus, cross-national analyses on land pressure and conflict have generally failed to find support for such a linkage (Salehyan, 2008; Theisen, 2008). In single-country analyses there is more support. Testing the effect of land pressure on routine and episodic violence in Indonesian provinces, Østby et al. (2011) find no effect, but they do find some interactive effects between intergroup inequalities and population growth on violence. Similarly, Urdal (2008) finds some evidence for a link between rural population density and conflict in India. Looking at land scarcity, distribution, and violence in a Rwandan community for the period 1988 to 1995, André & Platteau (1998) find that a decreasing land per person ratio combined with rising inequalities and low off-farm employment opportunities increases tensions considerably. What empirical support there is for the resource scarcity viewpoint can be found in statistical studies of single countries rather than in global or regional studies. Before I proceed to conduct such a test, I will have a closer look at the proposed causal linkages between scarce resources and conflict for Kenya.

Droughts and violence

The arid and semi-arid lands (ASALs) of Northern and Eastern Kenya are predominantly inhabited by pastoralists. Districts such as Marsabit, Turkana, and West Pokot see persistent cattle rustling followed by cycles of revenge – indeed it is very rare that a year goes by without reports of members of different groups killing each other. Groups in much of Northern Kenya and the border areas of Uganda, Sudan, Ethiopia, and Somalia are involved in similar interaction patterns that oscillate between cooperation and cycles of violence. In these areas the population depends on the bimodal rainy season for their livelihood. A drought can have devastating effects on herds, frequently leading to migration to wells and rivers that members from different ethnic communities have to share. As pointed out by Witsenburg & Adano (2009: 515) and Meier, Bond & Bond (2007: 721), the direct reliance on rainfall and the persistence of violence in drylands dominated by pastoralists give the linkage between climate factors such as droughts and violence some face validity. The suggested mechanisms are not always well understood and some are partly contradictory.

Reuveny (2007) has argued that climate change-induced migration can cause violence under certain circumstances. McCabe (2002: 130ff) describes being attacked by Pokot raiders while trekking with a Turkana family southward to dry season pastures in the borderlands between West Pokot and Turkana districts during an extreme drought. The Turkana took the risk of being raided due to the relatively good dry season pastures. The family lost two herders and over 100 small stock. It was not competition over scarce pasture or water that caused the raid, but the fact that the drought brought Pokot and Turkana into proximity of each other, thus facilitating raiding by the better armed Pokot. Echoing this, Mkutu (2008) argues that tension is frequently fuelled by the migration to pasture in dry periods, which involves crossing into another group's area.

However, dry periods could also potentially reduce the risk of conflict as they are found to have a clear impact on the relative prices of vital commodities in pastoralist areas of the Horn of Africa. Hence, they also reduce the economic value of the raiding output. During one drought the price of a goat fell from approximately USD 20 to 5 (GOK, 2000). Due to difficulties of finding water and pasture for the herds, the price of cattle drops in drier years, whereas the prices of grain necessary for survival rise. The same tendency can be found in other pastoralist areas in the Sahel belt (see, for instance, Legge, 1995 on Niger). Droughts also thin the vegetation that provides camouflage for rustlers (Meier, Bond & Bond, 2007; Witsenburg & Adano, 2009), increase labor time in herding cattle for pasture and water, reduce the ability of cattle to sustain longer treks, and prolong the visibility of cattle trails (Witsenburg & Adano, 2009). Thus, our expectations as to whether droughts should increase or decrease the risk of conflict depend on whether cattle raiding should be seen as an activity where the aim is to gain assets, whether it should be seen as straightforward conflicts over scarce resources, or whether droughts simply and indirectly increase the risk as implied by the Turkana study by McCabe (2002) by increasing interaction between groups. In short, the issue is whether violence should be seen as opportunistic calculation or as a sign of desperation. Although the argument based on rainfall deficiency is arguably most relevant for the ASALs of Northern Kenya and cattle-raiding related conflicts, violence in southern Kenya has also been argued to be over scarce river water during drought (Homer-Dixon, 2007). In light of the contrasting expectations and findings in the literature on droughts and violence, two competing hypotheses can be derived:

H1a: Drier years see more conflicts and events.

H1b: Drier years see fewer conflicts and events.

Violence does not necessarily take place where the droughts occur, but could occur in less drought-prone areas close to the droughts if migration or similar processes are at play. Hence, an alternative hypothesis can be put forward:

H2: A shorter distance to drought increases the risk of conflict.

Since Burke et al. (2009) have argued that warming fuels conflict, I also test:

H3: Warmer years see more conflicts and events.

Land, elections, and violence

Kahl (2006) stresses that political factors alone cannot explain electoral violence in Kenya – they must be complemented by an explanation that takes into consideration demographics as well as natural resources. Feeling threatened by political liberalization, segments of the Moi regime capitalized on environmental, demographic, and historical grievances by fuelling violence in densely populated and agriculturally rich areas in order to stay in power after the 1992 elections:

> The overcrowding of the violence-affected areas is obvious ... The end result of rapid population growth, environmental degradation, and unequal land distribution was thus an increasingly fierce competition between individuals and social groups for arable land. (Kahl, 2006: 138)

Mueller (2008) echoes this, claiming that resentment towards non-KANU groups in the Rift Valley among Moi's supporters was growing due to landlessness and a feeling of marginalization. Given the prominence of the land-pressure question in arguments on violence in LDCs in general and Kenya the following hypothesis should be tested:

H4: Areas with a low land per capita ratio run a higher risk of experiencing violence.

Oucho (2002) argues that this violence in central Kenya has taken the form of ethnic cleansing as smaller ethnic groups have called for ethnically homogenous constituencies and regionalism – so-called 'majimboism' – in fear of being dominated by larger ethnic groups. This becomes evident when political competition heats up around elections.

Land and elections are therefore frequently linked in generating violence, as in the case of the 2007 elections (Tostensen, 2009). Bates (2008) concurs, arguing that violence between the Kikuyu and KANU-affiliated groups in the time up to and after the 1992 elections was a result of militias being built around politicians as they 'sought to build reputations for being able to defend rights to land'. As Mueller (2008: 190) puts it: 'mobilizing resentment against outsiders [non-KANU] over land dovetailed with the self-interest of local elites and with efforts to ensure Moi's political survival after 1991'. If land-based grievance has been used as a political instrument up to and following periods of heightened political competition, it could be expected that:

H5: Areas with a low land per capita ratio run a higher risk of experiencing interethnic violence in election years than other areas.

The stories of election-related violence in Kenya point to ethnicity and political competition as central factors (see Kasara, 2010). Although this is obviously a highly relevant topic, the scope of this article will not permit an analysis that would do justice to these factors. Ethnicity is therefore only treated as a control variable in this study.

Research design and analysis

Data on intergroup violence in Kenya

To date there exists no dataset with time-series information on intergroup violence in Kenya. The logical starting point for gathering information on ethnic violence would at first glance be police records or other official statistics. However, as Bocquier & Maupeu (2005) point out, in Kenya there is no extensive database that records all deaths. Police archives for the last 30 or so years are almost completely inaccessible. Their solution is to use the relatively free and independent press in Kenya to generate a dataset on violent deaths. Similar approaches have been employed by, among others, Varshney, Tadjoeddin & Panggabean (2008) to collect information in Indonesia on violence from the level of civil conflict right down to the level of routine violence.

Since the focus is on large-scale violence, I chose to follow Varshney, Tadjoeddin & Panggabean (2008) by not including violence between two individuals unless it triggered a larger group clash. What is covered is violence conducted by a group on another group, as well as violence by the state or state actors on a group or on civilians.[2] As news reports, particularly from the Northern districts bordering Sudan, Ethiopia, and Somalia, can be sparse and the most violent cases are much more likely to be reported, I set a lower limit on violence that generated 25 deaths in a calendar year.[3] If one incident resulted in 25 or more killed but there were uncertainties with one of the parties, I included the conflict as long as it did not overlap in time or space with another incident or conflict. The dataset includes other forms of violence than exclusively group on group violence. In addition to so-called communal conflicts, it also includes state violence against civilians/militias[4] and state-sponsored violence via non-state actors towards civilians. The dividing line between what is state-instigated violence, what is exclusively communal warfare, and what is repression by police or other state forces is hard to draw. For instance, conflicts involve fighters from other countries' insurgent or government armies – UPDF fighters together with Karamojong (these UPDF soldiers might very well be ethnic Karamojong) and Oromo Liberation Front and Ethiopian forces along the Ethiopian border. Here the lines between acting as a soldier for the state, acting on behalf of a group interest (more or less altruistic), and one's own self-interest can be blurred. It is hard to justify an objective criterion that distinguishes between different forms of violence. I have therefore chosen a quite inclusive criterion. The only event that generated 25 or more deaths in the study period that is left out is the Al Qaeda attack on Nairobi in 1997. I used the Factiva database as a starting point and supplemented it with material from scholarly work and NGO reports to generate the dataset. My dependent variable *conflict* is simply the first event of a conflict that generated at least 25 deaths in the same year. The other dependent variable is each recorded event for the conflict. This means that

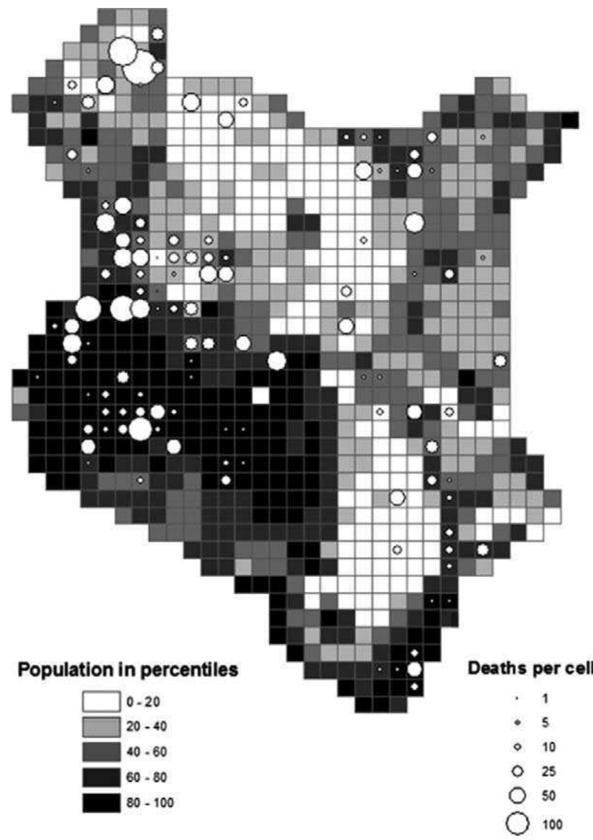

Figure 1. Population and conflict events, 1989–2004

events with less than 25 killed are included as long as they are part of a conflict that killed 25 persons that year. Events that are not part of a conflict pattern that in total do not generate 25 deaths in a year are not included. Both *conflict* and *event* are dichotomous variables, although I performed extra robustness checks using the count of events in a cell per year. I recorded the most accurate location of each event and assigned geographic coordinates. In cases where no exact location could be assessed, I assigned it to the administrative unit of the lowest order that could be identified. For an illustration of where the events occur in relation to population density, see Figure 1.

Research design

My analyses are for the years 1989–2004, as my measure of rainfall is limited up to 2004. There were in total 47 separate conflicts (counted by year) in this period, and 172 separate cell-years that include events. I use a grid fishnet of 0.25° by 0.25° resolution. I use artificially imposed cells rather than political-administrative units or ethnic group areas for three reasons mainly. Firstly, there is a huge variation in size between districts, and the same is the case for areas defined by ethnic

[2] Police killings of criminals or civilians are not included unless there is a clear ethnic or organizational overtone (such incidents rarely lead to more than 25 killed anyway). The General Service Units (GSU) frequently intervene to curb cattle rustling between communities. Such incidents are included.

[3] As Bocquier & Maupeu (2005: 334) put it, 'The press not only underreports violent deaths, its reports are also biased towards the most extreme events.'

[4] The two instances in the dataset of state repression that was not provoked by some violent prelude with an interethnic element are the repression of the Saba Saba demonstrations in 1990 and the KANU-regime's use of police and KANU-supporters against the opposition in Central Kenya in 1997.

characteristics. Secondly, in Kenya administrative as well as ethnic borders are in themselves analytically interesting in explaining violent conflict, and therefore not suitable as units of analysis studying violence. For instance, Kasara (2010) has shown that the growth of districts in Kenya is influenced by electoral competition. In contrast, artificial grid cells are not affected by political processes on the ground. Finally, modeling dependence between observations is more straightforward in a set-up with uniformly shaped units.

Independent variables

Rainfall deficiency. Geo-referenced precipitation data were derived from the Global Precipitation Climatology Centre of the World Meteorological Organization (Rudolf & Schneider, 2005) and contain annual estimates of total precipitation (mm) for the global land surface at 0.5° resolution for all years, 1989–2004. I test three operationalizations of rainfall shortage. I follow Hendrix & Salehyan (2012) in operationalizing rainfall deviation as the percentage deviation from mean rainfall in the cell in year *t* divided by the panel standard deviation.[5] Large parts of Kenya are susceptible not only to annual aberrations in rainfall patterns but also intra-annual deviations from the norm causing droughts in 'normal' years, with profound consequences for livelihoods (McCabe, 2002). In order to capture both inter- and intra-annual deviations from normal precipitation, I employed the Standardized Precipitation Index, SPI6. The index is based on an aggregation of monthly aberrations from normal rainfall during the six preceding months and then given an index value. These running monthly values are then aggregated to a yearly format (McKee, Doeskin & Kleist, 1993), coded as a dummy for at least a moderate drought in the year of observation. In order to tap whether violence occurs near droughts but not necessarily exactly where droughts occurred due to migration and related processes, I also used a measure that gives the distance in kilometers to the nearest drought.[6] All precipitation measures were tested for the current and previous year. Since the data are only available in a 0.5° by 0.5° resolution, this resulted in less than desired spatial variation for my 0.25° by 0.25° cells.

Temperature. My measure of temperature is the CRU TS 3.0 data from the University of East Anglia (CRU, 2008). These data contain annual estimates of temperature (Celsius) for the global land surface at 0.5° resolution for all years, 1989–2004 (Mitchell & Jones, 2005). The assumption is that the higher the temperature the drier the cell, all other things being equal. The operationalization and resolution is the same as for the deviation in precipitation measure.

Population density and land pressure. My measure of population density is the Gridded Population of the World dataset, Version 3 (CIESIN, 2005) aggregated up to the 0.25° cell size which gives the cell-specific estimates of population size for 1990 and every five years on. I interpolated the trend between each data point and extrapolated the values for 1989. Since population density is not a precise measure of land pressure, I generated the share of a cell with intensive agriculture in order to test Hypotheses 4 and 5. The data are derived from 1980 Landsat data by JICA, National Water Master Plan, Kenya (1987), accessed at ILRI (http://192.156.137.110/gis/search.asp? id=288). The dataset contains information on land use classified in 14 classes. Dense agriculture (11) and plantation (13) represent intensive agriculture. The cell values are the share of the cell's landmass that falls into either of these two categories. As an alternative measure I derived the land of a cell that is defined as cropland by WRI (2007). To obtain a measure of population pressure, both the intensive agriculture and cropland measures were normalized by the population count in the cell. The measures for population per cell and cropland per capita have been divided by 1,000 to ease interpretation.[7] Since large parts of Kenya are too dry for crops and therefore would get zero or very low values on these land-scarcity measures, I include a dummy for cells with an average annual precipitation of less than 700 mm, the conventional threshold for semi-arid land. Since largely urban regions with non-agricultural economies may get 'false' low land to person ratios, I employed a dummy capturing the cells containing Kenya's towns with over 100,000 inhabitants.

Control variables. The most fine-grained and suitable dataset on ethnic groups in Kenya is the Ethnologue v.16 dataset (Lewis, 2009). From this dataset I generated two dummies, one capturing whether a cell harbors two groups, the other three or more groups to allow for an elevated risk of greater ethnic heterogeneity. Both

[5] This goes for all my deviation measures.

[6] Divided by 1,000 to get readable regression results.

[7] Agricultural land per capita was multiplied by 1,000 and the interaction between cropland per capita and election by 1,000,000, to ease interpretation.

boundaries between ethnic groups and overlapping ethnic areas are taken into account. The election variable is a dummy for the years 1992, 1997, and 2002 in which Kenya had parliamentary elections.

Poverty is one of the most central factors explaining civil violence, but less is known for other forms of organized violence. To capture the effect of poverty, I used the 1999 estimates of the so-called poverty density, which is the proportion of the population living below the poverty line[8] per square kilometer (CBS, 2003). The data were aggregated from the mean poverty density for polygons within each cell. As the poverty density closely follows population density, the values were normalized by the population in the cell in 2000 to get an approximation of the proportion of persons in a cell who live below the poverty line. The original data for most of Kenya are at the location level (CBS, 2003), whereas for North-Eastern Province the data are at the Constituency level (CBS, 2005).

In order to control for temporal dependence I created a variable capturing the time since last violent event for each cell (Raknerud & Hegre, 1997), operationalized as a decay function with the risk of conflict halving approximately every half-year. Since unmeasured geographic variables could affect the conflict risk, I generated a measure capturing the share of neighboring cells up to the third order that experienced an event the previous year. This is similar in approach although not identical to the measure used in Hegre, Østby & Raleigh (2009).

Results[9]

Table I shows the results from the effect of climate factors on the risk on conflict. Model 1 shows that a positive deviation in precipitation from the period mean in the current year is negatively related to conflict, that is, drier years are marginally more at risk of conflict, but this is far from significant. To test whether an abnormally wet or dry year runs a higher risk of conflict, I included a squared term for precipitation, both in the current year and the previous year. Model 1 shows that there is no such curvilinear tendency for conflicts for the current year. The results for the lagged rainfall deviation variables indicate that the linear term is negatively related to conflict, whereas the squared term is positively related to conflict, but neither of them is significant. The two terms are highly correlated, and dropping the squared term reveals that the linear term is positively and highly significantly increasing conflict risk, as shown in Figure 2 (see also web appendix Table IE). Years following wetter rather than drier years are systematically more at risk of conflict, in contrast to what one should expect from much of the environmental security literature. On the other hand, the finding is quite in line with the results from Witsenburg & Adano (2009) for Marsabit and Moyale districts, which indicate that droughts can have a temporary cooling effect on tensions. To check if this was in line with the literature on violence in pastoralist areas where drier periods have been found to be less violent, I ran Model 2 on cells with an average annual precipitation of less than 700 mm. The results remained the same (see Table IE in the web appendix). Thus, the peaceful effect of dry years applies both to arid and semi-arid areas.

As already discussed, a year with above average precipitation measured at the annual level can mask an actual drought if the precipitation is plentiful but falls too late, too suddenly or in excessive concentration. The SPI6 dummy captures such deviations, as well as years of substantial below average precipitation. In contrast to the simpler measures in Models 1 and 2, both the current year measure and the one-year lag are negative but far from significant. Model 4 captures the effects of droughts in the neighborhood via processes such as migration. Distance to drought in the current year is negatively but insignificantly related to conflict, whereas for the previous year it is positive and significant, signaling that proximity to drought last year decreases conflict risk. This is in line with the findings in Model 2. However, the average distance to drought as measured by SPI6 is actually significantly lower in the wetter parts of Kenya than in the drier areas, although in substantive terms the difference is quite small (70 vs. 75 km is average distance for ASAL vs. non-ASAL cells). The SPI6 measure thus reveals that high-rainfall areas are just as prone to erratic rainy seasons as drier areas are. Regarding Hypothesis 2, the conclusion is that the closer a cell was to a drought last year, the lower the risk of conflict.

[8] There is a substantial difference between rural and urban poverty, as subsistence agriculture and access to natural resources make it easier to survive for less in the countryside. The data on the poverty line reflect the easier access to subsistence resources in rural areas. The poverty line is defined as spending less than Ksh 1,239 per month in the countryside versus Ksh 2,648 per month in urban areas (WRI, 2007: 13).

[9] All climate models were also run with relogit (see web appendix posted with the replication data). This resulted in more variables being significant. But this was the same if these models were run with OLS. Thus, using a fixed-effects model is necessary to catch some time-invariant factors that affect conflict risk. Dropping outliers did not substantially affect my results.

Table I. Conflict and climate factors

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Precipitation %	0.003					
	(0.003)					
Precipitation % squared	–0.001					
	(0.000)					
Precipitation % $_{t-1}$		0.004				
		(0.003)				
Precipitation % squared $_{t-1}$		–0.000				
		(0.000)				
SPI6 drought			–0.001			
			(0.002)			
SPI6 $_{t-1}$ drought			–0.002			
			(0.001)			
Distance to SPI6				–0.005		
				(0.004)		
Distance to SPI6 $_{t-1}$				0.014**		
				(0.006)		
Temperature %					0.002	
					(0.005)	
Temperature % squared					0.000	
					(0.001)	
Temperature % $_{t-1}$						–0.005
						(0.003)
Temperature % squared $_{t-1}$						0.001*
						(0.001)
Neighborhood $_{t-1}$	0.033	0.030	0.031	0.031	0.031	0.031
	(0.026)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Time since event	–0.009	–0.009	–0.009	–0.009	–0.009	–0.009
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Constant	0.010	0.009	0.007	0.007	0.012	0.002
	(0.008)	(0.008)	(0.006)	(0.006)	(0.014)	(0.007)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,520	13,520	13,520	13,520	13,520	13,520
R^2	0.002	0.003	0.002	0.003	0.003	0.002
Number of cells	845	845	845	845	845	845

Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
1991 dummy dropped due to perfect prediction of peace.

Models 5 and 6 show results for the warming hypothesis. Neither is significant at the 5% level, however. The warming hypothesis is therefore not supported.

Table II reports the climate models for events. Both the linear and squared term for precipitation in the current year significantly affect event risk. The risk of an event increases quite steadily up to around the 80th percentile, where the effect shows a slight downward trend (see Figure A1 in the web appendix). Thus, the impact of the non-linear effect captured in the polynomial is small. The effect is not very robust; dropping the neighborhood variable renders both the linear and squared rainfall variables insignificant. For precipitation in the previous year, the effect of the linear term is significantly increasing event risk just as it did in the parallel model for conflicts (Model 2). The results for the SPI6 measure of drought confirm the findings for deviations in precipitation. Whereas there is a negative but non-significant effect for the current year, the effect is significant for SPI6 drought last year. Looking at the results from Tables I and II jointly, we find some support for Hypothesis 1b rather than for 1a – conflicts measured as the first event or as all events in a year tend to be less likely in years following drier years.

The results for proximity to an SPI6 drought for events are similar to those found for conflicts. A higher

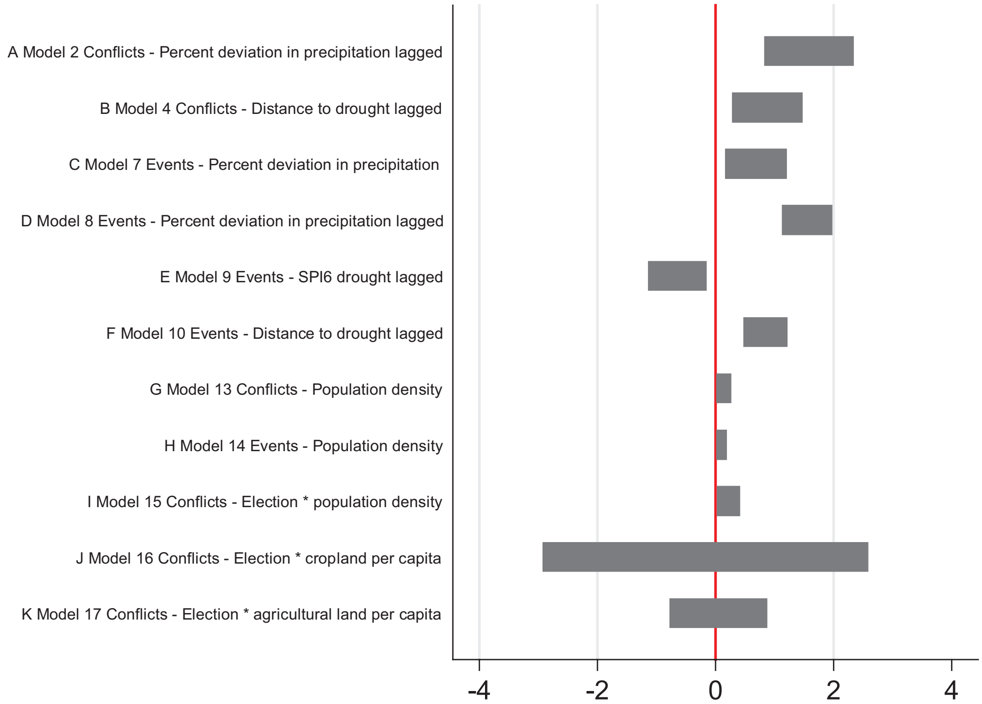

Figure 2. Relative risk of conflict or event, 1989–2004
The graph illustrates 95% confidence bands of difference in estimated risk between the 10th and 90th percentiles of the variable of interest, holding all control variables at their median. If the gray box crosses the line at zero the effect is non-significant. For Model 16, the 99th percentile was used, and for Model 17 the 95th percentile had to be used in order to get variation. The calculations were conducted using the relogit software (King & Zeng, 2001).

distance to last year's closest drought elevates the risk of a cell experiencing an event (higher values on the proximity to drought measure indicate longer distances). This implies that there is quite strong support for the notion that drought has a peaceful effect on the following year, operationalized as deviation from period mean, SPI6 drought, or distance to SPI6 drought.

Regarding the deviations in temperature, only last year's value affects event risk significantly. For the previous year the linear term is negatively associated with event risk, whereas the squared term is increasing risk and both are significant. A plot of the risk (Figure A3 in the web appendix) reveals a U-shaped curve where both very cold and very warm years increase the risk of an event the following year. Hypothesis 3 therefore receives mixed support. To test the robustness of the results for events, I ran the analyses in Table II with the current year's neighborhood effect instead of last year's. This made all climate results insignificant (see Table IIC in the web appendix). However, to control for all other events in the neighborhood the same year automatically introduces reverse causation for events that occurred prior to their neighboring events. This control is not run on the conflict variable, as this is almost invariably the first in a neighborhood in any given year, and controlling for neighboring events would be controlling for subsequent events in the same conflict. For this reason, my conclusion is based on last year's neighborhood variable.

Table III shows the analyses of land pressure and elections on the risk of violence. The results are nearly identical for the variables of interest between the models for conflicts and events respectively. I therefore show only the baseline model for events (Model 14 – see web appendix Tables IIIA and IIB for all models). All models show that population density increases conflict risk, even after controlling for major towns. This is a conventional finding in disaggregated conflict studies. However, no one has been able to point a finger to the mechanisms behind this finding. Candidate explanations are land scarcity, strategic objectives, and perhaps most convincingly simply violence occurring where there is more interaction (more densely populated areas) and hence a higher baseline risk of being killed.

Regarding Hypothesis 4, the baseline risk for a conflict is not elevated in areas with a low cropland per capita ratio (Model 16) or intensive agriculture (Model 17). To stop at an unmitigated relationship between land pressure and conflict would not do justice to the claims made

Table II. Events and climate factors

	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Precipitation %	0.013**					
	(0.006)					
Precipitation % squared	–0.002**					
	(0.001)					
Precipitation % $_{t-1}$		0.016***				
		(0.005)				
Precipitation % squared $_{t-1}$		–0.001				
		(0.001)				
SPI6 drought			–0.002			
			(0.003)			
SPI6 $_{t-1}$ drought			–0.008***			
			(0.003)			
Distance to SPI6				–0.008		
				(0.008)		
Distance to SPI6 $_{t-1}$				0.047***		
				(0.013)		
Temperature %					0.005	
					(0.007)	
Temperature % squared					0.000	
					(0.002)	
Temperature % $_{t-1}$						–0.027***
						(0.006)
Temperature % squared $_{t-1}$						0.004***
						(0.001)
Neighborhood $_{t-1}$	0.201***	0.185***	0.190***	0.194***	0.192***	0.200***
	(0.053)	(0.052)	(0.052)	(0.053)	(0.052)	(0.053)
Time since event	–0.034	–0.034	–0.034	–0.034	–0.034	–0.034
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Constant	0.034**	0.032**	0.023**	0.020*	0.033	0.005
	(0.014)	(0.013)	(0.011)	(0.011)	(0.021)	(0.014)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,520	13,520	13,520	13,520	13,520	13,520
R^2	0.012	0.015	0.012	0.013	0.012	0.013
Number of cells	845	845	845	845	845	845

Robust standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
1991 dummy dropped due to perfect prediction of peace.

by scholars such as Kahl (2006) and Oucho (2002), who argue that electoral competition is crucial in explaining why latent land-related grievances are turned into violence. Although the interaction term between elections and cropland in Model 16 has a positive effect on conflict risk, Figure 2 reveals that only interaction with population density leads to a significant (but marginal) increase in risk. In sum, land pressure on its own or in interaction with elections does not increase conflict risk. Hypotheses 4 and 5 are not supported.

Table III shows that factors other than land scarcity explain conflicts and events in Kenya. Arid and semi-arid areas run a higher risk of conflict, but this is not significant at the 5% level. In the discussion on what factors increase the risk of violence, it was quite clear that elections should affect the risk as they can be employed as an instrument to either displace groups from a district or to prevent them from voting in order to influence the outcome of the election. In line with the qualitative literature on violence in Kenya, elections increase the risk significantly for both conflicts and events. This finding corroborates Fjelde's (2009) study of communal violence in Nigeria. Ethnic diversity also affects conflict and event risk. Whereas the dummy for two groups in a cell is far from significant, the dummy for three or more groups in a cell is quite consistently related to a higher risk. Poverty

Table III. Land pressure and elections

Variables	Model 13 Conflict	Model 14 Event		Model 15 Conflict	Model 16 Conflict	Model 17 Conflict
Election	2.311**	3.541***	2.241**	2.244**	2.380**	2.311**
	(0.944)	(0.880)	(0.953)	(0.949)	(0.956)	(0.944)
Population	0.001**	0.001**	0.001	0.001**	0.001**	0.001**
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Population*election			0.001			
			(0.001)			
Cropland adjusted				–0.012		
for population				(0.023)		
Cropland*election				113.897***		
				(31.444)		
Agric. land adjusted					14.744	
for population					(16.332)	
Agric. land*election					–0.003	
					(0.036)	
Semiarid	0.623*	–0.054	0.635*	0.596*	0.628*	0.623*
	(0.336)	(0.196)	(0.336)	(0.346)	(0.350)	(0.336)
Poverty (ln)	–0.279**	–0.223**	–0.278**	–0.269*	–0.276*	–0.279**
	(0.141)	(0.090)	(0.141)	(0.138)	(0.141)	(0.141)
Large town	–0.287	0.358	–0.315	–0.284	–0.275	–0.287
	(0.823)	(0.365)	(0.833)	(0.803)	(0.817)	(0.823)
Two groups	–0.182	0.210	–0.186	–0.189	–0.192	–0.182
	(0.396)	(0.218)	(0.396)	(0.393)	(0.394)	(0.396)
Three or more groups	0.920**	0.557**	0.909**	0.880**	0.878**	0.920**
	(0.413)	(0.248)	(0.412)	(0.415)	(0.419)	(0.413)
Neighborhood $_{t-1}$	6.141**	8.015***	6.193**	6.198**	6.152**	6.141**
	(3.047)	(1.522)	(3.018)	(3.048)	(3.046)	(3.047)
Time since event	1.846***	1.683***	1.877***	1.862***	1.841***	1.846***
	(0.452)	(0.270)	(0.447)	(0.451)	(0.454)	(0.452)
Constant	–9.920***	–9.371***	–9.899***	–9.726***	–9.906***	–9.920***
	(1.593)	(1.333)	(1.593)	(1.596)	(1.596)	(1.593)
Year dummies	Yes	Yes		Yes	Yes	Yes
Trend	Yes	Yes		Yes	Yes	Yes
Observations	13,232	13,232		13,232	13,232	13,232

Robust standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
1992 and 1994 dummies dropped due to multicollinearity. Dummy for 1991 dropped due to perfect prediction of peace.

Table IV. Summary of results

Hypothesis	*Conflict*	*Event*
Hypothesis 1a: Drier years	Not supported	Not supported
Hypothesis 1b: Wet years	Supported for t–1	Supported
Hypothesis 2: Distance to drought	Opposite for t–1	Opposite for t–1
Hypothesis 3: Warmer years	Not supported	Mixed
Hypothesis 4: Land pressure	Not supported	Not supported
Hypothesis 5: Low land per capita ratio × Elections	Not supported	Not supported

measured as poverty density divided by population density turns out to be significantly and negatively related to events and less robustly so for conflicts. This finding might seem counter-intuitive. While the pastoralist areas that see an overwhelming share of the conflicts are quite uniformly poor, due to the sheer size of the country, quite a few of the cells covering these areas are also peaceful. It is very likely that these poor and sparsely populated areas have markedly higher per capita risk of violence than agricultural areas. However the focus on large-scale violence is posing a different question. For a study that uses a per capita measure of persons killed, see Witsenburg & Adano (2007). Disaggregated single-country studies have found poverty both to decrease the risk of violence (Hegre, Østby & Raleigh, 2009) and increase it (Østby et al., 2011), and risk rising to a point where it starts to drop (Tadjoeddin & Murshed, 2007). From Table III we see that both a shorter time since the previous event in the cell and a higher share of neighboring cells with events last year increases conflict and event risk.

Discussion

Tests of the hypotheses on resource scarcity lend most support to those that argue that resource scarcity does not fuel violence and seems even to favor those that see droughts as temporarily cooling tensions. Whereas land scarcity in the traditional Malthusian sense is not fuelling violence, climate factors play a role. Firstly, precipitation last year has an effect opposite to that suggested in the Environmental Security literature. Secondly, the effect of temperature goes in both directions and is significant in one model only. Since the majority (40 out of 47) of the conflicts involve pastoralists, the dynamics described by Witsenburg & Adano (2009) could be at play in explaining why a drier year leads to more peace in the next. Their argument is based on one area, however, and should be compared with anthropological explanations from other areas. Eaton (2008), analyzing raiding behavior in North-Western Kenya and the adjoining part of Uganda, came to similar conclusions. Raiding is much less likely during droughts. As he puts it, 'The people of the North Rift are well aware that intensive fighting during a drought is suicidal', and therefore cooperation and reconciliation are sought in years of hardship (Eaton, 2008: 101). Whether climate change will exacerbate conflict incidence and intensity is uncertain and cannot necessarily be extrapolated from my results here, since they are based on short-term fluctuations rather than trends. That being said, climate change is likely to increase the frequency of extreme weather events such as droughts.

As a critical test case for environmental security theory, this analysis lends little support to the resource scarcity perspective. Future studies should test the external validity of the findings for Kenya to see if the effects of climate factors found here conform to a broader pattern as suggested by Suliman (1999), among others. Furthermore, other indicators of land scarcity, such as the share of people being landless in agricultural economies and effects of soil erosion, should be investigated. To date, there is a paucity of good data on this. Border politics of weak states, particularly in sparsely populated drylands, should be studied more closely, as these are factors that arguably affect mobility, interaction, and conflict risks in many African countries. Lastly, and perhaps most importantly, in order to gain a fuller understanding of interethnic violence below the level of civil conflict, the agency and constraints of central actors such as local and national level politicians should be assessed. The environmental security paradigm is largely a bottom-up perspective of violence and is therefore not very well suited for this purpose.

Conclusion

This article has shown the merit of using subnational data to test general theories on one form of violence which has been given little attention in systematic studies. I find that climatic factors do influence the risk of conflict and conflict events. I find quite strong evidence for years following wetter years being less safe than drier years. This is probably due to the infeasibility of large-scale violence in times of extreme scarcity as reconciliation, cooperation, and peace are normally sought in pastoralist societies if a drought occurs. Such an end to hostilities is frequently not long-lasting and fighting is more likely when groups have recovered from hardship. The thesis that land scarcity breeds violence in itself and in election years receives little support, although population density per se is found to increase conflict risk. Future research should try to identify which characteristics of sparsely populated borderlands make them more susceptible to violence. Is it political marginalization, spillover of civil conflicts, or hideouts for criminal elements?

Replication data

The dataset, codebook, and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets, along with a web appendix with additional tables. All analyses were done using Stata 11.2.

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Does climate change drive land-use conflicts in the Sahel?

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Abstract

While climate change scenarios for the Sahel vary and are uncertain, the most popularized prediction says there will progressively be drier conditions with more erratic rainfall. According to some, an increase in violent conflicts over scarce resources should also be expected. This article investigates the climate–conflict nexus in detail, focusing on a distinct area at the heart of the Sahel, the inland delta of the Niger river in the Mopti region of Mali. Two complementary analytical approaches are applied. The first consists of collection and analysis of court data on land-use conflicts, 1992–2009, from the regional Court of Appeal in Mopti. A comparison of the conflict data with statistics on contemporaneous climatic conditions gives little substance to claims that climate variability is an important driver of these conflicts. Second, we carried out a qualitative analysis of one of the many land-use conflicts in the region. Again, we find that factors other than those directly related to environmental conditions and resource scarcity dominate as plausible explanations of the violent conflict. We argue that three structural factors are the main drivers behind these conflicts: agricultural encroachment that obstructed the mobility of herders and livestock, opportunistic behavior of rural actors as a consequence of an increasing political vacuum, and corruption and rent seeking among government officials.

Keywords

climate change, conflicts, Mali, Sahel

Introduction

During the last few years, violent land-use conflict in the Sahel has become the most popular example of the alleged link between global climate change and conflict. Many politicians and international civil servants seem particularly attracted to this idea (Benjaminsen, 2009). For instance, in an article in the *Washington Post* in 2007, UN Secretary-General Ban Ki-moon claimed that there is a connection between global warming and the Darfur conflict (Ban, 2007). The idea was also at the core of the decision to award the 2007 Nobel Peace Prize to former US vice-president Al Gore and the Intergovernmental Panel on Climate Change (IPCC). In the justification for the award, the chair of the Nobel Peace Prize Committee declared that 'global warming not only

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has negative consequences for "human security", but can also fuel violence and conflict within and between states' and that the Sahel belt has already seen the first 'climate wars' referring, in particular, to clashes between herders and sedentary farmers (Mjøs, 2007).

The idea that climate change leads to violent conflict in general can be regarded as a continuation or revised version of the Malthusian concept of resource scarcity as a cause of environmental degradation, poverty, and an escalating struggle for resources (Homer-Dixon, 1994). Traditionally, the scarcity literature has primarily been concerned with 'overpopulation' and the associated 'overuse' of renewable natural resources (see Homer-Dixon, 1999). With global warming and the subsequent climate security discourse, the putative impact of anthropogenic climate change on the security of societies and livelihoods has gained prominence. Again, the Darfur conflict is presented as the best example of the correlation between climate and conflict. For example, Sachs (2007: 24) states that

> Darfur's extreme poverty, rising population, growing water stress and desertification are all important contributors to the Darfur crisis . . . . extreme poverty, falling incomes and failing rains . . . are the crucial drivers of conflict in less developed countries; much less solid evidence implicates political repression.

Similarly, a recent report by the United Nations Environment Programme (UNEP), which received extensive media coverage and obtained political influence, also draws a link between climate change, desertification, and the conflict in Darfur (UNEP, 2007). The report attaches a great deal of importance to the fact that the average rainfall in some parts of Darfur has decreased by 16–34%, if the periods 1946–75 and 1976–2005 are compared, failing to mention that since the mid-1980s, rainfall has increased again (see also Kevane & Gray, 2008). Both these examples illustrate how traditional Malthusian factors and climate change are often merged into one story of 'environmental conflict'.

This study sets out to explore the alleged relationship between climatic conditions and conflict in the Sahel using the inland delta of the Niger river in Mali as a case. This is a hotspot area in West Africa in terms of land-use conflicts. It consists of a large wetland area in the midst of a dry savanna, and it is highly valuable to rice farmers, pastoralists, and fishers alike. Land-use conflicts in the delta are frequent and usually concern access to water for livestock, irrigation, fishing grounds, or access to a plot of land for farming or grazing.

The analysis consists of two components. First, we present and assess a new dataset of more than 800 mostly nonviolent land-use disputes that appeared in the regional Court of Appeal in Sévaré between 1992 and 2009. A simple comparison of the court data with statistics on contemporaneous meteorological conditions in the region offers little support for the notion that climate variability drives intercommunal conflicts. Although there seems to be some overlap in the timing of unusually wet periods and subsequent increases in land-use disputes, the overall downward trend in such cases in the Court of Appeal cannot be explained by climatic conditions. We then present a qualitative study of one of the many farmer–herder conflicts found in the delta, which serves to provide a more thorough assessment of the role of environmental conditions and to illustrate some of the causal processes that are descriptive of many of the conflicts in the area. Again, we find that factors other than those directly related to environmental conditions and scarcity of subsistence resources dominate as plausible explanations of the violent conflict. We argue that three structural factors are the main drivers behind this conflict: agricultural encroachment on key productive resources for pastoralism and on livestock corridors, decentralization creating a political vacuum, and rent-seeking among government officials.

On Environmental Change and Conflict in the Sahel

Recent years have seen a surge in academic publications on whether and how particular environmental conditions and climate characteristics affect the risk of armed conflict (for reviews, see Nordås & Gleditsch, 2007; Salehyan, 2008). The question is by no means resolved, although a significant majority of empirical studies suggests that the environment at best has a trivial impact on the risk of organized violence (e.g. Buhaug, 2010; Raleigh & Urdal, 2007; Theisen, 2008). This fact notwithstanding, alarmist reports by think-tanks and NGOs are flourishing, and 'even the IPCC, which rightly prides itself of being a synthesis of the best peer-reviewed science, has fallen prey to relying on second- or third-hand information with little empirical backing when commenting on the implications of climate change for conflict' (Nordås & Gleditsch, 2007: 628).

Few studies that claim a causal connection between environmental change and armed conflict fail to mention farmer–herder clashes in the Sahel. High-profile cases include the border conflict between Senegal and Mauritania in 1989, the Darfur conflict, and recent clashes between ethnic groups in northern Nigeria. Many of these intercommunal conflicts are violent, and some have generated massive casualty figures. There may be several reasons for the prevalence of land-use conflicts in the region. One important factor is the juxtaposition of communities with different lifestyles and economic activities, whereby the conflicts in this way are an expression of ongoing agrarian changes (modernization) in Sahelian societies. In addition, the local population, and notably herder communities, may have little confidence in the government's ability and willingness to solve conflicts in a peaceful and just manner (Benjaminsen & Ba, 2009).

There is a rich body of case-study literature that focuses on the relationship between farmers and herders in Africa (e.g. Bassett, 1988; Benjaminsen & Ba, 2009; Benjaminsen, Maganga & Abdallah, 2009; Hagberg, 2005; Hussein, Sumberg & Seddon, 1999; Moritz, 2006; Turner, 2004; Witsenburg & Adano, 2007). In the case of local conflicts, national policy narratives often put the blame on pastoralists. This seems to be part of an overall strategy of agrarian modernization and of converting mobile peoples into 'productive' sedentary farmers. Such policies have been criticized by scholars pointing out that the causes of conflicts often have a political origin (Bassett, 1988; Benjaminsen, 2008; Turner, 2004; Moritz, 2006), which is associated with an ongoing process of pastoral marginalization (Benjaminsen & Ba, 2009; Benjaminsen, Maganga & Abdallah, 2009; Bonfiglioli & Watson, 1992; Hagberg, 2005); underestimation of pastoral productivity and pastoral contribution to the national economy (Grandin, 1987; Hesse & MacGregor, 2006); and overestimation of negative impacts of grazing on the ecology (Behnke, Scoones & Kerven, 1993; Ellis & Swift 1988; Turner, 1998). In fact, specialized pastoralists may be just as healthy and may feed their families just as well or better than farmers in the same dryland environments (Pedersen & Benjaminsen, 2008).

Although farmer–herder clashes represent the archetypical image of Sahelian disputes, different actors may be involved in these conflicts, and as we will show, most of these conflicts do not lead to violence.

The inland delta of the Niger river

This delta is the largest wetland area in West Africa that in good years covers up to 30,000 km^2 (Figure 1). The flooding in the delta depends on the annual rainfall in the upper catchment area of the Niger river in Guinea and southern Mali. For centuries, the area has provided rich resources for rice cultivation, fishing, and pastoralism. According to official censuses, the population of the Mopti region, which covers most of the delta, increased from 910,713 in 1964 to 1,478,505 in 1998 (Cotula & Cissé, 2006). An assessment report forecasted that the delta population would reach 2 million by 2010 (Sahel Consult, 2007). The region consists of a mix of sedentary farmers (Bambara, Songhay, Malinké, Fulani), pastoralists (Fulani, Tuareg, Moor), and fishers (Bozo). These communities have a long tradition of cooperation and coexistence, though intercommunal raids and clashes have also happened from time to time.

The pastoral system in the delta is based on livestock using pastures in the delta as a dry season grazing area during December–June, combined with migration to dryland pastures in the rainy season. From the beginning of the rainy season in June/July, many delta pastoralists move northeast or northwest before they return to the delta during the dry season.

The main fodder resource in the delta is *burgu*, which grows on deeper water than paddy rice. During the last decades paddy fields have expanded considerably at the expense of burgu. According to Kouyaté (2006), about one quarter of the burgu areas in the delta have been converted to rice fields since the 1950s. This can be explained in part by decreased levels of flooding in the Niger river, especially as a result of the droughts of the 1970s and 1980s, and partly by the construction of the hydropower dam upstream at Sélingué that was completed in 1982 (Turner, 1992). Since the Sahel drought in the mid-1980s, flood levels have increased somewhat again (Figure 2).

Recent environmental change in the delta region

The Sahelian zone is generally considered highly vulnerable to climatic fluctuations due to the strong dependence of its population on rain-fed agriculture and livestock keeping. The recurring droughts of the 1970s and 1980s had devastating implications for livelihoods across the region, where hunger, malnutrition, diseases, and loss of lives and livestock led to massive human displacement. The conditions have since improved and seasonal rainfall has increased again, although the region is still marked by significant interannual variations in rainfall (Buontempo, 2009). As a result of this relative recovery in rainfall, environmental research on the Sahel has shifted from focusing on 'desertification' to acknowledging the fact that the region has become greener during the last two decades (e.g. Hutchinson et al., 2005).

Although there is general agreement on the long-term climate developments in the region throughout the 20th

Figure 1. The inland delta of the Niger river in Mali

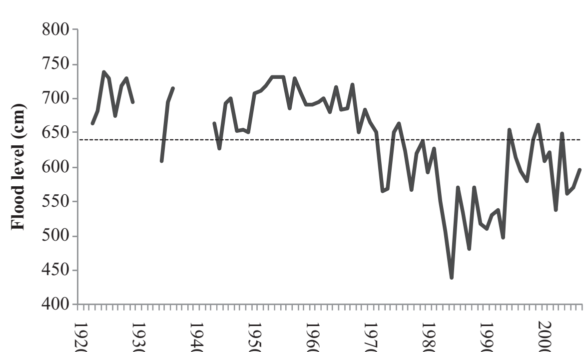

Figure 2. Niger river flow variability in Mopti, 1922–2006
The graph shows maximum annual flood level of the Niger river in Mopti. Several years are missing in the early period. The dotted line represents the mean value for all years. Data received from Direction Nationale de l'Hydraulique in Bamako.

century, researchers are much less certain about future changes. This is underlined by the IPCC in its fourth report (Boko et al., 2007: 444), which points out that the various models do not concur concerning future climate scenarios for the Sahel. While some models indicate that the region will become drier, other models suggest that Sahelian rainfall might increase in the future (e.g. Haarsma et al., 2005; Odekunle, Andrew & Aremu, 2008). Projections for temperatures tend to be more uniform than for rainfall and suggest an increase, especially for the summer season (Buontempo, 2009).

Figure 3 illustrates short-term climate variability (rainfall and temperature) in the Mopti region of Mali during the period 1960–2008. The graph reveals substantial interannual variability in precipitation – so characteristic of the Sahel belt – with dry and wet years in an

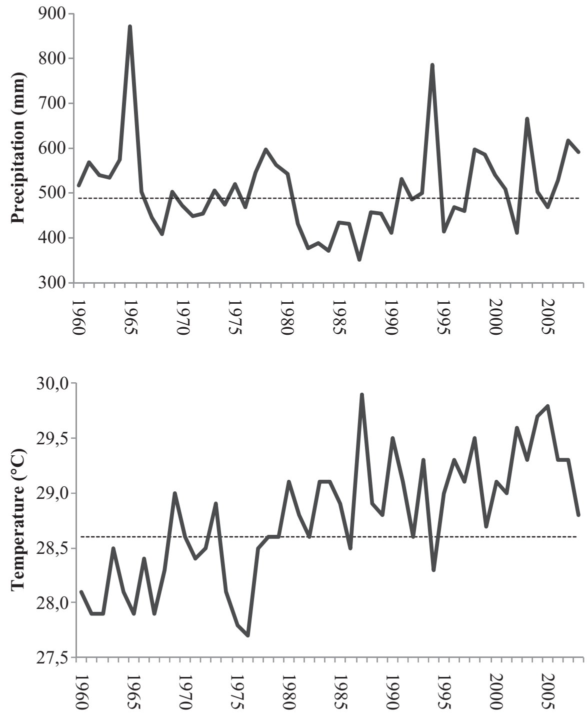

Figure 3. Climatological trends for Mopti, 1960–2008
The figure shows total annual precipitation and mean annual temperature for the Mopti region with dotted lines representing the mean values for the 1961–90 period. Statistics derived from gridded climatological data from the Center for Climatic Research, University of Delaware (http://climate.geog.udel.edu/~climate/).

irregular pattern. The Sahel drought of the 1970s and 1980s is also easily detectable in Mopti meteorological statistics, with the early 1980s displaying particularly large negative deviations in rainfall. The driest years in the period lost almost 150 mm from the yearly average (1961–90) of 487 mm (dotted line), equivalent to 1.4 standard deviations below the mean. Since 1990, precipitation has normalized, including some very wet years. These trends do not provide any evidence of global climate change having played a role in driving the droughts of the 1970s and 1980s (Christensen et al., 2007).

As expected, the temperature data display less dramatic variability over time although a significant overall warming is discernible, especially early in the period. Only three years since the mid-1970s have been colder than the long-term annual mean temperature of 28.6 degrees Celsius (dotted line).

Land-use conflicts in the delta

The current land tenure system in the delta is based on the principles introduced by invading Fulani warriors in the 14th century, the so-called Ardobé (Ba & Daget, 1962). The Ardobé constituted the military and political leadership in the area for more than 400 years, from about 1400. They 'provided floodplain land to subordinates for farming, which led eventually to the bounding of their spheres of influence into leyde' (Turner, 1999: 110). Furthermore, the Ardobé introduced local chiefs (*jowros*) to manage the *leyde* (sing. *leydy*). The jowros who were noble Fulani (*rimbé*) pastoralists were 'owners of grass', and hence responsible for the management of pastures in these territorial units.

In 1818, Islamic clergymen mobilized a jihad and conquered the delta region through the leadership of Cheikou Amadou. This resulted in the establishment of an Islamic theocratic state, the Dina, which also codified and formalized many of the resource management principles and rights introduced by the Ardobé. For instance through this codification, the jowros were formally granted the authority to manage the leyde, rights to burgu fields were defined, and a list of livestock entry routes in the delta was established in order to keep farmers' fields at a distance (Gallais, 1967).

In 1895, the colony of French Sudan was established. The principles of spatial organization and resource management inherited from the Dina were sustained by the French administration (Barrière & Barrière, 2002). The French governed the delta through the authority of jowros by letting them maintain their role as managers of pastures. The colonial government also agreed that the jowros were entitled to receive a rent from the users of burgu pastures.

In 1960, Mali gained independence, and the country's first President, Modibo Keita, was inspired by socialist ideas of industrialization and agricultural modernization. Pastoralism was looked upon as an obstacle to development and the Keita government sought to convert pastoralists into 'productive' citizens by taking up farming (Benjaminsen & Berge, 2004). The socialist government also saw the jowros as feudal landlords and generally tried to undermine their authority. After a coup d'état in 1968 and the establishment of the military government of Moussa Traoré, the position of jowros was gradually rehabilitated. Towards the end of Traoré's reign, until he was toppled in another coup d'état in 1991, the jowros had again become powerful local actors through alliances with officials of the governing party.

After the introduction of democracy in 1991, a constitution committed to decentralization was accepted by referendum (1992), and in 1993 and 1995 laws on decentralization were adopted by the National Assembly.

However, how to deal with land-use conflicts remains one of the key challenges of the decentralization reform.

In French Sudan, the state and individuals with title deeds were the only formally recognized landowners. After independence, as a heritage from colonial law, the Land Code of 1986 acknowledged property rights only in the case of individually held title deeds. Customary rights were defined as use rights with a much weaker status than titled land. In 2000, the Land Code of 1986 was replaced by a Land Ordinance.[1] However, this new law remains focused on 'mise en valeur'[2] and does not address pastoral land tenure and its various challenges. The livestock policy of 2004 is also largely focused on modernization of the livestock industry and, for instance, neglects land-use conflicts as an issue.

A number of reports hold that in recent years the delta has been marked by numerous land-use conflicts (Barrière & Barrière, 2002; Benjaminsen & Ba, 2009; Cotula & Cissé, 2006). Given the area's sensitivity to rainfall fluctuations and its dependence on the seasonal flooding of the Niger River, one might surmise that the high frequency of land disputes in part reflects a decline in the water level in the river. A possible, and often repeated, scenario in Mali is that declining water levels lead to less land available for rice cultivation and burgu pastures, which in turn leads to more land-use competition, especially between farming and pastoralism. However, lack of systematic data on such conflicts has prevented a systematic comparison of trends in conflict and climate.

Court data on land-use disputes

For this study, we consider data on land-use disputes settled by the Mopti regional Court of Appeal in Sévaré.[3] We chose the Court of Appeal as our source of conflict data because its domain covers a larger area (and hence a larger number of cases) than individual Primary Courts and because it is common practice in Mali that the losing party in Primary Court takes the case to the Court of Appeal.[4] Hence, little information is lost by focusing only on cases in the second tier of the judicial system. We considered using newspaper reports and statistics from the local police as additional sources. The former are, however, infrequent and unreliable, and the latter are difficult to access and would only include cases that involved use of violence.

The archives in Sévaré have not been digitalized; instead, court decisions are available as printed documents, catalogued by year and type (criminal or civil matters). As the Appeal Court in Sévaré was established in 1992, we only report data on disputes starting from this year. Land and natural resource conflicts are normally recorded under civil matters, although violent land conflicts may be considered criminal matters. We disregard all cases relating to divorce, matrimonial quarrel, credit reimbursement, and succession, except if the succession concerns ownership of rural land. The remaining files were classified according to the main issue of contest (agricultural lands, pastures, fisheries, and customary leadership) and actor constellation (farmer/farmer, farmer/herder, etc.). In all, we have data on 820 distinct land/resource disputes in the region between 1992 and 2009.

Before assessing the statistics, a note on data quality is warranted. Taking a dispute to court is usually considered a last resort (except if an involved party has enough power and money to be confident of victory). Obviously, most land (and other civil) disputes never appear in court – many are solved through various conflict resolution mechanisms, such as intervention of customary authorities (jowros, village leaders, community meetings) or local administrative authorities. In addition, some enduring conflicts are never taken to court because of lack of funds. Court cases are expensive, largely because of the bribes the parties need to pay to the judge and his entourage (Benjaminsen & Ba, 2009). This suggests two possible selection biases. First, the data might be biased in that disputes involving very poor parties will be underrepresented. Second, there is a potential for bias relating to conflict severity, where high-intensity disputes, that is, violent and fatal events, are more likely to appear in court. According to our sources, violent cases represent about 10% of all cases in the Court of Appeal in Sévaré.[5] While this share may seem rather low, it is likely to be considerably lower for non-court land-use conflicts in the delta. A final caveat concerns the temporal

[1] In French legislative terms, a *loi* is a piece of legislation enacted by vote of the National Assembly, an *ordonnance* is enacted by the head of State, a *décret* is an executive order, often used to clarify a loi or ordonnance or to provide the guidelines for its application, and an *arrêté* is formulated and promulgated at the ministerial, or even the regional level (Elbow & Rochegude, 1990).

[2] Increasing the value of land though productive use, which usually means farming.

[3] The data were collected by Koffi Alinon between November 2009 and February 2010.

[4] One of our informants, a lawyer defending cases at the Court of Appeal, estimated that well above 90% of the land-use conflicts in Primary Court are appealed and taken to the next level.

[5] This is based on an assessment by a lawyer who has specialized in this type of land-use conflict and who appears in the Sévaré Court of Appeal every week.

dimension – the time it takes from a dispute materializing until a verdict is reached in the Court of Appeal.[6] Given that this study seeks to explore the sensitivity of rural communities to short-term variations in environmental conditions, the timing of dispute onset might be more important than the date of court decision per se.

These concerns are all real, yet we do not regard them as sufficiently grave to question the overall merit of this assessment. First, our data show that about two-thirds of all cases appeared in the Court of Appeal within two years of the stated starting date of the dispute (according to the parties involved). Less than 6% of all filed conflicts lasted for more than five years before a court decision was made. Hence, a comparison between frequency of land disputes and contemporaneous climate statistics should reveal a co-variation pattern if the two phenomena are linked in a systematic manner. Second, while the data might be skewed in the direction of more affluent conflict parties and more severe events, we have no indication of sample selection bias with regard to the distribution of conflict types, or, more crucially, the relevance of environmental conditions for the occurrence and timing of conflicts.

An overwhelming majority of court cases (83%) list agricultural fields as the main issue of contestation. This corresponds to the fact that about 70% of all cases are disputes between farmers (Table I). These conflicts originate, for instance, from two individuals claiming rights to the same field, disagreement about borders between fields, or disagreement about the management of communal fields. We also note that conflicts between farmers and herders only represent about 12% of the cases in our material. There are two main origins of these conflicts: livestock corridors being blocked through agricultural extension and encroachment of rice cultivation on burgu pastures. We should, however, add a caveat to the counting of cases: while conflicts between farmers are usually smaller conflicts opposing individual farmers, farmer–herder conflicts are larger disputes opposing communities. Each of these latter conflicts therefore has more serious consequences for more people and they are also at the center of on-going processes of agrarian change in Sahelian societies.

Table I. Land-use conflicts in the Sévaré Court of Appeal by type, 1992–2009

	Farmer	*Herder*	*Fisher*
Farmer	573 (69.9%)		
Herder	100 (12.2%)	19 (2.3%)	
Fisher	63 (7.7%)	13 (1.6%)	50 (6.1%)

Frequency of conflict by actor constellation; share of all recorded events given in parentheses. Two disputes involving other actors not listed. N = 820.

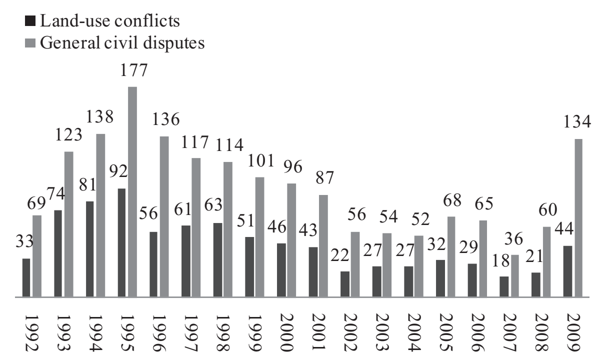

Figure 4. Frequency of cases in the Sévaré Court of Appeal
The graph shows the number of disputes settled in the Sévaré Court of Appeal by category and year, according to the court's records.

Farmer–fisher conflicts are usually about access to agricultural land for fisher folk. Disputes among herders may be about the management of burgu pastures, disagreement about the limits of leyde and of burgu pastures, refusal to pay fees to graze animals on burgu pastures, and refusal to respect the established cycle of entry and exit dates related to burgu pastures. Herder–fisher conflicts are often either about burgu pastures being extended into fishing grounds or about animals grazing in the water and causing damage to fishing gear. Finally, conflicts among fishers are usually about the management of fishing grounds or the usage of fishing gear (for different types of conflicts in the delta, see also Barrière & Barrière, 1995).

Next, we inspect the aggregate temporal pattern of land and resource conflicts, relative to general civil disputes for all years since 1992 (Figure 4). As one might expect, we see a sharp increase in appeal court cases in the years following the political reforms of 1991–92. This probably reflects both increased opportunities for taking disputes to the court system and increased confidence in

[6] The starting point of a conflict might be difficult to define in itself and there might be different interpretations of when a conflict materializes among various actors. In violent conflicts, the starting point may be defined as when violence first broke out or when the parties first disagreed. In a nonviolent conflict, the onset is interpreted as either when the case was brought to the authorities or when the parties first disagreed over access to the resource in question.

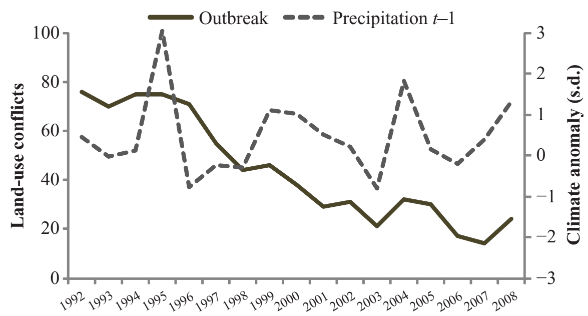

Figure 5. Outbreak of land-use conflicts and rainfall variability in Mopti

The figure overlays statistics on the outbreak of land-use disputes that have appeared in the Sévaré Court of Appeal with data on climate anomaly in the Mopti region (one-year time lag), defined as significant deviation from normal annual precipitation, 1961–90.

the judicial system in Mali.[7] Since the peak in 1995, the number of relevant court cases dropped considerably and it now appears relatively stable at around 20–30 cases per year (despite a notable rise in 2009). Most interestingly, however, we see that the trend in land-use disputes is remarkably similar to the temporal pattern in general civil disputes (petty crime, divorce, etc.). This provides at least indicative evidence that factors other than environmental conditions drive the temporal fluctuation in land disputes in the Court of Appeal in Sévaré.

Finally, in Figure 5 we compare the annual frequency of tenure disputes with rainfall statistics for the Mopti region. However, instead of using data on court settlements (as in Figure 4), we consider conflict *outbreaks*, that is, the number of disputes that started in each year (solid line). We believe the timing of land-use dispute onsets is more relevant than when they eventually appear in court (although bringing a conflict to court may be seen as an escalation of the conflict, which plausibly might be related to increasing strains on rural livelihoods). The rainfall data are expressed in standard deviations from normal annual levels (dashed line) during the reference period 1961–90. We apply a one-year time lag to the climate data to account for a slight delay in a possible effect of environmental 'shocks' on land/resource conflict. A simple bivariate comparison of trends certainly cannot be used to demonstrate or falsify hypothesized relationships, but it may provide some hints that require further scrutiny.[8] Conversely, a complete lack of temporal correspondence is indicative of a trivial association (although it is possible that the relationship between x and y is conditional on a third factor z).

Figure 5 gives little reason to suspect that short-term climatic anomalies are an important driver of land-use disputes in the Mopti region. While precipitation has remained relatively stable during the observation period (although with notable inter annual variability), there is a distinct downward trend in the number of land disputes breaking out and taken to court. At the margin, however, we may be able to decipher a weak overlap in trends as local peaks in new disputes (1994–95, 1999, 2004, 2008) appear to follow unusually wet years. This could reflect a pattern whereby wetter years lead to an expansion of the pastoral area and resources of potential contestation, covering new land with less established norms of sharing, which in turn increases the overall number of land-use conflicts. However, we would be hesitant to claim such a causal link for several reasons. First, the visual inspection covers less than two decades, which really is too short a time period for determining a systematic pattern of covariance. Second, the graph ignores possibly important third factors, such as contextual socio-economic developments. Third, our measures of local environmental conditions and 'shocks' are based on climatological statistics and hence do not capture directly the impact on crops and livestock. Also, there may be uncertainties in the coding of land dispute onset (which is based on the accusers' formal statements in the Appeal Court) (see also footnotes 6 and 12).

We should also note that the decline in the outbreak and settlement of land-use disputes in the Court of Appeal in Sévaré goes against the idea of increasing numbers of land-use conflicts in the delta expressed by some observers. This might reflect a real trend, but it might also be the result of a loss of confidence in the court system among the local population and/or increasing obstacles to bringing a dispute to court.

In sum, the data from the Court of Appeal in Sévaré and local climatic statistics give little substance to claims that short-term variations in weather patterns drive social conflicts among pastoral and agrarian societies in rain-dependent environments. Yet, the somewhat crude

[7] The average ages of court cases were higher in 1993 (4.1 years) than in any other year in the sample period, suggesting that conflicts had accumulated for several years when opportunities and/or motivation for bringing the conflict to the court suddenly increased. The sample mean age of resolved disputes is 2.8 years.

[8] The most influential correlates of civil war in a multivariate framework also correlate significantly with the outbreak of civil war at the bivariate level (see Hegre & Sambanis, 2006).

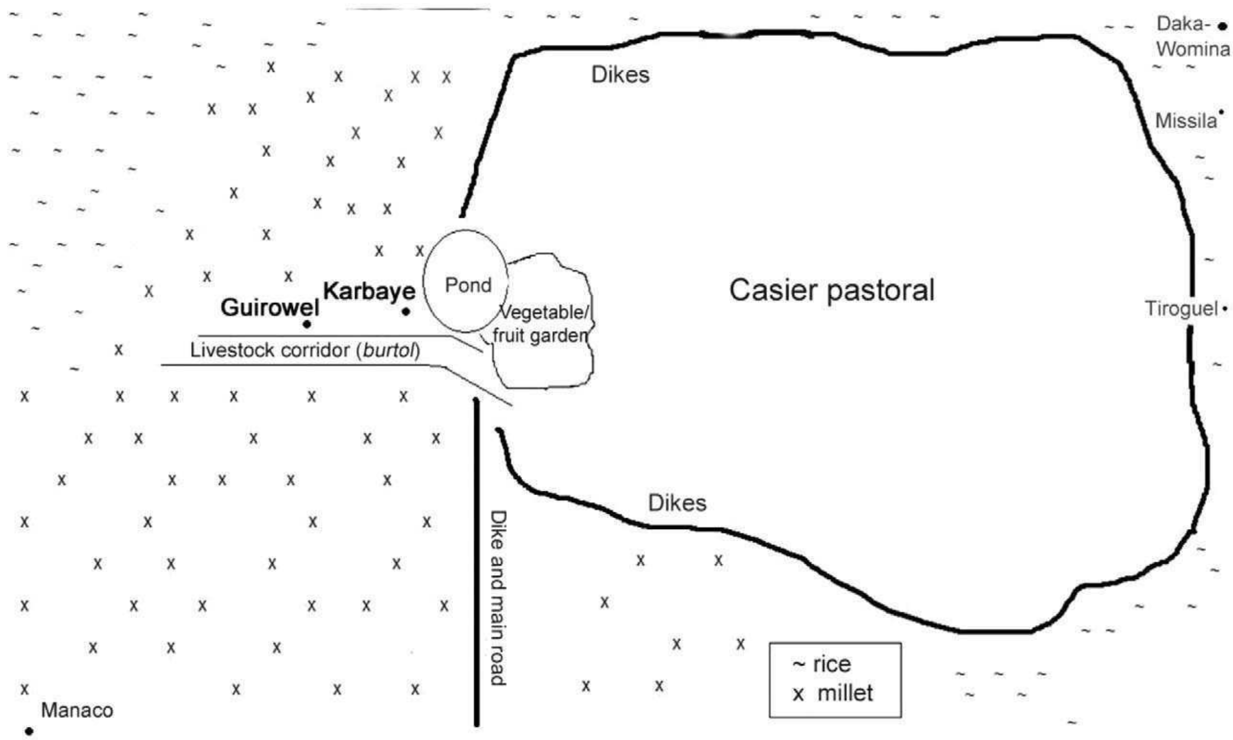

Figure 6. Resource map of the case study area

climatological data (using annualized measures on rainfall and temperature as proxies for water scarcity and drought) and the short time series of the court data (e.g. missing the Sahelian drought of the mid-1980s) imply that we cannot conclude definitively in one direction or another based on these statistics alone. Hence, we next present an in-depth study of intercommunal relations and land conflicts in the Mopti region that may be better suited to identify important conflict processes and assess the true impact of climate variability.

A case study[9]

At sunrise on 6 August 2001, near the village of Karbaye in central Mali, young men from the village wait with rifles in the bushes and open fire at a group of herders who bring livestock to a pond close to the village. Some three to five people are killed and 15–30 injured in the skirmish that follows. Most of the killed and injured are herders who came from the neighboring village of Guirowel.

The two villages are located approximately one kilometer apart (Figure 6) and are situated in the leydy of Kounary in Mopti Region. Guirowel is primarily a pastoral Fulani village while in Karbaye the majority are Malinké farmers. There are approximately 400 inhabitants in Karbaye and about 1,070 in Guirowel (Direction Nationale de la Statistique et de l'Informatique, 1998). Even though 'farmers' may also own livestock and 'herders' may also farm (or at least control farmland), these two identities still hold a strong position in Mali and in the delta area. Farmers in Karbaye cultivate paddy rice on flooded land in addition to the growing of rain-fed millet, fruits, and vegetables, while burgu pastures represent a key resource for pastoral production.

Several development interventions have been implemented in this area during the last decades. The *Office Riz Mopti* (ORM) was established in 1972 with World Bank funding, as part of a large national initiative aiming at increasing agricultural production. ORM has focused on transforming 'vacant' land into rice fields and building irrigation systems to distribute water to plots of one hectare each, which people can rent. ORM established a

[9] This case study is based on fieldwork by Jill T Buseth in October 2008 and March 2009. Data collection consisted mostly of interviews with key actors both locally (farmers and herders) and in the government and NGOs. In total there were 55 interviews with villagers (about half in each of the two villages) and an additional 21 with government officials, NGO representatives, and resource persons.

large *casier rizicole*[10] outside Karbaye in 1977. This perimeter of 900 hectares was traditionally burgu land established during the Dina. The area is, however, far from the river, and in the 1970s, it was not flooded adequately because of the droughts. ORM therefore regarded the land as underutilized and transformed it into rice fields.

Opération de Développement de l'Élevage dans la région de Mopti (ODEM), which was established in 1975, was another World Bank funded development initiative. ODEM was concerned with livestock problems and pastoral development (de Bruijn & van Dijk, 1995). As the herders of Guirowel had lost access to burgu pastures after the establishment of the casier rizicole, ORM and ODEM re-transformed the casier rizicole back into the original casier pastoral in 1984. This is the main site of contestation in this conflict. In addition, there is the point where a *burtol* (livestock corridor) enters the casier (Figure 6). The burtol runs from Guirowel past Karbaye and enters the casier where there is presently a dam and a garden with the production of vegetables by farmers from Karbaye. In April 2001, the Canadian Environmental Rehabilitation and Food Security Project (RESA) assisted in rehabilitating the dam that had dried out. It had earlier been used for brick production, household consumption, and the watering of livestock by all the surrounding villages, but mostly Karbaye and Guirowel. All villages agreed on the rehabilitation of the dam on the condition that they would get access to it. Villagers of Karbaye, however, regarded the dam as theirs as it was located on the border to their village land. They had also paid half of the costs, while the other villages paid the other half. The total cost for the rehabilitation was 200,000 CFA (about 340 euros). As Figure 6 shows, the dam is situated on the border of the casier pastoral where the burtol enters the casier. The purpose of the dam is largely disagreed upon, but according to Canadian project staff, it was intended both to facilitate fruit and vegetable farming, and to serve as a source of water for livestock.[11]

Shortly after the establishment of the dam, people from Karbaye allegedly announced that other villagers were not allowed to use it. Farmers from Karbaye thereafter started to cultivate vegetables and fruits in gardens next to the dam. They also prohibited the watering of livestock, as animals would damage the gardens. In addition, the gardens started to encroach on the burtol, eventually blocking it for any passage.

Herders from Guirowel did not accept, however, that access to the dam was denied and that the burtol leading to the casier pastoral with burgu pastures was blocked. They felt they had the right of access to the dam, as they had contributed to its financing. Many people in Karbaye, on the other hand, believed that the only reason the herders insisted on using the dam and the burtol was to provoke, and not because they necessarily depended on the water resource.

The violence between Guirowel and Karbaye took place next to the dam, just outside Karbaye, on the livestock corridor, and only 20–30 meters from the casier pastoral. The two villages largely disagree on what happened before and during the conflict. The common story from Guirowel was:

> The farmers do not accept that we want to pass with our animals. They just want all the land for themselves, and one morning they started shooting at us when we came. They had planned this slaughter for several months. They don't accept that the casier pastoral is ours.

Many people from Karbaye claim that it was the other way around. However, even several informants from Karbaye admitted that it was farmers from Karbaye who opened fire, but they were reluctant to talk about it, and they also claimed that they had no choice.

The violent attack at Karbaye occurred in August 2001. Neither 2000 nor 2001 were dry years. Both years had around average rainfall (414 mm in 2000 and 453 mm in 2001) and we have no other indication that anything but normal environmental conditions prevailed at the time violence broke out. Thus, instead of interpreting this event as a classic scarcity-driven conflict, we argue that several dominant structural factors are essential in understanding this particular conflict – and numerous other low-intensity conflicts that occur in the delta. The first factor is the large-scale expansions of rice fields, which has led to a massive loss of pastoral land; the second is a political vacuum that prevailed following democratization and decentralization from 1991; and the third is corruption and rent-seeking by government officials.

Large-scale expansions of rice fields

The expansion of rice fields is primarily a result of national agricultural policies promoting rice cultivation

[10] *Casiers* are large zones of land set aside for specific purposes, mostly pastoral grazing (on *casiers pastoraux*) or rice cultivation (on *casiers rizicoles*).

[11] Information from the Canadian donor was obtained from email correspondence with one employee of CIDA's Mali program based in Canada in 2009.

at the expense of pastoralism, but it has also to some extent been caused by a decline in flood levels in the river. Lower water levels were partly caused by a decrease in rainfall during the 1970s and 1980s, which left large areas of the floodplain dry. The construction of the upstream hydropower dam at Sélingué in 1982 also contributed to the declining water levels (Turner, 1992). As burgu grows on deeper water than rice, the declining water level led to a massive expansion of rice fields into burgu areas on the floodplain, which directly confronted farmers and herders and pushed out the latter and their livestock.

Land legislation and policies largely favor farmers at the expense of herders. This is clearly illustrated by the ORM projects. Studies in other parts of the delta have shown that agricultural encroachment is a continuous process and a major threat to the pastoral system (e.g. Benjaminsen & Ba, 2009; Cotula & Cissé, 2006; Turner, 1999). For instance, a herder in Guirowel said: 'I don't know if the ORM benefited the farmers, but I know one thing: It destroyed the land of the herders!'

This case is, however, unique in the way it led to a retransformation of a rice field into burgu pastures. The farmers reacted strongly to this decision and it was not enforced by the government. According to the local mayor, all the surrounding villages except Karbaye agreed on establishing a casier pastoral, because it was regarded as highly necessary in order to give the herders some land for grazing. The farmers were given new areas about 7 km away where they could cultivate, but most farmers did not accept this, and continued to cultivate in the casier pastoral. Because of the general agricultural development policies encouraging expansion of rice fields, farmers felt that they had the authorities on their side.

Hence, farmers from Karbaye continued to cultivate the casier pastoral, and every year cattle from Guirowel damaged the harvest, and nothing was done to solve the problem. Both herders and farmers felt they held priority rights to the land.

Conversions of pastures to rice fields are mainly the result of the general policy and laws of *mise en valeur* favoring agriculture at the expense of livestock keeping. Land laws that authorize state ownership and marginalize customary practices have, since colonization, played a key role in the ongoing exclusion of pastoral use. This situation is not specific to Mali. In fact, pastoral marginalization as a result of agricultural policies and land legislation favoring farmers is a well-known phenomenon in the African studies literature (see e.g. Bonfiglioli & Watson, 1992).

In the area around Mopti and Sévaré, where this case study was carried out, the main agent to implement the policy of agricultural expansion has been the ORM. One of the jowros interviewed estimated that about 80% of the leydy of Kounary is currently cultivated, while at most 40% was cultivated at independence. People interviewed also stress that neither farmers nor livestock keepers were consulted when ORM confiscated burgu land and closed livestock corridors.

Political vacuum

Following democratization and decentralization in Mali, the management of the casier pastoral in question and the dikes were handed over in 1998 to a customary organization called *Association Boumani*, which is focused on conflict resolution. It consists of three representatives from each of the villages surrounding the casier pastoral. As this organization does not have a formal or official status, it soon faced problems in terms of lack of authority in carrying through its recommendations.

It became easy for farmers to cultivate in the casier pastoral following this lack of governmental management, monitoring, and policing, Moreover, when Karbaye wanted to rehabilitate the dam, there was a lack of officials who could participate in the preparations and discussions in advance. Judging from the timing of the rehabilitation of the dam (April 2001) and the eruption of violence (August 2001), it seems likely that the rehabilitation may have sparked the violent attack, though tension between the two parties had been latent for decades.[12]

Many informants stated that the conflict was caused by what they called a 'lack of authorities' in the sense of lack of state presence in the area. One key informant said that 'the conflict is related to the fact that now, everybody is free and can do what they want', referring to uncertainty and confusion after the reforms. Another said: 'It is a farmer–herder conflict that is caused by the government'. Hence, many blame the authorities and their ambiguity in the allocation of the casiers for the conflict.

[12] One could, however, question whether this conflict started when the violence broke out in August 2001 or whether it was the building of the dam in April 2001 that sparked off the dispute. The starting date could also have been in 1977 when the casier rizicole was established, in 1984 when the casier again became a grazing area, or some time after 1991 with decentralization and decreased government presence in the rural areas. This case, thus, also illustrates some of the problems with identifying a starting point of a dispute in general.

In the first few years after the introduction of democracy in 1991, government presence in rural areas was weak and there was considerable uncertainty about future directions with the restructuring of government services and decentralization. Some people took advantage of this void by taking possession of land or by making claims to land in various ways.[13] Expansion of farmland at the expense of pastures caused by a growing population is a common phenomenon throughout Africa. The droughts led to a more rapid encroachment of rice fields into burgu areas, while decentralization in the beginning created uncertainty around future power structures and policies. This led actors to try their luck and make claims to land in various opportunistic ways.

Rent-seeking

'Rent-seeking' implies extracting value from activities without making any contribution to productivity, and it is usually linked to the misuse of governmental authority. Corruption by a rent-seeking bureaucracy is also perpetuating land-use conflicts in Mali. For instance, in order to open up a new livestock corridor, a jowro has to pay off a number of state technicians and administrators. One well-informed interviewee in a key position said that the administration benefits from the fact that jowros hold only informal positions. As long as they only have informal power, they need the support of the administration in order to be able to manage pastures effectively. This support is obtained through payments. 'A jowro who tries to be correct without paying off the administration will never be able to do anything', the interviewee said.

The yearly entry of livestock into the delta, the dates of which are discussed at annual conferences and widely announced, is a particularly lucrative business. At this time, herders pay fees per head of livestock to the jowros at the various entry points. On the entry dates, key politicians and public administrators tend to show up to claim their shares of the income. In fact, some jowros are said to distribute all the income from these occasions just to keep the powerful people on their side. This corroborates Turner (2006: 61) who states that 'each year virtually all of the money [the jowros] obtain in the form of pasture taxes is spent in the form of bribes'. By distributing these bribes, the jowros establish relations with administrative officers that are indispensable. It has often been stressed to us that the one who pays the most to the administration is also the one who will be most listened to. This also goes for the legal system. Benjaminsen & Ba (2009) report that both sides in a court case they studied complained about all the expenses involved. Millions of FCFA were spent by the parties to cover lawyer fees, court fees, and bribes to judges. Through receiving payments from both parties, the courts' decisions become ambiguous. This again contributes to perpetuating conflicts. In our research, we have often heard complaints that the rural population has become milch cows for state officials.

A judge in the Appeal Court stated that corruption is an important aspect of this conflict and of farmer–herder conflicts in general in the area. He said: 'I do not have proof of corruption, but these conflicts would have been very easy to solve, so it is not difficult to see.'

What is perceived by rural actors as lack of government interest in solving land-use conflicts and the subsequent lack of trust in the government among the rural population can explain why the farmers chose to use violence in this particular case.

Conclusions

This article has investigated the roles of climate variability and environmental conditions on land-use conflicts in the Mopti region in Mali – a heartland of the Sahel. To this end, we collected new data on land-use disputes in the Regional Court of Appeal, which we compared to contemporaneous climate statistics. Moreover, we carried out a detailed case study of one of the conflicts in the delta, to obtain a more thorough understanding of important factors contributing to the outbreak of the dispute. These complementary analyses provide little evidence supporting the notion that water scarcity and rapid environmental change are important drivers of intercommunal conflicts in the Sahel. The statistical comparison of temporal variations in rainfall and variations in land-use disputes in the Court of Appeal revealed little overlap in trends. Tellingly, civil cases, which presumably are less sensitive to climatic variations, followed the same fluctuating pattern as land disputes. We interpret this finding as indicative evidence that land-use conflicts in the delta region are shaped by political and economic contexts (e.g. confidence in the judicial system, economic opportunities, and learning) rather than climate variability.

[13] Several interviewees said that every time there is a change of power, land claims and conflicts increase. This supports the notion by Bierschenk & Olivier de Sardan (2003: 152) that 'each change of political regime at the national level opens the way for the emergence of new local political institutions and new actors on the local political scene'.

The results from the case study of the farmer–herder conflict in Karbaye corroborate this conclusion. Rather than being driven by exogenous pressures on the fertile land, we see this conflict as a result of several structural conditions that are likely to shape a large number of land-use conflicts across the Sahel. First, there is agricultural encroachment on productive key resources for pastoralism and on livestock corridors, obstructing the necessary mobility of herders and animals. This has led to massive loss of dry season pastures that are essential for the survival of the pastoral system. This trend is primarily caused by agricultural policies and laws promoting farming at the expense of pastoralism. Second, decentralization from the early 1990s caused a political vacuum that led rural actors to follow opportunistic strategies to claim ownership of land and natural resources. Third, rent-seeking among government officials has undermined rural people's trust in government institutions and the willingness and interest of officials to solve conflicts. This lack of trust may have contributed to some actors taking action on their own, including using violence to lay claim to resources.

When it comes to the effect of environmental variability on the onset of conflicts, we have observed two different and contrasting scenarios. First, the Sahelian droughts of the 1970s and 1980s led rice farming to move down the riverbed and encroach on the dry season burgu pastures. In this sense, a drought may play a role in causing confrontations between farmers and pastoralists, increasing intercommunal tensions and, quite possibly, escalating latent conflicts to the use of violence. Conversely, as indicated in Figure 5, good rainfall years with generous flooding might also induce more conflicts as the zone of potential contestation is expanded to areas with less established norms of ownership and control. The key factor in avoiding both these scenarios would be better policies and laws recognizing the needs of pastoralists and generally improving the relationship between the government and rural populations.

Replication data

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Climate variability, economic growth, and civil conflict

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Abstract

Despite many claims by high-ranking policymakers and some scientists that climate change breeds violent conflict, the existing empirical literature has so far not been able to identify a systematic, causal relationship of this kind. This may either reflect de facto absence of such a relationship, or it may be the consequence of theoretical and methodological limitations of existing work. In this article we revisit the climate–conflict hypothesis along two lines. First, we concentrate on indirect effects of climatic conditions on conflict, whereas most of the existing literature focuses on direct effects. Specifically, we examine the causal pathway linking climatic conditions to economic growth and to armed conflict, and argue that the growth–conflict part of this pathway is contingent on the political system. Second, we employ a measure of climatic variability that has advantages over those used in the existing literature because it can presumably take into account the adaptation of production to persistent climatic changes. For the empirical analysis we use a global dataset for 1980–2004 and design the testing strategy tightly in line with our theory. Our empirical analysis does not produce evidence for the claim that climate variability affects economic growth. However, we find some, albeit weak, support for the hypothesis that non-democratic countries are more likely to experience civil conflict when economic conditions deteriorate.

Keywords

civil conflict, climate change, climate variability, democracy, economic growth

Introduction

The assessment reports of the Intergovernmental Panel on Climate Change (IPCC, 2001, 2007) and the Stern Review (2007) demonstrate that human activity is contributing in important ways to climatic changes, and that those changes have far-reaching effects on plants, animals, ecosystems, and humanity. Among the wide range

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of negative effects, climate change tends to exacerbate the scarcity of important natural resources, such as freshwater, and it may trigger mass population dislocations (migration) due to extreme weather events, droughts, floods, desertification, and rising sea-levels. Could these developments increase the risk of violent conflict within and between countries?

The IPCC's Third and Fourth Assessment Reports (IPCC, 2001, 2007) as well as a recent study by the German Advisory Council on Global Change (WBGU, 2008) refer to a possible link between climate change and violent conflict. Furthermore, recent scientific work seems to support such a link (Devitt & Tol, 2012; Burke et al., 2009; Miguel, Satyanath & Sergenti, 2004).

High-ranking policymakers have also, on many occasions, warned that climate change may contribute to armed conflict. For instance, UN Secretary-General Ban Ki-moon (2007) has argued that 'The Darfur conflict began as an ecological crisis, arising at least in part from climate change.' President Obama (2009) has stated that 'No nation, however large or small, wealthy or poor, can escape the impact of climate change. More frequent drought and crop failures breed hunger and conflict in places where hunger and conflict already thrive.'

In contrast to such unambiguous statements by some policymakers, even a cursory review of the existing scientific literature reveals that there is rather little consensus on the climate–conflict relationship (for critical reviews, see Buhaug, Gleditsch & Theisen, 2010; Salehyan, 2008; Nordås & Gleditsch, 2007; Gleditsch, 1998). A better understanding of whether or not, and if so under what conditions, climatic changes contribute to violent conflict is very important not only for scientific reasons, but also because of its policy implications. If climatic changes do indeed contribute to violent conflict, this could serve as a powerful argument in favor both of drastic cuts of emissions of greenhouse gases and of providing climate adaptation support to vulnerable countries, which are often also the poorest ones. The recent Himalayan glaciers episode of the IPCC (2010) reminds us, however, that we need robust scientific evidence when advocating costly policies. In addition, a better understanding of pathways leading from climate change to conflict (to the extent they exist) can help in avoiding or reducing, through appropriate policies, conflict-promoting effects of climate change.

In this article, we study the climate change–civil conflict nexus by examining the relationship between climate variability and conflict.[1] We contribute to the existing literature on the climate–conflict relationship (e.g. Buhaug, 2010; Theisen, Holtermann & Buhaug, 2011–12; Burke et al., 2009; Buhaug, Gleditsch & Theisen, 2010; Salehyan, 2008; Raleigh & Urdal, 2007; Hendrix & Glaser, 2007; Miguel, Satyanath & Sergenti, 2004) in several ways. First, while most of the existing literature empirically tests the climate–conflict hypothesis in the form of a direct relationship, we submit that climatic changes are likely to affect the potential for violent conflict via negative effects on economic growth – an argument also adopted in the empirical works of Miguel, Satyanath & Sergenti (2004). Hence our theoretical argument specifies a causal pathway leading from climatic conditions through economic growth to civil conflict, and our empirical analysis is designed to test this two-step causal argument. Second, we argue that political system characteristics, notably democracy, may mediate conflict-promoting effects of sluggish economic growth. By implication, we argue that democratic systems are likely to be better equipped for avoiding violent conflict when climatic changes reduce economic growth.[2] Third, we employ a measure of climate variability that we think is better suited for identifying the effects of climatic developments on the probability of civil conflict. This measure takes into account that choices regarding production structures (e.g. crop choices, methods of cultivation, choices regarding infrastructures and energy production) tend to be climate-specific and are also adapted to persistent changes in climatic conditions.

The next section reviews the relevant literature. We then develop the theoretical argument. In the fourth section we discuss the empirical approach, and then present the results in the subsequent section. The final

[1] Climate change is a phenomenon that unfolds over long periods of time. This poses difficulties for testing directly its relationship with political and economic developments; reliable information on the latter variables (in particular economic performance) is available only for the past few decades, especially for countries that have experienced civil conflict (e.g. sub-Saharan countries). Consequently, we examine the effects of climate *variability* on conflict onset. While climate change and climate variability are different analytic constructs, they are likely to have common effects on conflict. For instance, studying the effects of a persistent period of high temperatures could yield imperfect yet useful insights into the effects of global warming.

[2] Brückner & Ciccone (2007) also argue that democratic institutions might mediate civil war onset (if measured using the more than 1,000 battle deaths threshold) better than autocratic ones when economic conditions deteriorate. In their empirical analysis, however, they instrument economic growth with international commodity price growth.

section summarizes the findings and discusses their policy implications.

Literature review

One major consequence of global warming could be greater scarcity and variability of renewable resources in many parts of the world (IPCC, 2001, 2007). With increasing concerns about such global effects of climate change, a group of scholars, commonly referred to as neo-Malthusians, posits that climate change is a threat to international security because it could increase resource scarcity (WBGU, 2008; Homer-Dixon, 1999; Homer-Dixon & Blitt, 1998; Bächler et al., 1996). Other scholars, commonly referred to as cornucopians or resource optimists, do not share this pessimistic view. They believe that humanity can adapt to increasing resource scarcity through appropriate market mechanisms (pricing), technological innovation, and other means (Lomborg, 2001; Simon, 1998).

The neo-Malthusian argument has been criticized for being overly complex and deterministic, and for ignoring important economic and sociopolitical factors (e.g. Gleditsch, 1998; Barnett & Adger, 2007; Salehyan, 2008). Critics have argued that scarcity of renewable resources is only one of the many factors in the overall relationship between climate change and conflict. Buhaug, Gleditsch & Theisen (2010) reject the idea that climate change has a direct effect on the likelihood of conflict and propose several causal pathways through which economic and political instability, social fragmentation, and migration could increase the probability of climate change leading to armed conflict.

Qualitative case studies provide some, albeit anecdotal evidence that climatic factors can induce environmental degradation (such as increased water scarcity, soil degradation, or deforestation) and contribute to conflict in some parts of the world (e.g. the Sahel region). But it remains unclear to what extent these case-specific findings can be generalized. Large-N studies have, so far, not been able to provide conclusive evidence in support of one or the other side in the debate. As the brief literature review below shows, persisting disagreement is at least in part due to the use of different measures of climatic change, and different sample sizes and time periods.

Hendrix & Glaser (2007) examine the impact of short-term climatic changes (interannual variability in rainfall) on civil conflict onset in sub-Saharan Africa. They report that positive changes in rainfall significantly decrease the conflict risk in the following year. Similarly Miguel, Satyanath & Sergenti (2004) – henceforth referred to as MSS – study 41 African countries in 1981–99 and find that lower rainfall growth reduces economic growth and, indirectly, increases the probability of intrastate conflict. Brückner & Ciccone (2007, 2010), on the other hand, do not find any significant effects of rainfall growth on civil war onset. Jensen & Gleditsch (2009) point out that MSS's finding is due to the inclusion of cases where countries participate in civil wars in other states. They show that exclusion of these cases reduces the estimated effects of rainfall growth on civil conflict. Ciccone (2011) also re-evaluates the MSS findings using rainfall levels instead of rainfall growth rates. He reports that lower rainfall levels are associated with a lower probability of civil conflict. Ciccone's criticism of MSS has two components. First, he claims that the use of rainfall growth rates is not an appropriate measure of a rainfall shock because of mean reversion in rainfall levels. This means that the growth rate of rainfall may take a negative value and indicate an adverse effect of climate variability on economic conditions even when the level of rainfall is above its normal level. Second, if the growth rate of rainfall is indeed the relevant climatic variable, then the estimation can still be done using rainfall levels, but it imposes testable sign restrictions on the various lagged levels. According to Ciccone, these sign restrictions are not satisfied by the coefficients estimated by MSS. Ciccone's first – and most important – criticism seems compelling. The second one, however, is more difficult to implement without strong exclusion restrictions (see Miguel & Satyanath, 2010).

Hendrix & Salehyan (2012) also focus on Africa. They investigate the effect of deviations from normal rainfall patterns on civil conflict as well as civil unrest (e.g. riots, strikes) during the last 20 years. They find that wetter and drier than normal conditions are associated with both civil conflict and civil unrest. Zhang et al. (2007) hypothesize that climate change affects conflict through its effects on agricultural productivity. Bivariate correlations over the period 1400–1900 indicate that changes in average temperature are related to changes in agricultural production and the frequency of wars. Devitt & Tol (2012) rely on a simulation model to examine the interaction between climate change, economic growth, and civil war. They report that climate change (higher temperature) through its negative impact on economic growth will increase the probability of civil war by 1% in Lesotho in 2100. Theisen, Holtermann & Buhaug (2011–12), using various drought measures, do not find any effect of drought on civil conflict in Africa during the 1960–2004 period. Burke et al. (2009), on the other hand, find that temperature increases in Africa between 1981 and 2002 have a significant, positive effect on the occurrence of civil war. Buhaug (2010) shows, however, that this result is not robust to alternative model specifications. He also finds that climate variability, measured as interannual growth and deviation from annual mean precipitation and temperature, is a poor predictor of civil conflict. Bergholt & Lujala (2012) also do not find significant effects of hydro-meteorological disasters (an instrument for economic growth) on the likelihood of civil conflict.

Most research in this area has focused on identifying a direct link between climatic conditions and conflict.[3] The absence of a direct effect, however, does not necessarily imply the absence of any effect. An alternative, useful research strategy is to look for conditional effects that vary with the level of economic performance and the political system in place. Furthermore, the use of growth rates in rainfall might not be a suitable measure because rainfall growth is mean reverting (see Ciccone, 2011; Buhaug, 2010). It may thus fail to capture the true economic impact of rainfall because it is not conditioned on its 'normal' level. In this article we propose a politically moderated relationship between climate change and conflict that involves conditional effects (through economic performance and political institutions). Moreover, we evaluate this relationship using a measure of climatic conditions that is both more compelling theoretically and more immune to problems of endogeneity.

A politically moderated relationship

Our argument starts with the assumption that climate change per se is unlikely to trigger civil conflict. However, it is possible that certain changes in rainfall and temperature, coupled with volatile weather patterns swinging between extremes, could reshape the productive landscape of entire regions and exacerbate food, water, and energy scarcities, as envisaged in the traditional resource scarcity (neo-Malthusian) model. Consequently, we argue that climatic changes, through their effects on economic growth, might induce competition among groups inside a state and thus increase the likelihood of conflict. However, violence is likely to occur only in states where the capacity for dealing with climate-induced economic deterioration and associated conflict potential is low. We argue that democratic institutions, such as those imposing constraints on the executive, separating power, creating a large number of veto players in public policymaking, and safeguarding property rights, collectively serve to strengthen the rule of law and thus mitigate conflict. The remainder of this section elaborates on the pathway through which climate variability could, via its effects on economic conditions, lead to civil conflict.

Climate change and economic growth

Climate and weather can impact on many human activities, from leisure to agriculture to industrial production. However, estimating the consequences of climate change for economic growth is difficult. The main reason is that the impact of climate change will vary with levels of economic development and the political capacity of a country, with levels and types of climatic conditions (more/less rain, higher/lower temperature, more/less frequent and/or intense storms, etc.). In other words, although economic and political actors respond to climatic conditions by developing and implementing adaptation strategies, their ability to do so depends critically on institutional, economic, and technological capabilities.

The existing literature provides some evidence that climatic changes affect economic output (GDP), for example by reducing agricultural yields when temperature rises (precipitation falls) (e.g. Mendelsohn et al., 1998; Mendelsohn, Dinar & Williams, 2006; Nordhaus & Boyer, 2000; Tol, 2002; Deschenes & Greenstone, 2007; Barrios, Bertinelli & Strobl, 2010). Such evidence also suggests that climatic changes should affect economic growth. One can even suspect that the effect on economic growth is more distinct: if climatic changes affected only the level of economic output, we would observe mostly a short-term effect. This should be the case as for example a rise in temperature (decrease in precipitation) would be compensated by subsequent temperature decreases (precipitation increases) – due, for example, to stringent abatement of emissions – which should then return the GDP to its previous level. But this is not the case if climatic changes affect economic growth. The reasons are the following. First, economic growth will be lower even if GDP returns to its previous level because of forgone consumption and investment due to lower income during the period of higher temperature (lower precipitation). In addition, as long as countries spend some resources adapting to climatic changes, they incur opportunity costs in terms of not spending these resources on R&D and capital investment. This has negative effects on economic growth. Moreover, given the short time series used in existing research on the effects of climate on economic

[3] Bergholt & Lujala (2012), Zhang et al. (2007), Miguel, Satyanath & Sergenti (2004) are notable exceptions.

conditions, even slightly persistent effects on the level of output will impact on the sample mean of growth. That is, using economic growth rates will also capture the effects on GDP levels. But using the level of GDP instead of its growth rate may miss the effects on the growth rate. For these reasons we concentrate on the effects of climate variability on economic growth.

The empirical literature offers some evidence that climatic conditions affect economic growth. For instance, Miguel, Satyanath & Sergenti (2004) find that rainfall growth increases economic growth in Africa. Dell, Jones & Olken (2008) show that higher temperatures have negative effects on economic growth, but only in poor countries, whereas precipitation has no effect. Hence we expect that climate variability should affect economic growth.

Economic growth and conflict

Previous research has shown that reduced levels of domestic economic activity tend to create incentives for conflict.[4] Building on this research, we posit that climate change, by reducing economic growth, affects the utility of individuals and groups to engage in civil conflict. It does so in two ways: first, negative climatic conditions, via their negative effect on economic growth, can reduce resources available to the government (e.g. by reducing tax revenue). The government thus has fewer resources to invest in people, for instance to provide better nutrition, schooling, and on-the-job training that would lead to improved living conditions. It also has fewer resources to provide for the people, for example in terms of sustaining peace through the maintenance of law and order – the latter, for instance, lowers the probability of rebel victory by increasing the cost of rebellion.

Second, climate-related phenomena, such as lower precipitation, higher temperature, and extreme weather events lead to lower personal income from production and also decrease the opportunity for future employment. Consequently, the opportunity cost of rebellion decreases because the expected returns from peaceful employment, say farming, compared to joining criminal or insurgent groups are lower. In situations like these, when individuals expect to earn more from criminal or insurgent activity than from lawful and peaceful activity, predatory behavior becomes more likely. The latter implicates conditions in which each individual or group effort to increase its own welfare reduces the welfare of others and also increases the probability of mutual attacks (Jervis & Snyder, 1999).

The argument that poverty breeds conflict and war is supported by several empirical studies (e.g. Hidalgo et al., 2010; Dube & Vargas, 2008; Hegre & Sambanis, 2006; Collier & Hoeffler, 2004; Miguel et al., 2004; Fearon & Laitin, 2003). For example, Collier & Hoeffler (2004) find that low economic growth, which is a proxy for foregone earnings, increases the risk of conflict. Dube & Vargas (2008) show that a drop in the price of coffee substantially increased the incidence and intensity of intrastate conflict in coffee-intensive areas in Colombia in 1994–2005. They attribute this result to the lowering of opportunity costs of joining a rebel movement (via depressed wages) in these areas. Hidalgo et al. (2010) also show that land invasions by the rural poor in Brazil occur immediately after adverse economic shocks, which in the statistical analysis are instrumented by rainfall.

Political regimes/institutions and conflict

As discussed above, we expect the probability of violent conflict to increase when economic conditions deteriorate due to climatic changes: individuals anticipate that their returns from labor diminish, and the ability of the government to provide goods and services for the people and to maintain order decays. This decreases the opportunity costs of engaging in political violence. We submit, however, that armed conflict is more likely to occur in states where existing institutions and mechanisms for conflict resolution cannot provide people with the assurance that climate-induced economic problems will be resolved without recourse to violence. Formal institutions that help enforce commitments intertemporally can mitigate commitment problems in situations in which each individual or group's effort to increase its own well-being reduces the well-being of others.[5] Consequently we posit that democratic institutions that 'restrain the dark side of self-interest',[6] such as a constrained executive and separation of powers, a civil society, elections, an independent judiciary, as well as the rule of law, collectively work to reduce the risk of conflict. Conversely, societies with weak government institutions and few checks and balances are likely to be more prone to armed conflict. This implies that autocratic countries are more likely to experience intrastate

[4] See Chassang & Padro-i-Miquel (2010), Garfinkel & Skaperdas (2007), Collier & Hoeffler (2004), Fearon & Laitin (2003). See also Blattman & Miguel (2010) for a critical review of the literature.

[5] See Powell (2006) on the commitment problem and Snyder & Jervis (1999) on mutual fears and security.

[6] Skaperdas (2003: 135).

conflict than democratic countries when economic conditions deteriorate due to climatic changes.

The main reasons why democracies are expected to mitigate conflict are the following: in democratic political systems citizens are informed by independent mass media about the state of their environment and economy as well as government policies and they can thus subject their government's actions to close scrutiny. They also have the opportunity to express freely their opinions and organize around alternative political views (Payne, 1995). Political parties are not only instrumental in aggregating preferences and representing interests, thus solving the collective action problem, but also in managing conflict since they help decrease uncertainty about the intentions and actions of important political actors (Aldrich, 1994). Moreover, through electoral mechanisms opposition parties are free to redress their grievances[7] and express their preferences without state repression. Elections also provide political leaders with incentives to satisfy their citizens' demands if they wish to retain power. In addition, since democratic political leaders are responsive to a larger winning coalition and lack sufficient resources to reward their comparatively large group of supporters with private goods, they have to resort to the provision of public goods – including economic prosperity – to ensure political support and, thus, their survival in office (Bueno de Mesquita et al., 2003). Furthermore, an independent legislature ensures the representation of a broad range of interests and also guarantees that no group will have to suffer from (governmental) policies and actions that are considered to be detrimental to its own interests. Finally, an independent judiciary, by ensuring that the rule of law is observed and maintained, preserves political stability and increases the legitimacy of the state.

Studies on the relationship between political institutions and intrastate conflict have mostly focused on the effects of democracy and have thus far produced mixed results. While several studies (e.g. Collier & Hoeffler, 2004; Fearon & Laitin, 2003) find that democracy is not a good predictor of the probability of intrastate conflict, others (e.g. Gleditsch & Ruggeri, 2010; Elbadawi & Sambanis, 2002) show that democracy has a negative effect on civil conflict onset. Furthermore, Gleditsch, Hegre & Strand (2009), Reynal-Querol (2002), Sambanis (2001), and Hegre et al. (2001) find that partly democratic countries (that is, semi-democracies, meaning regimes in the middle range of the democracy–autocracy Polity index) are more prone to intrastate conflict than full democracies and full autocracies. All these studies, however, examine the direct effect of democracy on intrastate conflict, whereas we are interested in the interaction effect of democracy and climate-impacted economic growth on intrastate conflict.[8]

Methods and data

We test our argument on the climate variability–economic growth–conflict relationship using panel data from all countries of the world in the period 1980–2004.

Rather than using an instrumental variable approach merely as a technical solution, as previous studies have done (e.g. Miguel et al., 2004), our theoretical considerations suggest that climate variability may indirectly affect the probability of intrastate conflict via its effect on economic growth. For this reason we employ a two-stage procedure,[9] taking into account that conflict and the state of the economy are not independent of each other (see Blomberg, Hess & Thacker, 2006; Blomberg & Hess, 2002). We use measures of precipitation and temperature to estimate per capita economic growth in the first stage of the model (subscript 1):

$$\begin{aligned}\text{growth}_{it} = \alpha_{1i} + \beta_{1,0}\text{Pre}_{it} + \beta_{1,1}\text{Temp}_{it} \\ + c_1 X_{it} + d_1 \text{year} + e_{1it}\end{aligned} \tag{1a}$$

where *Pre* and *Temp* are measures of climate variability, *X* are other exogenous variables, *year* denotes a linear time trend, β, c and d are coefficients to be estimated, α is a country fixed effect (see below) and e is an iid error term.

In order to be able to introduce an interaction term between economic growth and a country's political system in the second stage, we estimate

$$\begin{aligned}\text{growth}_{it} * \text{democracy}_{i,t-1} = \alpha_{1i} + \beta_{1,0}\text{Pre}_{it} \\ + \beta_{1,1}\text{Temp}_{it} + c_1 X_{it} + d_1 \text{year} + e_{1it}\end{aligned} \tag{1b}$$

We then estimate the effect of predicted income growth and the predicted interaction term on intrastate conflict in the second-stage equation (subscript 2):

[7] Reynal-Querol (2002) argues that what matters for conflict is not necessarily the degree of democracy but rather the type of democracy. She shows that proportional representation systems have a lower probability of experiencing a civil war than majoritarian ones because such systems are likely to be more inclusive and hence curb grievances.

[8] Gizelis & Wooden (2010) make a similar argument pertaining to the impact of water scarcity on conflict and find evidence that democracy mediates water scarcity on civil conflict onset.

[9] A similar procedure is employed by Bergholt & Lujala (2012).

$$\begin{aligned} \text{conflict}_{it} &= \alpha_{2i} + \gamma_{2,0}\text{growth}_{i,t-1}(\text{predict}) \\ &\quad + \gamma_{2,1}\text{democracy}_{i,t-1} + \gamma_{2,2}(\text{growth}_{i,t-1} \\ &\quad * \text{democracy}_{i,t-1})(\text{predict}) + c_2 Z_{it} + d_{2,1}\ \text{peaceyears} \\ &\quad + d_{2,2}\ \text{peaceyears}^2 + d_{2,3}\ \text{peaceyears}^3 + e_{2it} \end{aligned} \tag{2}$$

Equation (1) is estimated using the fixed effects vector decomposition (fevd) estimator by Plümper & Tröger (2007). This estimator allows us to include time invariant variables alongside country fixed effects. We also correct for autocorrelation.

Equation (2) is estimated using logit regression with bootstrapped standard errors.[10] To model temporal dependence, time since the last conflict as well as the squared and cubic terms (peaceyears) are included in the model (Carter & Signorino, 2010). This approach acknowledges that the likelihood of intrastate conflict onset at present depends strongly on conflict that occurred in the years before and thus controls for time effects.

Variables and data sources

Economic growth. The dependent variable in the first equation is economic growth. We use the data on economic growth from the Penn World Tables Version 6.2 (Heston, Summers & Aten, 2006).

Onset of civil conflict. We use data on civil conflict onset from the Onset of Armed Conflict Dataset, a joint project of the Uppsala Conflict Data Program and the Centre for the Study of Civil War at the Peace Research Institute Oslo (see Gleditsch et al., 2002). An armed civil conflict is defined in the UCDP/PRIO database (Strand, 2006) as a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which one is the government of the state, results in at least 25 battle-related deaths. We use the onset variable that specifies a nine-year intermittency threshold. This means that for a new conflict onset to occur, the country must not have had any civil conflict within the past nine years.

Climate variables. We use measures of precipitation and temperature to estimate the impact of climate on economic growth and subsequently on the probability of conflict onset. While many environmental variables such as water scarcity and soil erosion are directly affected by human behavior, climate variability is a large-scale phenomenon that is beyond human control at the *local* level and within the *short to medium* term. Thus, using precipitation and temperature avoids the endogeneity problem that plagues much of the literature on the neo-Malthusian hypothesis.

Our climate variables are defined in terms of the deviation of the current level of precipitation and temperature from their past, long-run level (defined as a 30-year moving average of past values). In the existing literature, most studies use levels of rainfall and/or growth in rainfall (e.g. Miguel et al., 2004; Hendrix & Glaser, 2007; Brückner & Ciccone, 2007, 2010) and precipitation/temperature deviation from the sample mean (i.e. Buhaug, 2010; Hendrix & Salehyan, 2012). We believe that Ciccone's (2011) criticism of studies that use the growth rate of rainfall is appropriate. Nonetheless, his proposed measure of rainfall levels is problematic because of the possibility that the choice of production structure (e.g. crop choices, choices regarding infrastructure and energy production) may be climate-specific. If so, then the level of rainfall does not accurately capture the economic consequences of climatic variability. For example, high rainfall levels in a region that is adapted to dry weather conditions could be as detrimental as low rainfall in a region that is adapted to wet conditions. Country fixed effects cannot deal with this problem to the extent there is adaptation to changing climatic conditions.[11] Hence our climate measure has an advantage over those that simply rely on levels.

Our data sources are the Global Precipitation Climatology Centre (GPCC) (Beck, Grieser & Rudolf, 2004), the Climatic Research Unit (Mitchell & Jones, 2005) for precipitation, and CRUTEM3 (Brohan et al., 2006) and the Climatic Research Unit (CRU) (Mitchell & Jones, 2005) for temperature. As a robustness check we use the Standardized Precipitation Index (SPI6) (McKee, Doesken & Kleist, 1993).

[10] Another possibility would be to use the estimator proposed by Maddala (1983), which is designed to test a two-equation system with a dichotomous endogenous variable (see also Keshk, 2003). In contrast to the approach described by Maddala (1983), we need to incorporate in the second equation the interaction effect between democracy and the predicted values for economic growth from the first equation. Doing so in the context of Maddala's approach is, however, not straightforward. This is why we opted for the procedure described above.

[11] While the commodities price index used by Brückner & Ciccone (2007, 2010) seems more informative than current growth in rainfall, it is still not as appropriate as our measure because it may suffer from endogeneity problems, and it is not as country-specific as the climate variable.

Political institutions (xpolity). Our indicator for democracy is based on the combined Polity score from the Polity IV dataset. Polity assigns scores to democracy according to three components: competitiveness of executive recruitment (XRCOMP), openness of executive recruitment (XROPEN), and competitiveness of participation (PARCOMP). Since the competitiveness of participation component makes explicit reference to civil conflict (Vreeland, 2008), we use the xpolity data by Vreeland (2008), which excludes the participation dimension of the original Polity IV data. We also check the robustness of our results using the original Polity IV index (Marshall & Jaggers, 2004). To capture the interaction effect between a country's political institutions and growth in the second equation, we introduce an interaction term between the two variables.[12]

Control variables

GDP per capita and initial per capita income. Since income convergence plays a key role in all economic growth theories and is always included in empirical studies of economic growth, we use the initial real income to capture convergence factors. In addition, we include the lagged value of the log of GDP per capita to control for the stylized fact that poverty breeds conflict, that is, the hypothesis that civil conflict is observed mostly in poor countries. We use data from Gleditsch (2002), which is an enhanced version of the Penn World Tables Version 6.2 (2006).

Population. We include population size and population growth because population is considered to be an important determinant of civil conflict (North, 1984; Homer-Dixon, 1999; Hegre & Sambanis, 2006). For example, North (1984) claims that a growing population creates an increasing demand for resources and concludes that states with high population growth and inadequate resources are more conflict prone. Fearon & Laitin (2003) also argue that a large population implies difficulties in controlling local level activity and increases the number of potential rebels that can be recruited by the insurgents. Simon (1998), however, posits that as long as population growth stimulates advances in technology, the economic motivation for territorial expansion will diminish and wars driven by population growth may be less common in the future. We use data from Gleditsch (2002).

Ethnolinguistic fractionalization. Although there is disagreement in the literature on the relationship between the heterogeneity of a country's population and its propensity for intrastate conflict (e.g. Fearon & Laitin, 2003; Cederman & Girardin, 2007), we account for the possibility that ethnolinguistic fractionalization affects the potential for civil conflict. We use data from Fearon & Laitin (2003).

Rough terrain. Fearon & Laitin (2003) argue that mountainous countries are likely to experience a higher risk of civil conflict because rebels find it easier to hide in mountains and forests. We control for this potential effect, measuring rough terrain by the estimated percentage of mountainous terrain and using data from Fearon & Laitin (2003).

Oil-exporting countries. Proponents of the 'resource curse' argument claim that civil conflict is more likely in oil-producing countries. The reason is that 'oil revenues raise the value of the "prize" of controlling state power' and oil-exporting countries tend to have weaker state apparatuses (Fearon & Laitin, 2003: 81). To control for this possibility we include an indicator for countries in which oil constitutes more than one-third of export revenues. We use data from Fearon & Laitin (2003).

Regional dummy variables and time trend. We include regional dummy variables, with Europe serving as the baseline category, to control for any regional variation in both economic growth and conflict. We also introduce a linear time trend in the model to explain economic growth.

Descriptive statistics are shown in the Appendix.

Results

Table I reports the results from the regression of income growth on climate variability and the control variables described above. It does so for two samples: all countries and African countries only.

We conduct a separate analysis for Africa because much of the existing literature focuses on Africa (and often on sub-Saharan Africa only). The reason for focusing on Africa is that agriculture is the most important sector in these economies and a high percentage of the

[12] Democracy could be endogeneous to conflict, in which case we should have an instrument for democracy (Elbadawi & Sambanis, 2002). However, given our interest in the mediating effect of democracy on conflict, we believe that the lag value of the xpolity is sufficient to alleviate endogeneity concerns.

population lives in rural areas. At the same time, water storage capacity (dams, reservoirs) and the percentage of irrigated land in Africa are the lowest in the world. In combination with low economic and state capacity, this is likely to make these countries more vulnerable to climatic changes. African countries also experience more frequent civil conflict than other parts of the world. Hence they constitute critical cases. That is, if we cannot detect a climate variability effect on civil conflict in Africa, such an effect is, presumably, unlikely to exist in other parts of the world. We think that this justification sounds plausible, but also think that an explicit empirical test is better, notably because agriculture is also important in other regions of the world, for example in Asia and Latin America, and because climate variability is occurring in other regions as well.

The results show that there is no statistically significant impact of climate variability on economic growth. This finding is independent of the sample used. Hence our analysis does not support the argument that economic growth is affected by climate variability. Table II reports the results from the regression of civil conflict onset on predicted economic growth.[13]

Because we use a multiplicative term of lagged predicted growth and lagged democracy, the main effect of interest in this regression is best understood when presented in graph form. Figure 1 shows the coefficients of predicted economic growth on the likelihood of civil conflict onset at different values of the democracy variable for the sample including all countries. If the vertical lines, which show the confidence intervals of the respective point estimate, do not cross the zero line, the coefficient on predicted economic growth is significant for the respective value of the democracy variable. Figure 1 shows that predicted economic growth has a statistically significant effect on civil conflict onset for certain xpolity scores that indicate autocracies, but not in democracies. However, Figure 2 does not confirm this result for the African subsample. Here the coefficients of predicted economic growth never reach standard significance levels for any xpolity score.[14] Overall, the results from the second stage estimation offer some, albeit weak, support for the theoretical argument that economic growth can have an effect on civil conflict primarily in non-democratic countries.

Table I. Climate variability and economic growth

	(1) World, MA 30	*(2) Africa, MA 30*
Temperature MA 30	–0.22	–1.13
	(0.53)	(3.83)
Precipitation MA 30	0.00	0.00
	(0.00)	(0.00)
Xpolity, lagged	–0.05	0.02
	(0.35)	(0.50)
Population growth	11.98	47.13**
	(11.49)	(20.22)
Log population, lagged	3.65	–3.69
	(6.35)	(34.17)
Log GDP/capita, lagged	–9.43***	–6.27
	(2.18)	(6.97)
Trend	0.15	0.10
	(0.25)	(0.98)
Oil	0.52	3.62
	(2.86)	(29.29)
Ethnic fractionalization	–6.33	–1.77
	(4.85)	(66.55)
Rough terrain	–2.07	0.91
	(1.35)	(14.24)
GDP initial	0.00**	0.00
	(0.00)	(0.01)
North Africa	–12.15*	
	(7.38)	
Sub-Saharan Africa	–15.08***	
	(4.81)	
East Asia	–7.24	
	(4.77)	
West Asia	–13.79	
	(8.60)	
Middle East	–8.07	
	(6.85)	
Latin America	–6.88	
	(4.53)	
North America	–0.78	
	(12.75)	
η	0.87	0.96
	(0.00)	(0.00)
Constant	52.91	71.11
	(34.63)	(184.98)
Observations	2818	1321
R-squared	0.16	0.10

Standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.
Both models are estimated using the fixed effects vector decomposition (fevd) estimator by Plümper & Tröger (2007).

[13] Although we use the two-stage procedure for theoretical reasons, the second-stage results should be interpreted with caution since we do not find a significant impact of climate variability on economic growth in the first stage.
[14] Miguel, Satyanath & Sergenti (2004) did not find any significant interaction effects between economic growth and democracy in their study of African countries.

Table II. Predicted economic growth and civil conflict

	(1) World conflict, MA 30	(2) Africa Conflict, MA 30
Predicted growth, lagged	–0.04	–0.16*
	(0.07)	(0.09)
Xpolity, lagged	0.03	0.08
	(0.05)	(0.06)
Predicted (Polity*growth), lagged	0.02	–0.01
	(0.02)	(0.03)
Population growth	7.28	15.94
	(6.77)	(10.36)
Log population, lagged	0.21	0.10
	(0.13)	(0.17)
Log GDP/capita, lagged	–0.78***	–0.92**
	(0.26)	(0.38)
Oil	1.23**	0.42
	(0.50)	(0.66)
Ethnic fractionalization	1.15	0.04
	(0.77)	(0.98)
Rough terrain	–0.07	0.13
	(0.18)	(0.20)
GDP initial	–0.00	0.00
	(0.00)	(0.00)
North Africa	–1.02	
	(1.20)	
Sub-Saharan Africa	–2.34*	
	(1.25)	
East Asia	–2.38***	
	(0.86)	
West Asia	–1.19	
	(0.97)	
Middle East	–2.08*	
	(1.08)	
Latin America	–1.10	
	(0.99)	
Peace years	–0.09	0.08
	(0.09)	(0.15)
Peace years^2	0.01	–0.00
	(0.01)	(0.01)
Peace years^3	–0.00	0.00
	(0.00)	(0.00)
Constant	1.45	0.70
	(2.39)	(2.64)
Observations	2,746	1,356
Log likelihood	–227.1	–177.1
Pseudo R2	0.132	0.0541

Bootstrapped standard errors in parentheses.
* significant at 10%; ** significant at 5%; *** significant at 1%.

As to the control variables, only oil production has a positive and statistically significant effect on conflict in the global sample, whereas the log of GDP per capita has a negative effect. Presumably due to the lower number of observations, only the log of GDP per capita has a significant and negative effect in the African sample.

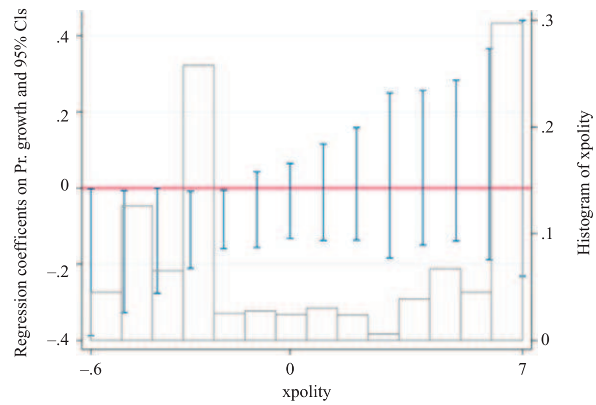

Figure 1. Coefficients of predicted economic growth on civil conflict at different levels of democracy
MA 30 in first stage of the model; fixed effects vector decomposition estimator; sample: world.

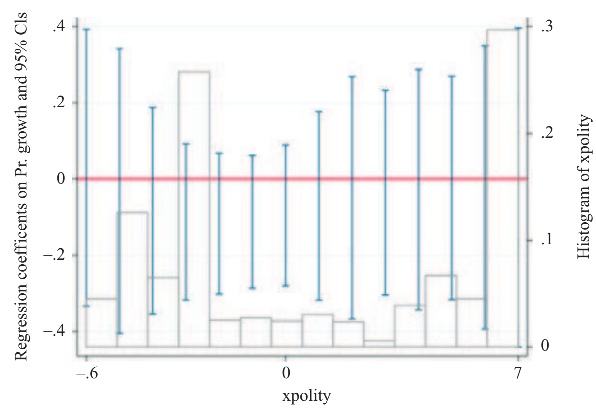

Figure 2. Coefficients of predicted economic growth on civil conflict at different levels of democracy
MA 30 in first stage of the model; fixed effects vector decomposition estimator; sample: Africa.

Robustness checks

We have evaluated the robustness of our results to the estimation procedure and to the specification of the variables. Using a fixed effects procedure instead of the fixed effects vector decomposition (fevd) estimator does not change the main results (Tables III and IV). However, in contrast to Figure 1, we do not see a significant effect of predicted growth on the likelihood of conflict onset in Figures 3 and 4. Hence the conclusion that the effect of economic growth on civil

Table III. Climate variability and economic growth

	(1) *World, MA 30*	*(2)* *Africa, MA 30*
Temperature ma30	0.01	–0.56
	(0.25)	(0.55)
Precipitation ma30	0.00	0.00
	(0.00)	(0.00)
Xpolity, lagged	–0.06	–0.01
	(0.06)	(0.10)
Population growth	12.10*	–5.38
	(6.22)	(15.99)
Log population, lagged	–8.68***	–4.64
	(1.63)	(3.34)
Log GDP/capita, lagged	–10.13***	–6.17***
	(0.74)	(0.91)
Trend	0.39***	0.13
	(0.04)	(0.09)
Constant	151.49***	83.59***
	(16.58)	(26.92)
Observations	3087	1471
R-squared	0.07	0.04

Standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%.
Both models are estimated using the fixed effects estimator.

conflict is mediated by a country's political system seems fragile.

Using SPI6, instead of our climate variability indicator, does not make any difference either (Tables A.I and A.II in the Web Appendix). Similarly, the figure presenting the interaction effect between predicted growth and xpolity (Figure A.1) resembles Figure 1: if we include all countries of the world we see that economic growth has a negative effect on civil conflict in autocratic countries only. In the same vein, the results are immune to replacing the xpolity indicator of Vreeland (2008) by the standard Polity IV index (see Tables A.III and A.IV in the Web Appendix). Using a threshold of 1,000 rather than 25 battle-related deaths to measure conflict onset does not change the results either (Tables A.V and A.VI in the Web Appendix).

Finally, we ran our regression models on a sample including particularly poor countries, namely those defined as 'the bottom billion' by Collier (2007), using the same list of countries as Buhaug, Falch & Gleditsch (2010). The logic is that poorer countries are more vulnerable to climate variability and should thus experience a greater risk of conflict due to lower capacity to adapt to negative effects of climatic changes on growth. Although fixed effects may capture the vulnerability of a country to climatic changes, we also address such vulnerability by running robustness checks with two subsamples: Africa, and all poor countries. Again the results remain the same (See Tables A.V and A.VI in the Web Appendix).

Table IV. Predicted economic growth and civil conflict

	(1) *World conflict, MA 30*	*(2)* *Africa Conflict, MA 30*
Predicted growth, lagged	–0.03	–0.16
	(0.07)	(0.13)
Xpolity, lagged	0.05	0.06
	(0.05)	(0.05)
Predicted (Polity*growth), lagged	0.01	0.03
	(0.04)	(0.05)
Population growth	2.01	15.87
	(4.47)	(11.76)
Log population, lagged	0.34	–0.53
	(0.98)	(0.55)
Log GDP/capita, lagged	–1.02	–1.78*
	(1.23)	(1.08)
Oil	1.09***	0.33
	(0.36)	(0.56)
Ethnic fractionalization	0.97*	0.18
	(0.57)	(0.79)
Rough terrain	–0.01	0.11
	(0.12)	(0.15)
GDP initial	–0.00**	–0.00
	(0.00)	(0.00)
North Africa	–0.71	
	(0.57)	
Sub-Saharan Africa	–1.75***	
	(0.56)	
East Asia	–1.79***	
	(0.67)	
West Asia	–1.02*	
	(0.56)	
Middle East	–1.59*	
	(0.88)	
Latin America	–1.26*	
	(0.70)	
Peace years	–0.06	–0.01
	(0.07)	(0.14)
Peace years^2	0.00	0.00
	(0.00)	(0.01)
Peace years^3	–0.00	–0.00
	(0.00)	(0.00)
Constant	2.34	13.43
	(5.90)	(11.90)
Observations	3,236	1,525
Log likelihood	–293.7	–204.6
Pseudo R2	0.110	0.0407

Bootstrapped standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

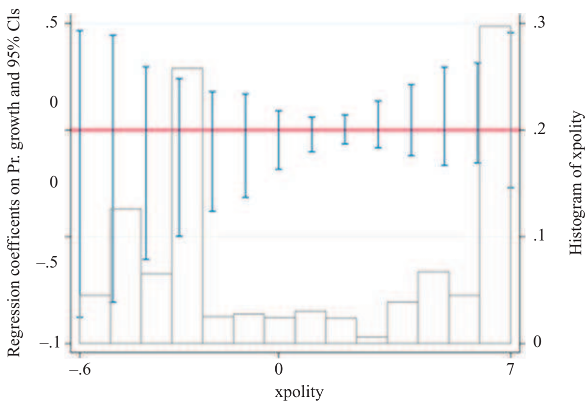

Figure 3. Coefficients of predicted economic growth on civil conflict at different levels of democracy
MA 30 in first stage of model; fixed effects estimator; sample: world.

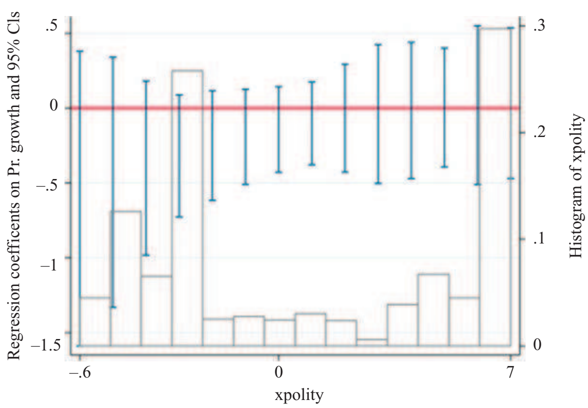

Figure 4. Coefficients of predicted economic growth on civil conflict at different levels of democracy
MA 30 in first stage of model; fixed effects estimator; sample: Africa.

Conclusion

Whether increasing local or regional climate variability due to large-scale, human-induced changes in the global atmosphere is associated with an increased risk of violent conflict remains contested, both among policymakers and in academic circles. In this article we contribute in two ways to the existing literature on the climate change–conflict nexus. First, we conceptualize this nexus in terms of a two-stage process in which climatic variability affects the probability of violent intrastate conflict via climate effects on economic growth, and where these effects may be contingent on political system characteristics. Second, we employ a measure of climatic variability that has advantages over those used in the existing literature, primarily because it takes into account the adaptation of economic activity to persistent climatic changes.

Our results suggest that climate variability, measured as deviations in temperature and precipitation from their past, long-run levels (a 30-year moving average), does not affect violent intrastate conflict through economic growth. This finding is important because the causal pathway leading from climate variability via (deteriorating) economic growth to conflict is a key part of most theoretical models of the climate–conflict nexus.

While our empirical results provide no support for the climate change–economic growth–conflict pathway, further research is required before we can move towards closure of the debate. In particular, it would be very useful to improve on existing indicators of climatic variability, adaptation to climate variability, and relevant (from the viewpoint of violent conflict) economic performance. For instance, in the absence of appropriate indicators for adaptation it remains difficult to estimate the effect of climatic variability on economic performance and hence on the probability of violent conflict.

Finally, our results offer only very weak support for a mediating effect of political system characteristics. Whereas some of our empirical models suggest that deteriorating economic growth can increase the likelihood of violent conflict in autocratic countries, this finding is fragile with regard to model specification. More research is needed to disentangle the mediating effects of political system characteristics and social institutions more broadly in the growth–conflict relationship and explore the channels through which they may be important for adaptation to increased climate variability and for conflict prevention.

Replication data

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Civil war, climate change, and development: A scenario study for sub-Saharan Africa

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Abstract

This article presents a model of development, civil war and climate change. There are multiple interactions. Economic growth reduces the probability of civil war and the vulnerability to climate change. Climate change increases the probability of civil war. The impacts of climate change, civil war and civil war in the neighbouring countries reduce economic growth. The model has two potential poverty traps – one is climate-change-induced and one is civil-war-induced – and the two poverty traps may reinforce one another. The model is calibrated to sub-Saharan Africa and a double Monte Carlo analysis is conducted in order to account for both parameter uncertainty and stochasticity. Although the IPCC Special Report on Emission Scenarios (SRES) is used as the baseline, thus assuming rapid economic growth in Africa and convergence of African living standards to the rest of the world, the impacts of civil war and climate change (ignored in SRES) are sufficiently strong to keep a number of countries in Africa in deep poverty with a high probability.

Keywords

civil war, climate change, economic development

Introduction

The socio-economic scenarios that underpin future projections of climate change are very peaceful (Nakicenovic & Swart, 2001). This is in sharp contrast to the past, which regularly saw violent conflict between and within states. The absence of (civil) war in future scenarios of climate change is even more surprising when one considers that violent conflict can have a profound impact on development (Butkiewicz & Yanikkaya, 2005), and that one of the more worrying assertions is that climate change could enhance violent conflict (Barnett & Adger, 2007). This article seeks to fill this void by developing a simulation model for the three-way interaction between civil war, climate change and development.

The model has a few, simple components: climate change has a negative impact on the economy, slowing down its growth. Climate change increases the probability of civil war. Civil war has a negative impact on economic growth. In turn, economic growth reduces the vulnerability to the impacts of climate change, and it reduces the probability of an outbreak of violent conflict. Although its components are simple, when put together the model is complex.

As far as we know, this is the first attempt to study the three-way interaction between climate change, civil war, and development. Essentially, we model a race.

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Economic growth reduces the risk of conflict and the impact of climate change. But climate change and conflict reinforce one another and reduce economic growth. If the first effect is stronger, countries will be rich, peaceful and not much bothered by climate change. If the latter effect is stronger, countries will be poor, torn by conflict and suffer from climate change. Phrased like this, the model is used to investigate whether there is a conflict-and-climate-induced poverty trap – or rather, the size of the trap and which countries are more likely to be caught by it.

We qualitatively sketch the mechanisms above. It is therefore possible to construct a mathematical model from which a conflict-and-climate poverty trap emerges. We do so below. We parameterize the model with realistic values and conduct a systematic sensitivity analysis on the parameters. This exercise takes the article from the question 'is it possible?' to 'how likely is it?'.

It would be preferable to investigate the strength of the hypothesized conflict-and-climate poverty trap using observations. However, rapid climate change has not happened in the period for which there are good data on conflict and development. We therefore rely on a simulation model.

While there are a number of articles on the relationship between conflict and economic growth and on climate change and growth, there is little quantitative evidence on conflict and climate change – see the next section for a literature review. Therefore, as a secondary contribution, the article also develops and estimates a model of the impact of climate change on civil war.

As a third contribution, we introduce a new richness to the scenarios of development used in climate change analysis. We apply the model to sub-Saharan Africa, the region that is least developed and most subject to (civil) war.

The article proceeds as follows. The next section reviews the literature. After that, we present the model, with additional material in the appendix. This is followed by a discussion of the results. As with any numerical model, the results follow from the assumptions, which are particularly uncertain in this case. We therefore conduct a systematic sensitivity analysis and focus on the qualitative results. The final section concludes.

Previous literature

Climate and conflict

Existing empirical research on the role of climate change in violent conflict is limited and inconclusive. Homer-Dixon (1994) examines a number of case studies, in order to determine if environmental scarcities cause violent conflict. Evidence from these case studies suggests that while conflict has indeed occurred in areas of resource scarcity, key contextual factors have played an important role. For example, he argues that serious civil unrest is unlikely to occur unless the political structure prevents challenger groups from expressing their grievances peacefully, but offers these groups an opportunity for violence against authority. Later research (Buhaug, 2010a,b; Buhaug & Rød, 2006; Burke et al., 2009, 2010; Dixon, 2009; Gleditsch, 1998; Gleditsch et al., 2006; Hauge & Ellingsen, 1998; Henderson, 2000; Henderson & Singer, 2000; Hendrix & Glaser, 2007; Nordås & Gleditsch, 2007; Raleigh, 2010; Raleigh & Urdal, 2007; Theisen, 2008; Urdal, 2005) finds conflicting evidence about whether or not environment and climate factors contribute to violent conflict. There is a consensus, however, that other, non-environmental factors dominate.

See also the other articles in this special issue, three of which are particularly relevant for our contribution. Gartzke (2012) seeks to estimate the effect of the annual global mean temperature on interstate conflict in the last 150 years but, since he fails to account for non-stationarity in the data (Engle & Granger, 1987), his results are not robust. Using panel data with 30 years and 170 countries, Bergholt & Lujala (2012) find that natural disasters negatively affect economic growth, but that this does not in turn influence the onset of civil war. In a similar analysis, Koubi et al. (2012) find that temperature and precipitation do not affect economic growth, but that growth does reduce the probability of armed civil conflict.

Collier & Hoeffler (1998) were the first to suggest an 'economic theory' of civil conflict – rent-seeking by violence – and to test their predictions with data. Later articles have refined the hypotheses and econometrics (Brunnschweiler & Bulte, 2009; Collier, Hoeffler & Rohner, 2009; Collier & Hoeffler, 2005; Elbadawi & Sambanis, 2000; Justino, 2009; Schollaert & van de Gaer, 2009; van der Ploeg & Poelhekke, 2010; Welsch, 2008; Wick, 2008; Wick & Bulte, 2006). While these articles tend to find a link between material deprivation and conflict and between specific resources and conflict, there is no direct link between climate and conflict. Material deprivation has many causes and climate is at best a contributing factor (Acemoglu, Johnson & Robinson, 2001, 2002; Easterly & Levine, 2003; Gallup, Sachs & Mellinger, 1999; Masters & McMillan, 2001). According to this strand of literature, people may fight over resources that are highly valuable and easy to smuggle (e.g. diamonds) but they tend not to fight over bulky goods such as water and food – climate- and weather-sensitive resources are, therefore, less conflict-prone.

Below, we augment the empirical work of Collier, Hoeffler & Rohner (2009) and find that drought does impact the probability of civil war. This finding is obviously in contrast with some of the literature touched on above. We therefore also show a sensitivity analysis without any impact of climate change on the risk of civil war.

Conflict and growth

From an economic perspective, the consequences of conflict may be severely damaging. Collier (1999) investigates the consequences of civil war for GDP, during the conflict years and in the early years following. He finds that during civil wars GDP per capita declines at an annual rate of 2.2%, relative to its counterfactual. This is partly explained by reduced production but is also the result of a gradual loss of the capital stock. Capital-intensive and transaction-intensive sectors will be severely affected: manufacturing, construction, transport, distribution and finance will all contract more rapidly than GDP. Collier argues that the restoration of peace does not necessarily imply a peace dividend, or a large bounce-back effect, as might be expected. He finds that if a civil war lasts only one year, it causes a loss of growth of 2.1% per annum, in the first five years of peace. This loss of growth is not significantly different from the loss that would have been experienced had the war continued. If the war has been sufficiently long, however, Collier argues that the repatriation of capital enables the economy to grow rapidly. Empirically he finds that after a 15-year war, the post-war growth rate is enhanced by 5.9% per annum. Later articles find similar effects, and also study the spillover effects on neighbouring countries and trading partners (Asteriou & Price, 2001; Azam, Fosu & Ndung'u, 2002; Bayer & Rupert, 2004; Bozzoli, Brück & Sottsas, 2010; Butkiewicz & Yanikkaya, 2005; Carmignani, 2003; De Groot, 2010; Fosu, 2003; Gyimah-Brempong & Corley, 2005; Kang & Meernik, 2005; Koubi, 2005; Murdoch & Sandler, 2002).

Climate and growth

Climate change would affect economic growth and development, but our understanding is limited. Fankhauser & Tol (2005) investigate four standard models of economic growth and three transmission mechanisms: economic production, capital depreciation and the labour force. They find that, in three models, the fall in economic output is slightly larger than the direct impact on markets – that is, the total impact is more than twice as large as the direct impact – while the 4th model (which emphasizes human capital accumulation) points to indirect impacts that are 1.5 times as large as the direct impacts. The difference is explained as follows. In the three models, impacts crowd out consumption and investment in physical capital, while in the fourth model investment in human capital too is crowded out. Hallegatte (2005) reaches a similar conclusion. Hallegatte & Théry (2007) highlight that the impact of climate change through natural hazards on economic growth can be amplified by market imperfections and the business cycle. Eboli, Parrado & Roson (2010) use a multi-sector, multi-region growth model. The impact of climate change would lead to a 0.3% reduction of GDP in 2050. Regional impacts are more pronounced, ranging from –1.0% in developing countries to +0.4% in Australia and Canada.

Using a biophysical model of the human body's ability to do work, Kjellstrom et al. (2009) find that by the end of the century, climate change may reduce labour productivity by 11–27% in the humid (sub)-tropics. Assuming an output elasticity of labour of 0.8, this would reduce economic output in the affected sectors (involving heavy manual labour without air conditioning) by 8–22%. Although structural change in the economy may well reduce the dependence on manual labour and air conditioning would be an effective adaptation, even the ameliorated impact would have a substantial, but as yet unquantified, impact on economic growth.

In a statistical analysis, Dell, Jones & Olken (2009) find that one degree of warming would reduce income by 1.2% in the short run, and by 0.5% in the long run. The difference is due to adaptation. Horowitz (2009) finds a much larger effect: a 3.8% drop in income in the long run for one degree of warming. In a yet-unpublished study, Dell, Jones & Olken (2008) find that climate (change) has no effect on economic growth in countries with an income above the global median (USD ^{PPP,2000}3,170) but a large impact on countries below the median. If companies can fully adapt to a new climate in 10 years time, economic growth in the 21st century would be 0.6% slower if climate changes according to the A2 scenario than in the case without climate change. This is a large impact. For example, if economic growth is 2.6% per year without climate change, and 2.0% with, then a century of climate change would reduce income by 44%.

The above studies are about the impact of climate and climate change on economic growth. However, some countries (or groups of people within countries) have not enjoyed any growth at all, living at subsistence level much like previous generations did.

Poverty is concentrated in the tropics and subtropics. This has led some analysts to the conclusion that a tropical climate is one of the causes of poverty. Gallup, Sachs & Mellinger (1999) emphasize the link between climate, disease and poverty, while Masters & McMillan (2001) focus on climate, agricultural pests and poverty. Other studies (Acemoglu, Johnson & Robinson, 2001, 2002; Easterly & Levine, 2003) argue that climatic influence on development disappears if differences in human institutions (the rule of law, education, etc.) are accounted for. However, van der Vliert (2008) demonstrates that climate affects human culture and thus institutions, but this venue has yet to be explored in the economic growth literature. Bloom, Canning & Sevilla (2003) find limited support for an impact of climate change on past growth in a single-equilibrium model, but strong support in a multiple-equilibrium model: hot and wet conditions and large variability in rainfall reduce long-term growth in poor countries (but not in hot ones) and increase the probability of being poor.

There are two equilibria in the model of Galor & Weil (1996). One is characterized by high population growth and low capital intensity (the 'Malthusian' equilibrium), the other by low population growth and high capital intensity (the 'Solowian' equilibrium). Physical labour plays a more important role in setting wages, output and savings in the Malthusian equilibrium than in the Solowian equilibrium. This implies that anything that affects physical labour is more important in the Malthusian equilibrium than in the Solowian one. And, as capital intensity separates the two equilibria, reduced productivity of physical labour would reduce savings and capital intensity and hence lock the economy deeper into the poverty trap. Physical labour would be negatively affected by an increase in morbidity and by a decrease of crop yields (as the model implicitly assumes that physical labour is primarily used in agriculture). Skilled labour is affected by long-term cognitive impairment, which is associated with childhood malnutrition and disease, both of which are linked to climate. Climate may thus help to explain the occurrence of poverty traps, and climate change could widen poverty traps.

Bonds et al. (2010) and Strulik (2008) posit theoretical models and offer limited empirical support. Climate-related diseases such as malaria and diarrhoea impair children's cognitive and physical development. This leads to poverty in their later life so that there are limited means to protect their own children against these diseases. Furthermore, high infant mortality may induce parents to have many children so that their investment in education and health care is spread thinly. An increase in infant and child mortality and morbidity due to climate change would thus trap more people in poverty.

In sum, the literature on the impact of climate and climate change on economic growth and development has yet to reach firm conclusions. There is agreement that climate change would moderate the rate of economic growth, by a little according to some studies and by a lot according to other studies. There is disagreement whether climate change would affect the nature of economic development, with some studies suggesting that more people may be trapped in poverty and fewer people might enjoy exponential growth. The latter effect is potentially more important – contrast the difference between 0% and 1% growth, and between 1% and 2% growth – but beyond the scope of the current article.

The model

Overview

The structure of the model, depicted in Figure 1, is as follows. There are six equations and six variables (see Table I). The risk of civil war is higher if people are poorer, if economic growth is slower, and if more people are affected by drought (Equation 1). The risk of drought is higher if people are poorer and there is less precipitation (Equation 2). Precipitation changes with climate (Equation 3). The number of people affected by drought, assuming there is one, falls as people grow richer (Equation 4). The impact of climate change gets worse as climate change gets more severe and as people are poorer (Equation 5). Economic growth is slower if a there is civil war in the country or in a neighbouring country, and if the impact of climate change is more negative (Equation 6). These equations make intuitive sense – the specifications and parameters are discussed below. Parameters are listed in Table II.

The qualitative behaviour of the model is as follows. Climate change drives its economic impact and affects the risk of civil war. Economic growth affects the impact of climate change and is affected by it. Economic growth affects the risk of civil war and is affected by it. This means that there are two potential poverty traps in the model – sluggish growth leading to civil war and further slow growth; climate change slowing growth and enhancing vulnerability to climate change – and the two poverty traps may reinforce one another.

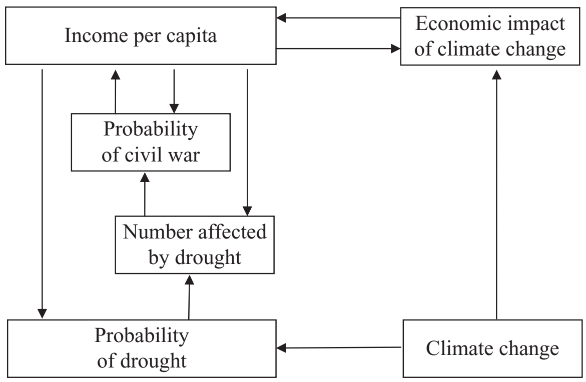

Figure 1. Flow diagram of the model

Equations

The risk of civil war is based on Collier, Hoeffler & Rohner (2009); see Appendix 1 for more detail, particularly on adding drought as a driver of civil war. We experimented with a number of climate variables in the context of the Collier model. Whereas a range of temperature and precipitation variables are not significant, the number of people affected by drought is. The risk of civil war is specified as a logistic function. It is given by

$$W_{c,t} = \frac{1}{1+e^{-Z_{c,t}}} \text{ with } Z_{c,t} := \alpha_0 + \alpha_{1,c} + \alpha_2 \ln y_{c,t} + \alpha_3 \frac{y_{c,t} - y_{c,t-1}}{y_{c,t-1}} + \alpha_4 A_{c,t} \quad (1)$$

where

- $W_{c,t}$ is the risk of civil war in country c at time t;
- c indexes countries;
- t indexes time;
- $y_{c,t}$ is per capita income in country c at time t;
- $A_{c,t}$ is the number of people (per million inhabitants) affected by drought in country c at time t; these parameters are estimated; see Appendix 1;
- $\alpha_2 = -0.33$ (0.12), $\alpha_3 = -0.061$ (0.030) and $\alpha_4 = 0.0073$ (0.0040) are parameters;
- $\alpha_{1,c}$ is a country specific constant[1]; see Appendix 2; and
- α_0 is a calibration constant such that the probability of a civil war is 6% in 2005 (when 3 out of 50 sub-Saharan African countries were at civil war); we calibrate to 2005 because that is the starting point of the simulations; note that civil war was at a historical low in 2005: on average over the period 1960–2000, 19% of African countries were in a civil war; calibration is necessary in the Monte Carlo analysis over the other parameters in Equation (1).

The risk of being affected by drought is determined by both annual precipitation (the risk of drought) and per capita income (the risk of suffering adverse impacts). It is given by

$$D_{c,t} = \frac{1}{1+e^{-Z_{c,t}}} \text{ with } Z_{c,t} := \beta_0 + \beta_1 \ln y_{c,t} + \beta_2 P_{c,t} \quad (2)$$

where

- $D_{c,t}$ is the risk of drought in country c at time t;
- $P_{c,t}$ is precipitation in country c at time t; see Appendix 2; and
- $\beta_0 = 4.0$ (0.4), $\beta_1 = -0.75$ (0.06) and $\beta_2 = -0.00025$ (0.00010) are parameters; these parameters are estimated; see Appendix 1.

Projections of precipitation are not particularly reliable. We therefore choose the simplest specification. Precipitation follows

$$P_{c,t} = \eta_{c,0} + \eta_{c,1} T_t \quad (3)$$

where

- T_t is the global mean surface air temperature (in degrees Celsius above pre-industrial); and
- $\eta_{c,0}$ and $\eta_{c,1}$ are country-specific parameters taken from Christensen et al. (2007); see Appendix 2 in the replication file.

Similarly, the specification of the number of people affected by drought is kept simple. No new variables (and hence no new scenario uncertainties) are introduced. The equation is monotonous. It is given by

$$A_{c,t} = \begin{cases} \gamma_0 + \gamma_1 \ln y_{c,t} & D*_{c,t} = 1 \\ 0 & D*_{c,t} = 0 \end{cases} \quad (4)$$

where

- $D^*_{c,t}$ is drought in country c at time t; and
- $\gamma_0 = 34$ (16), and $\gamma_1 = -4.1$ (2.4) are parameters; these parameters are estimated; see Appendix 1.

For the impact of climate change, we used the simplest functional form that can emulate the characteristics of *FUND*, an integrated assessment model with a

[1] The econometric model as estimated by Collier, Hoeffler & Rohner (2009) and re-estimated by ourselves contains a number of other control variables, which are held constant during the simulations.

Table I. Model variables

Symbol	*Description*	*Unit*	*Equation*
$W^{(*)}$	(Risk of) civil war	Number of conflicts per year	1
$D^{(*)}$	(Risk of) drought	Dummy variable	2
P	Precipitation	Millimetres per year	3
A	Number affected by drought	People per thousand inhabitants	4
C	Impact of climate change	Percent of gross domestic product	5
Y	Per capita income	Dollar per person per year	6

Table II. Model parameters

Symbol	*Description*	*Value*	*Source*
α_0	Basic risk of civil war	Calibrated	
α_1	Effect of log income on civil war	−0.33 (0.12)	App A
α_2	Effect of income growth on civil war	−0.061 (0.030)	App A
α_3	Effect of drought on civil war	0.0073 (0.0040)	App A
β_0	Basic risk of drought	4.0 (0.4)	App A
β_1	Effect of log income on drought	−0.75 (0.06)	App A
β_2	Effect of precipitation on drought	0.00025 (0.00010)	App A
$\eta_{c,0}$	Precipitation in 2005	Table B.I	App B
$\eta_{c,1}$	Effect of climate change on precipitation	Table B.I	App B
γ_0	Constant number of people affected by drought	34.2 (15.6)	App A
γ_1	Effect of log income on number of people affected by drought	−4.05 (2.42)	App A
λ_c	Basic impact of climate change	Table B.I	App B
λ_1	Effect of income on impact of climate change	$1.0\ 10^{-4}$ ($0.1\ 10^{-4}$)	App C
λ_2	Effect of temperature squared on impact of climate change	−0.48 (0.01)	App C
$\kappa_{c,t}$	Basic income growth rate	Table B.I	App B
κ_1	Effect of own civil wars on economic growth	0.022 (0.011)	Collier
κ_2	Effect of neighbours' civil wars on economic growth	0.009 (0.004)	Collier
κ_3	Effect of climate change impact on economic growth	0.05 (0.02)	Collier

particularly rich representation of the impacts of climate change (Link & Tol, 2011; Tol, 2002a,b). Impacts and marginal impacts increase in temperature but (relative to economic activity) decrease in economic growth. It is given by

$$C_{c,t} = \lambda_{c,0} + \lambda_1 \ln y_{c,t} + \lambda_2 T_t^2 \tag{5}$$

where

- $C_{c,t}$ is the impact of climate (in % of GDP) in country c at time t;
- T_t is the global mean surface air temperature (in degrees Celsius above pre-industrial); and
- $\lambda_1 = 0.00010$ (0.00001); and $\lambda_2 = -0.48$ (0.01) are parameters; $\lambda_{c,0}$ is a country-specific constant; see Appendix 2; these parameters estimated as a statistical surface of the *FUND* 2.8n model; see Appendix 3.

As above, we use a simple specification of economic growth. There is an exogenous growth path, perturbed by civil war in the own country, civil war in neighbouring countries, and climate change. Growth is given by

$$y_{c,t} = (1 + g_{c,t})y_{c,t-1} \tag{6a}$$

$$g_{c,t} = \kappa_{c,t,0} + \kappa_1 W*_{c,t-1} + \kappa_2 \sum_{j \neq c} W*_{j,t-1} I_{c,j} + \kappa_3 C_{c,t-1} \tag{6b}$$

where

- $g_{c,t}$ is the growth rate of country c at time t;
- $W^*_{c,t}$ denotes civil war in country c at time t;
- I is an indicator function, 1 if countries c and j share a border, and 0 otherwise;
- $C_{c,t}$ denotes the impact of climate change in country c at time t;
- $\kappa_1 = -0.022$ (0.011); $\kappa_2 = -0.009$ (0.004) and $\kappa_3 = -0.05$ (0.02) are parameters; these parameters are calibrated; $\kappa_{c,t,0}$ is a country- and period-specific

constant, capturing all variables omitted from Equation (6b); see Appendix 2.

Scenarios

The baseline economic growth rate κ_0 is taken from the IMAGE2.2 implementation of the IPCC SRES scenarios (IMAGE Team, 2001). IMAGE2.2 distinguished between three regions (east, south, west) in sub-Saharan Africa. We assume that every country within a region grows at the same rate. The SRES scenarios (Nakicenovic & Swart, 2001) ignore the impact of climate change on development[2] – so that indeed we should calibrate κ_0 rather than g to SRES.

We use the four SRES baseline scenarios. The A1 scenario assumes low population growth, rapid economic growth and rapid technological progress. A2 assumes high population growth, slow economic growth and slow technological progress. B1 assumes low population, rapid economic growth and very rapid technological progress, particularly in energy supply and use. B2 assumes moderate population growth, moderate economic growth and moderate technological progress.

Even the 'slow' economic growth assumed in the A2 scenario is, in fact, fairly rapid in its historical context. The IPCC is a UN body, and Africa has a large block of votes.[3] The SRES models rely on Solow's (1956) growth theory to predict unconditional convergence of income, a theory now widely seen as unsuitable (Barro & Sala-i-Martin, 1995) especially for Africa (Easterly, 2002). Unfortunately, there are no alternative scenarios available and building integrated scenarios of population growth, economic development and energy use is a rather complicated and elaborate activity.

Simulations

We conduct a double Monte Carlo analysis. In the outer loop, we consider parameter uncertainty. We use a Latin Hypercube sample of size 60 for all parameters (cf. Section 3.2). In the inner loop, we consider stochasticity, particularly the outbreak of civil war and drought. We use a simple sampling scheme with 2,000 runs. This makes a total of 120,000 runs.

The Monte Carlo analysis in the outer loop is best interpreted as a systematic sensitivity analysis around the best guess for the model parameters. Although we present numerical results below, the reader should focus on the qualitative results.

Results

The model has six variables: temperature (as an indicator of climate change), the probability of drought, the number of people affected by drought, the economic impact of climate change, the probability of civil war, and per capita income. We are primarily interested in the latter three variables, and particularly the evolution of per capita income and the possibility of a climate-change-induced poverty trap. Nevertheless, the first three variables are needed to understand the behaviour of the model and the results. We therefore briefly discuss these before turning to the main findings. Figure 1 shows that, apart from climate change, everything depends on everything else. We therefore first present the results at a phenomenological level (the model says . . .) before turning to the interpretation and meaning of the results.

There are many countries in the model, many runs in the Monte Carlo analysis of parameter uncertainty, and many runs in the Monte Carlo analysis of war and drought stochasticity. That is, there are a lot of results. We present and interpret the results mainly for the expected values for three countries – the Democratic Republic of the Congo (Kinshasa), Lesotho and Gabon – which are the countries with the lowest, median and highest expected per capita income in 2100.

Figure 2 shows the global mean temperature over the 21st century. It is assumed to rise from 0.8°C to 3.1–3.7°C above the pre-industrial (1750) level over the course of the century. The atmospheric concentration of carbon dioxide is highest in the A2 scenario but so are sulphur emissions (which cause regional cooling); the A1 scenario therefore shows the highest temperature. The B1 scenario shows the least warming. Precipitation is assumed to be a linear function of temperature – see Equation (3) – and thus shows the same pattern as temperature.

Figure 3 shows the number of people affected by drought over the 21st century for the A1 scenario. As 'drought' is defined as drought that does reportable damage – see Equation (2) – it depends also on per capita income – see Figure 1 – and is therefore an uncertain and stochastic variable. The number of people affected further depends on per capita income – see Equation (2). Figure 3 therefore displays the expected

[2] IPCC assessments progress unidirectionally from greenhouse gas emissions via climate change to the impacts of climate change. This reflects the state-of-the-art at the time of the foundation of the IPCC, in 1988.

[3] This article is not the right place to discuss the IPCC. See Tol (2011) and references therein.

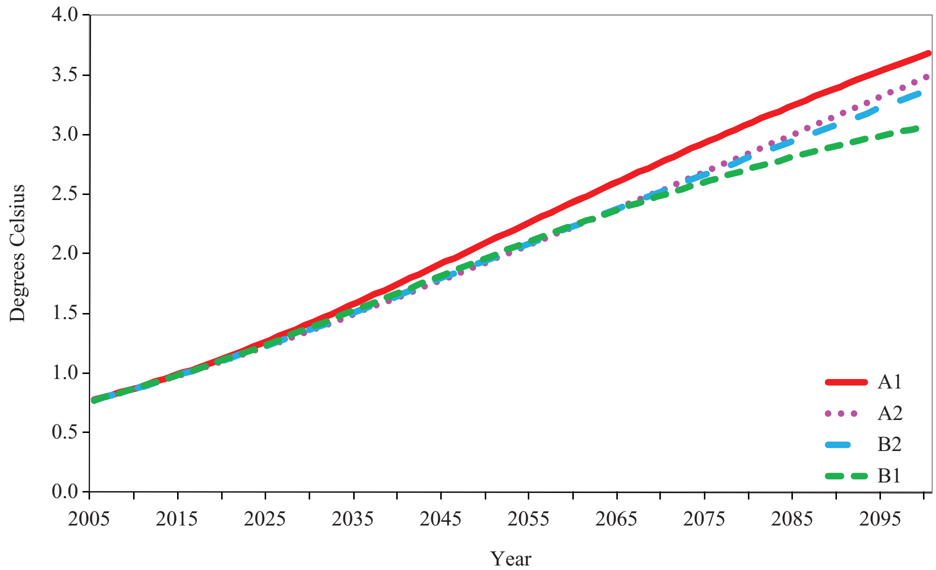

Figure 2. The global mean temperature for the four scenarios

value of the number of people affected by drought. For Lesotho, about five people in 1,000 suffer from drought in 2005. This falls by a factor eight over the course of the century. For Gabon, the drop is much steeper – a factor 33 – and from a lower base at that: one person in a thousand. The reverse is observed for the DR Congo. Some 12 people in a thousand are affected by drought in 2005; this falls at first, but then starts rising again in the second half of the century to about ten people in a million in 2100. There is a strong divergence between the countries of sub-Saharan Africa with regard to the seriousness of drought – which suggests that some countries may be caught in a poverty trap while others grow exponentially.

Figure 3 also shows results for the median country (Lesotho) under the four alternative scenarios. Results are very similar for A1 and B1, but the incidence of drought is considerably higher under B2 and particularly A2. These differences are primarily due to the assumed growth rate of per capita income; the change in precipitation has little impact.

Figure 4 shows the expected impact of climate change over the 21st century. Impacts are expressed as the welfare-equivalent income loss. For instance, in Lesotho, climate change reduces the welfare equivalent to losing over 4% of income in 2010. This rises to over 8% in 2100. For the DR Congo, the impact in 2100 would be almost 13% of GDP. The pattern for Gabon is different. A loss of 3% at the start of the century is turned into a gain of the same size by the end of the century as development has removed the main vulnerabilities to climate change and opened new opportunities to take advantage of climate change (e.g. through carbon dioxide fertilization of crops). As with drought, there is a strong divergence between countries – hinting at the existence of the poverty trap for some but not all countries.

Figure 4 also shows results for Lesotho under the four alternative scenarios. Impacts are less severe under B1 than under A1, primarily because climate change is less pronounced under B1 (cf. Figure 2). Impacts are more severe under B2 and worse still under A2. These differences are largely because of differences in per capita income.

Figure 5 shows the expected probability of civil war over the 21st century. For Lesotho, the probability of civil war starts at 2%, increases to over 5% and then tapers off to 3% as climate change and underdevelopment are the dominant signals in the medium term but development is the dominant signal in the long term. For Gabon, the expected probability of civil war starts at a low 0.4% and falls to almost zero. For the DR Congo, the expected probability of civil war starts high (69%) and remains high (62%). The combined impact of civil war and climate change mean that development in the DR Congo stagnates – and the country remains prone to civil war as a result. As with drought and climate change impacts, there is a strong divergence between countries – another sign of some countries trapped in poverty and other countries escaping.

Figure 5 also shows results for Lesotho under the four alternative scenarios. Results are almost identical for the A1 and B1 scenarios. However, the risk of civil war is

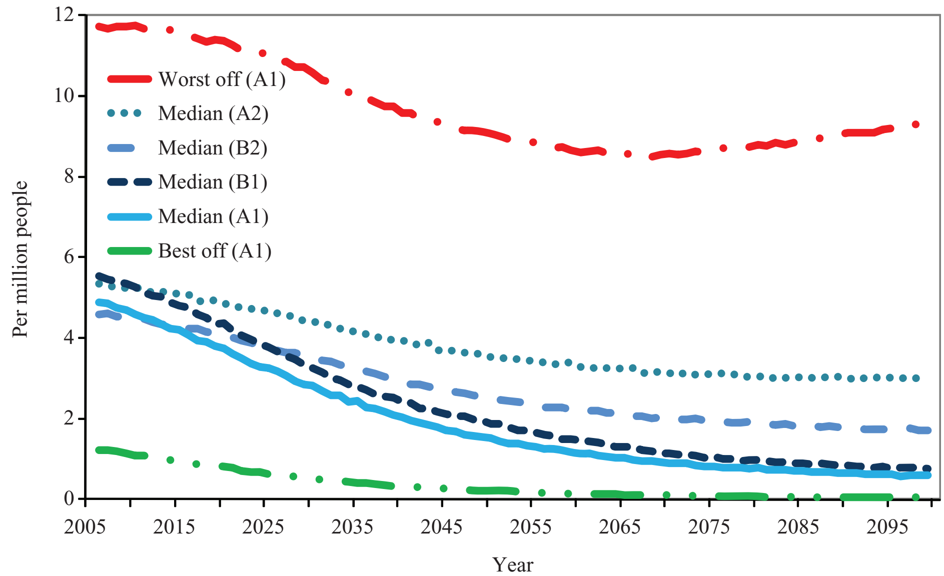

Figure 3. The expected fraction of people affected by drought for the best off (Gabon), worst off (DR Congo) and median (Lesotho) country in 2100

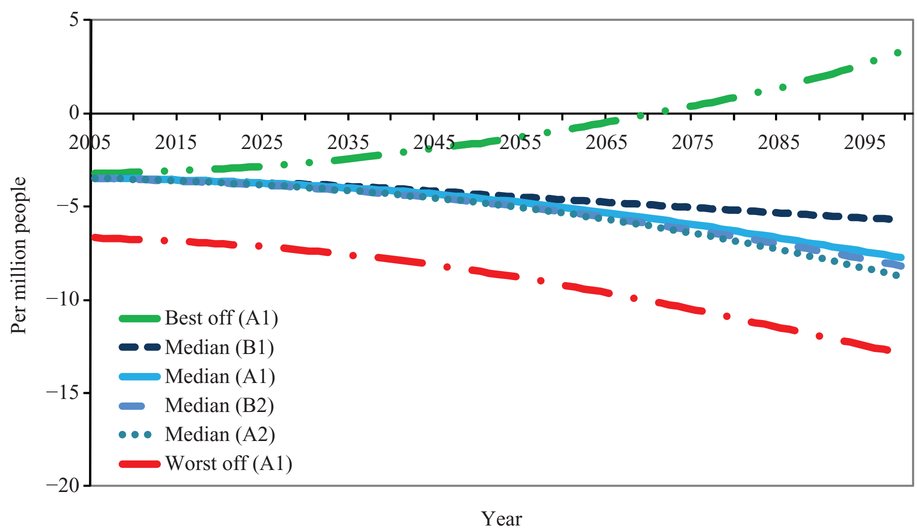

Figure 4. The expected impact of climate change for the best off (Gabon), worst off (DR Congo) and median (Lesotho) country in 2100

higher under the B2 scenario and higher still under the A2 scenario. These differences and similarities primarily reflect differences in the assumed economic growth rate; climate change has a minor impact.

Figure 6 shows the expected income per capita over the 21st century. For Lesotho, income rises from some USD 500 per person per year at the start of the century to almost USD 13,000/p/y at the end – a 26-fold increase. For the DR Congo, income rises too but only 7-fold from less than USD 100/p/y to less than USD 700/p/y. For Gabon, income rises 90-fold from USD 4,000/p/y to USD 350,000/p/y. A 90-fold increase over a century corresponds to an annual growth rate of 4.5%, well within the range of historical experience. As with the previous three indicators, there is divergence, big time. Evaluated at the mean, the DR Congo is not quite caught in a poverty trap, but economic growth is very slow. The

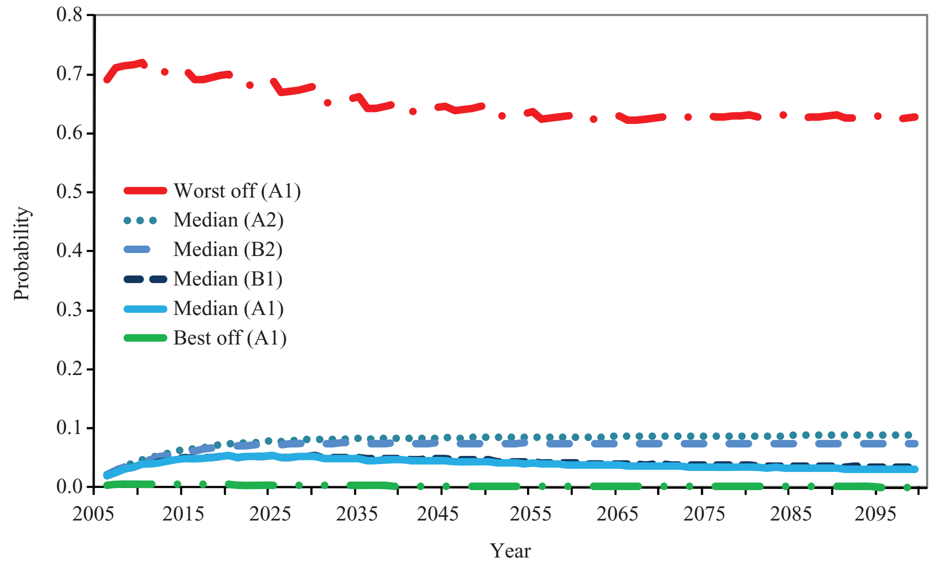

Figure 5. The expected probability of civil war for the best off (Gabon), worst off (DR Congo) and median country (Lesotho) in 2100

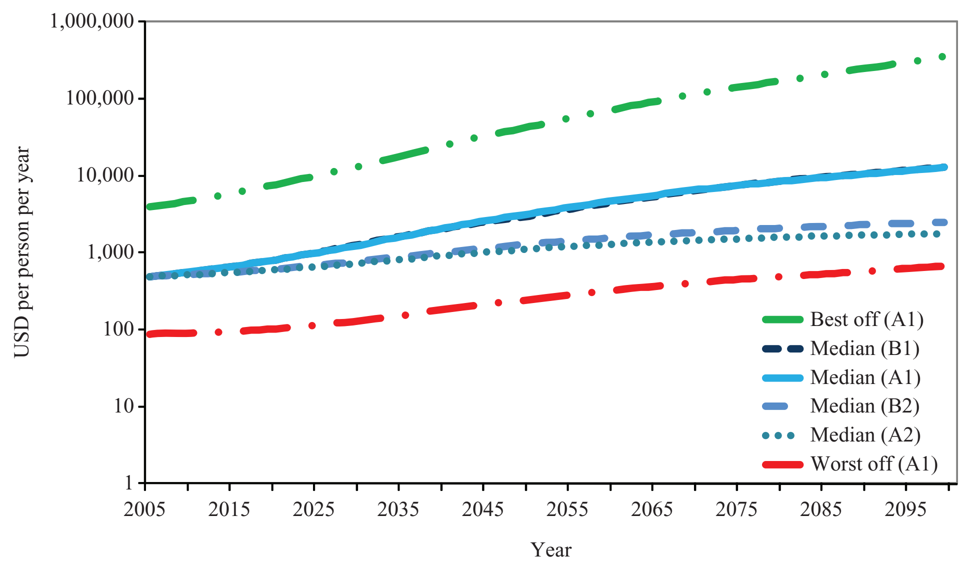

Figure 6. The expected per capita income for the best off (Gabon), worst off (DR Congo) and median country (Lesotho) in 2100

economies of other two countries display more healthy levels of growth.

Figure 6 also shows results for Lesotho for the four alternative scenarios. Per capita income is roughly the same under A1 and B1. However, it is much lower under B2 and lower still under A2. This partly reflects the assumptions, but the differences are enhanced by the impacts of civil war and climate change on economic growth.

Figure 7 shows the expected income per capita in 2100 for Lesotho (1) for the complete model, (2) for the model with the risk of civil war set to zero, (3) for the model with the impact of climate change set to zero, (4) for the model with climate change set to zero, and (5) for the model with both climate change and civil war risk set to zero. Model 5 corresponds to the IPCC scenario. In Model 1, climate change affects growth through two channels: economic impact and civil war; in Models 2 and 3 only one of these channels is operative; in Model 4, there is no impact of climate change. In Model 4, civil war affects growth, and in Model 1 this is enhanced by climate change.

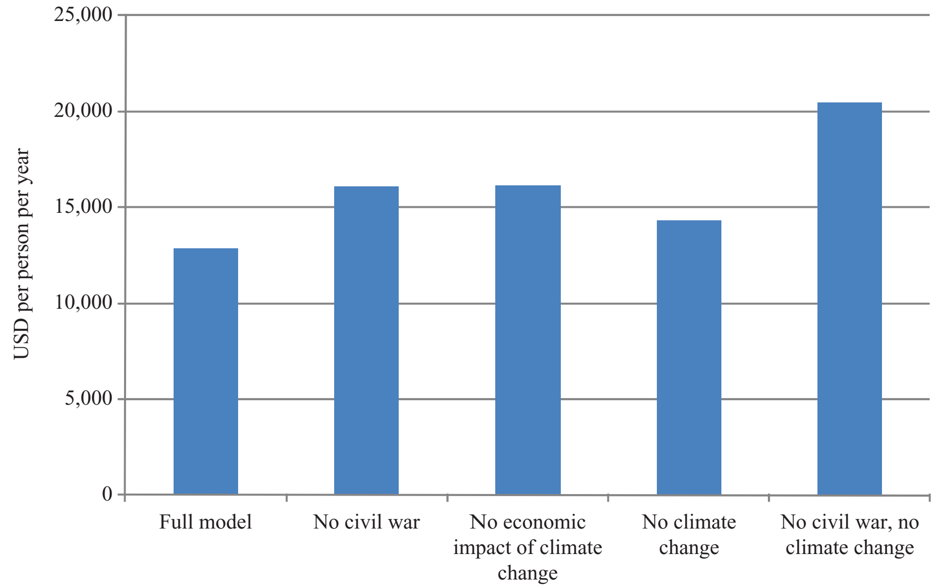

Figure 7. The expected per capita income for the median country (Lesotho) in 2100 for the full model and models without one or both risk factors

Civil war and the economic impact of climate change have a similar effect (but note that the two interact): without civil war, Lesotho would expect to be USD 3,200/p/y richer in 2100; without the economic impacts of climate change, per capita income would be USD 3,300 higher. Without climate change and civil war, income would be USD 7,600 higher. There is therefore a negative synergy (of USD 1,100/p/y) between the economic impacts of climate change and civil war. Without climate change (but with the baseline risk of civil war), income would be USD 1500 higher. Climate change thus more than doubles (from USD 1,500 to USD 3,300) the negative economic impacts of civil war. Taken separately, climate change and civil war have a relatively modest impact on economic growth. Taken together, the impact is more substantial – and indeed the sum is greater than the parts. A conflict-and-climate poverty trap is therefore more likely than either a climate poverty or a conflict poverty trap.

Figure 8 shows the expected impact of climate change in 2100 for Lesotho for the complete model, and for the model with the risk of civil war set to zero. The effect of civil war is small, raising the impact from 7.4% to 7.7% of GDP. Figure 9 shows the expected probability of civil war over the 21st century for the complete model, for the model without the impact of climate change on civil war, and for the model with the impact of climate change set to zero. The direct impact of climate change is modest (which follows from the regression results and indeed the literature review) and mixed (which follows from the opposite effects of climate change and development); climate change accentuates the pattern seen in Figure 5. The economic impacts of climate change, through their effect on economic growth, increase the probability of civil war by 1% in 2100. While absolute small, this is relatively large as the probability of civil war is 4% without the economic impacts of climate and 5% with. Together, Figures 8 and 9 confirm the synergistic nature of climate change and civil war.

Figure 10 shows the probability density function of per capita income in the year 2100. The distribution for Lesotho shows clear bimodality, as indeed suggested by the qualitative discussion of the model properties. The primary mode is an income of around USD 14,000 per person per year; the secondary mode is around USD 9,000/p/y. Less than 10 (out of 120,000) realizations are greater than USD 18,000/p/y, while the model without climate change and civil war would lift the average income in 2100 to USD 20,000/p/y. The impact of climate change and civil war on economic growth is unambiguously negative – and the bimodality is clear evidence that, if economic growth is insufficiently fast, climate change and civil war may hold back growth further.

The probability distribution for Gabon is unimodal, with a single peak around USD 356,000/p/y. This is lower than the scenario without climate change and civil war (USD 425,000/p/y). Interestingly, although the economic

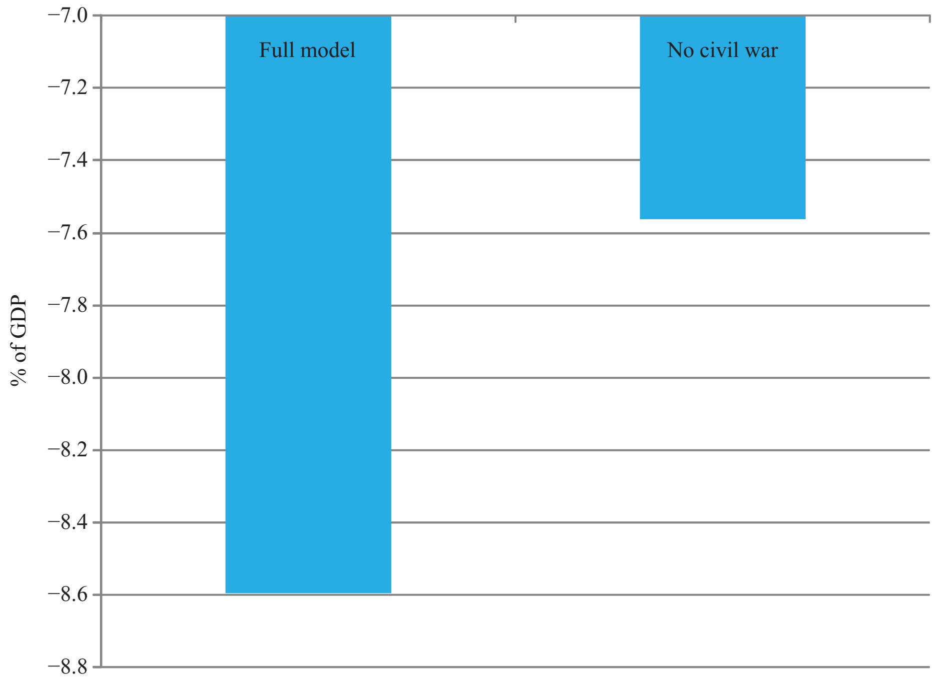

Figure 8. The expected impact of climate change for the median country (Lesotho) in 2100 with and without the risk of civil war

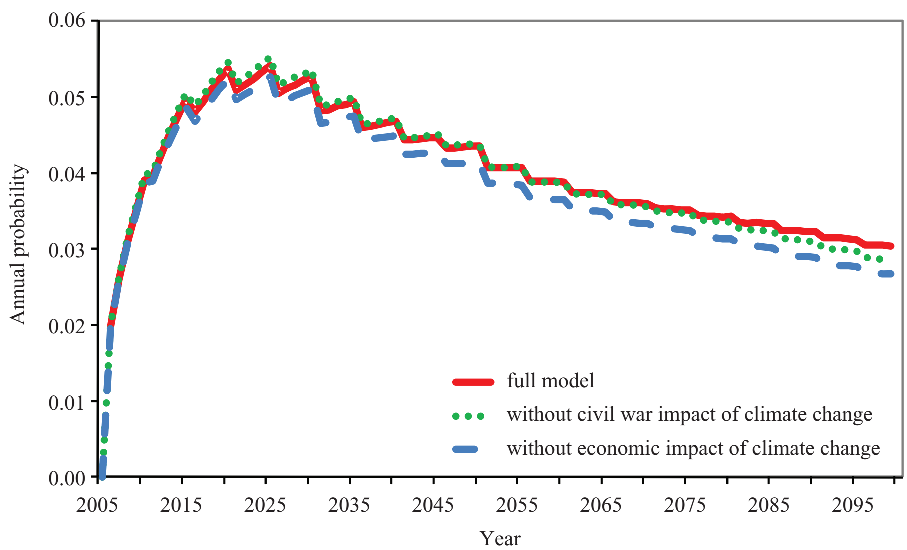

Figure 9. The expected probability of civil war for the median country (Lesotho) in 2100 with and without economic impacts of climate change and the impact of climate change on civil war

impact of climate change is expected to be positive for Gabon (cf. Figure 4), only 33 (out of 120,000) realizations see a net acceleration of economic growth over the century. This is because the negative impacts on growth in the early years are more important than the positive effects in later years. The left tail of the distribution shows that the negative economic impacts of climate change and civil war may be substantial – in the worst case, income in 2100 is 46% of the modal income – but the unimodality suggest that this would not lead to a poverty trap – indeed, in the worst case, per capita income grows by 3.8% per year.

The DR Congo's probability distribution is unimodal too, with a single peak at subsistence level. Without climate change and civil war, the DR Congo's

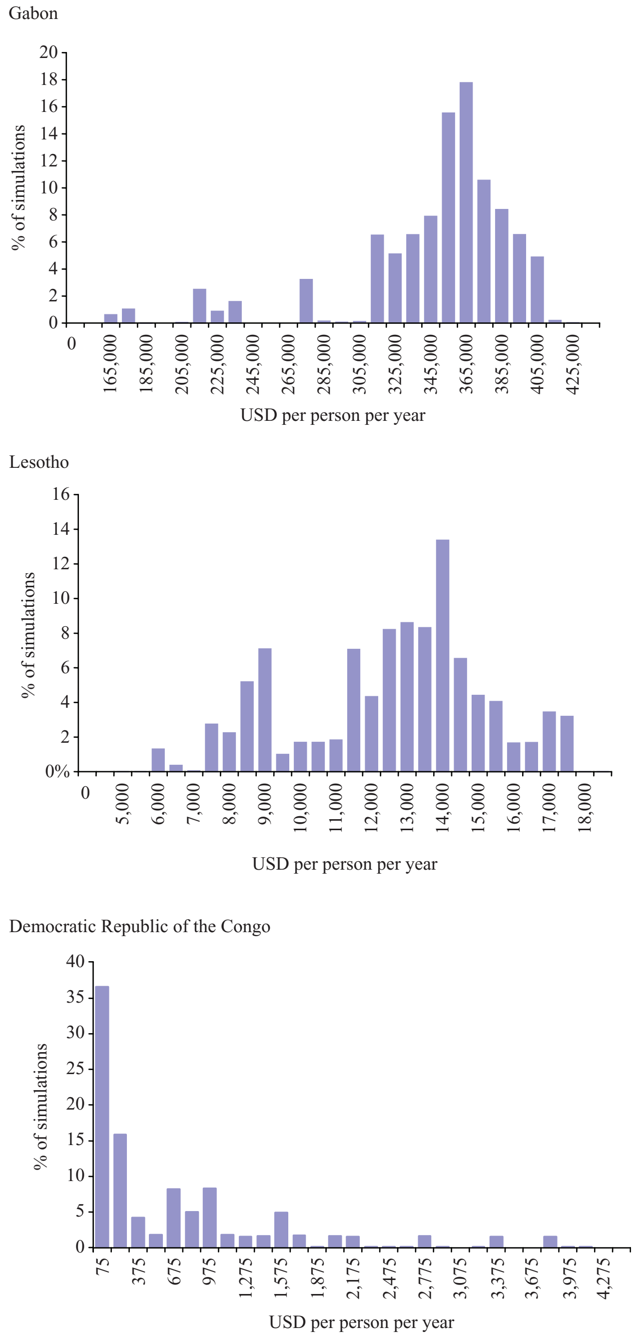

Figure 10. The probability density function of the per capita income in 2100 in the best off (Gabon), worst off (DR Congo) and median country (Lesotho)

income would be about USD 10,000/p/y in 2100 – 120 times the level in 2005. With climate change and civil war, income never exceeds USD 4,000/p/y. The DR Congo is firmly trapped in poverty and, if the model is correctly parameterized, there is little hope of escaping that trap because of climate change and civil war.

Combining the three probability density functions, we see that climate change and civil war have a limited effect on the economic development of some countries and, a devastating effect on others, and may or may not have a substantial effect on yet other countries. There is clear evidence that some countries are trapped in poverty by climate change and civil war. Other countries may fall into such a trap, while yet other countries face no such risk. The model thus has two solutions: a poverty trap and exponential growth.

We did not perform a sensitivity analysis on the model parameterization. Instead, we systematically varied the model parameters in a Monte Carlo analysis. Because of space limitations, we do not report results as a function of the values of the parameters. The model code and results are found with our replication data, so that readers can check such sensitivities for themselves. Qualitatively, the sensitivities are obvious. If the impact of climate change on civil war or the economy is smaller; if the risk of civil war or the vulnerability to climate change falls faster with development; or if the impact of climate change or civil war on development is smaller than assumed – then there is a lower risk of being trapped in poverty.

Discussion and conclusion

In this article, we construct a model of development, civil war and climate change. There are multiple interactions. Economic growth reduces the probability of civil war and the vulnerability to climate change. Climate change increases the probability of civil war. The impacts of climate change, civil war and civil war in the neighbouring countries reduce economic growth. The model has two potential poverty traps – a climate-change-induced one and a civil-war-induced one – and the two poverty traps may reinforce one another. We calibrate the model to sub-Saharan Africa and conduct a double Monte Carlo analysis accounting for both parameter uncertainty and stochasticity.

The parameter uncertainty is such that any particular numerical result is unreliable. However, systematic sensitivity analysis reveals the following, qualitative result. Although we use the SRES scenarios as our baseline, and thus assume rapid economic growth in Africa and convergence of African living standards to the rest of the world, the impact of civil war and climate change (ignored in SRES) are sufficiently strong to keep a number of countries in Africa in deep poverty with a high probability.

The following caveats apply. The model has simple, aggregate representations of complex and diverse phenomena. For example, we do not distinguish between civil wars of different intensities, and we treat climate change impacts as a deadweight loss to the economy. The model lacks a number of mechanisms that may affect our findings. These include human and physical capital, fertility, development assistance and interstate war. That said, the model is calibrated with realistic numbers and shows that conflict and climate change matter for development. This justifies repeating the analysis here with more complex models.

Replication data

The data replication files are available at http://www.prio.no/jpr/datasets. Appendices A, B and C present additional material on the regression analyses, model parameters and the FUND model, respectively. The data for the regression analyses (in Excel and Stata) and the Stata do-files are in regression.zip. The model code is in modelcode.zip, with auxiliary files in modelsupp1.zip and modelsupp2.zip. The graphs and the data behind the graphs are in figures.zip.

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Appendix 1: Regression results

Table AI. Regression results for the occurrence of civil war

Symbol	*Description*	*Mean*	*StDev*	*z-stat*
α_1	Ln(per capita income)	–0.3266	0.1210	–2.70
α_2	Income growth	–0.06095	0.02975	–2.05
α_0	Time since previous conflict	–0.05934	0.00954	–6.22
α_0	Former colony of France	–1.256	0.559	–2.25
α_0	Social fractionalization	1.752	0.723	2.42
α_3	Number affected by drought	0.007352	0.004015	1.83
α_0	Intercept	0.9811	0.8683	1.13
	Pseudo R^2	0.221	N	956

Table AII. Regression results for the occurrence of drought

Symbol	*Description*	*Mean*	*StDev*	*z-stat*
β_1	Ln(per capita income)	–0.746	0.064	–11.7
β_2	Income growth	–0.000248	0.000099	2.51
β_0	Intercept	3.948	0.444	8.89
	Pseudo R^2	0.147	N	1347

Table AIII. Regression results for the number of people affected by drought (per million inhabitants), conditional on drought occurring

Symbol	*Description*	*Mean*	*StDev*	*z-stat*
β_1	Ln(per capita income)	–4.05	2.42	–1.68
β_0	Intercept	34.2	15.6	2.20
	R^2	0.012	N	240

(Collier et al. 2009) estimate a logit model of the probability of an outbreak of civil war. We re-estimated their model, adding variables that would be sensitive to climate change. Specifically, we added cereal production (total, wheat, maize, coarse grains), precipitation and the number of people affected by drought. We also added the number of immigrants and the stock of immigrants, which would be affected by sea level rise, among other things. Only the number of people affected by drought has a significant effect on the probability of civil war. We use a general-to-specific strategy with joint significance tests (Hendry, 1995) to find the model specification given in Table AI.

Table AII shows the results of a logit regression of the occurrence of drought (according to http://www.emdat.be/) on income and growth. Table AIII shows the results of a regression of the number of people affected by drought on per capita income.

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Climate-related natural disasters, economic growth, and armed civil conflict

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Abstract

Global warming is expected to make the climate warmer, wetter, and wilder. It is predicted that such climate change will increase the severity and frequency of climate-related disasters like flash floods, surges, cyclones, and severe storms. This article uses econometric methods to study the consequences of climate-induced natural disasters on economic growth, and how these disasters are linked to the onset of armed civil conflict either directly or via their impact on economic growth. The results show that climate-related natural disasters have a negative effect on growth and that the impact is considerable. The analysis of conflict onset shows that climate-related natural disasters do not increase the risk of armed conflict. This is also true when we instrument the change in GDP growth by climatic disasters. The result is robust to inclusion of country and time fixed effects, different estimation techniques, and various operationalization of the disasters measure, as well as for conflict incidence and war onset. These findings have two major implications: if climate change increases the frequency or makes weather-related natural disasters more severe, it is an economic concern for countries susceptible to these types of hazards. However, our results suggest – based on historical data – that more frequent and severe climate-related disasters will not lead to more armed conflicts through their effects on GDP growth.

Keywords

armed civil conflict, climate change, climate-related natural disasters, economic growth

Introduction

Catastrophes such as typhoons and floods have caused significant economic and human losses throughout history. The heavy monsoon that hit Pakistan in July 2010 caused floods that ravaged the country, bringing enormous damage to homes, schools, fields, and infrastructure. The reported death toll for the event is about 2,000, while an estimated 20.3 million people, or more than 10% of the Pakistani population, were affected (OFDA, 2010).

We might be able to grasp the gravity of disaster damages through testimonies from victims, relief workers, and journalists, but the short- and long-term effects on economic growth and peace remain largely unknown. What happens to production and national income in the short run? Furthermore, with regard to ongoing transnational efforts to prevent armed civil conflicts, what are the effects of climate-related events?

The potential impact of climate change in the form of natural disasters is relevant not only for Pakistan: on average more than 270 devastating floods and storms are reported every year throughout the world (CRED, 2011).[1] Although it is the large-scale events that make the headlines, the frequency of smaller events is equally striking: even in the absence of large-scale events in

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[1] In fact, these two disaster classes alone represent more than 70% of all disasters reported in CRED's EM-DAT database for the latest decade. See http://www.emdat.be.

2009, more than 100 million people were victims of climatic disasters (Vos et al., 2010).

Questions about the impacts of such disasters are clearly of great importance for the livelihoods of a large number of people and countries and hence for international development agencies and policymakers throughout the global community. As global warming is expected to lead to an increase in both the severity and the frequency of climate-related disasters (IPCC, 2007: 43–54), it is important to understand how climate change will affect economies, and whether these changes will translate into more armed conflicts, directly or via impacts on economic growth. However, only a few studies have attempted to quantify the impact of these events using econometric methods and large N-scale panel datasets. In this article, we examine how climate-related natural disasters, including flash floods, surges, cyclones, blizzards, and severe storms, affect economic growth and peace. We label these events climatic disasters throughout the analysis.

By using ordinary least squares (OLS) and panel data on climate-related disasters and short-run economic growth,[2] we confirm that climate-related disasters have a negative impact on growth. However, our analysis of disaster data and conflict onset shows that climate-related natural disasters do not have any direct effect on conflict onset. We then instrument economic growth using our disaster measure in a two-stage least squares (2SLS) analysis to study whether climate-related disasters have an indirect effect on conflict onset via slowdown in economic growth. By doing this, we also address the simultaneity problem between income and conflict: we recognize that slow and negative economic growth may cause conflict, but also that an approaching conflict may lead to slow growth, for example, when extractive industries withdraw from unstable countries that are on the brink of sliding into conflict. Instrumenting growth using climatic disasters allows us to impose exogenous variation in growth. However, we do not find any evidence that economic shocks caused by climate-related disasters have an effect on conflict onset. This result differs from the negative causal link between economic growth and conflict found in other studies, including Collier & Hoeffler (2004) and Miguel, Satyanath & Sergenti (2004). However, our findings are similar to those in the recent cross-country study by Ciccone (2011).

Our study differs from previous work on natural disasters, economic growth, and conflict onset in several important ways. First, much of the previous work considers the economic effects of large-scale disasters. By contrast, this study includes small disasters in the analysis and, thereby, takes into consideration that the large majority of what we define as natural disasters are actually small-scale events. Second, we use fixed-effects methods to control for unobserved factors that may affect the results. For example, climate and closeness to coastline may affect both the occurrence of natural disasters and economic growth, or there may be overreporting on disaster magnitude in less developed countries to attract international aid. Finally, while most previous disaster studies ignore the possibility that different disaster types have different effects on the economy (for instance, by aggregating geophysical events such as volcano eruptions and earthquakes, biological events such as famines, and slow-onset events such as droughts, and then treat them as one), we only look at climatic disasters that come as sudden shocks and last for no longer than one month.

The article proceeds as follows. We begin by discussing the effect of climatic disasters on economic performance, drawing on recent literature, and how previous studies have considered natural phenomena in armed civil conflict research. Then we present our main hypotheses. Before turning to the analysis, we present our data and how our disaster variables have been constructed. We conclude by discussing the main results and their implications.

Economic effects of natural disasters

As the devastating 2010 floods in Pakistan demonstrate, climate-related natural disasters undoubtedly cause very real economic damage when they occur: lives are lost, people are forced to leave their homes, buildings and other infrastructure collapse, and extractable resources become unavailable. All these consequences can be defined as direct impacts in the sense that they arise as immediate outcomes of disasters. Such impacts are obviously negative for most of the affected individuals and their economic activities. There are also a number of indirect impacts that may follow in the aftermath of natural disasters and that are linked to economic activity such as income changes, demand and supply shocks, shifting terms of trade, and increased inflation.

The net effect on overall economic performance is the sum of the direct and indirect impacts. Although many authors believe that natural disasters are likely to have a negative impact on economic growth (Noy, 2009), this is not so clear from a theoretical point of view, at least

[2] We define the short run as the current year and next year.

not in the medium and long term and at the aggregate national level. People and companies repair the damage, governments set up large infrastructure projects to repair damages and to prepare better for future disasters, and there may be substantial inflows of emergency aid. All these actions generate economic activity that may exceed the direct damages caused by the disaster. Consequently, the short-run effects on economic growth that this article considers are really a matter of dynamics and the selected time frame, and hence an empirical question. In the face of global warming, it is imperative to study these effects.

Surprisingly little research has been conducted to identify the relationship between climatic natural disasters and economic growth. Of these studies, Skidmore & Toya (2002) report a positive link between persistent climatic events such as droughts, extreme temperatures, wildfires, and economic growth, while Loyza et al. (2009) find a positive effect on economic growth from floods and a negative effect from droughts. Raddatz (2007, 2009) reports that large-scale climatic disasters are negatively linked to economic growth. A negative effect on growth is also reported by Noy (2009), who assumes that geophysical, climatic, and biological disasters all have the same effect on growth and thus aggregates all these disasters together. As the results are partially ambiguous and the impacts of natural disasters may vary depending on their nature, more research is required. In this article we study a set of weather-related disasters which are likely to become more frequent in the future as they are related to climate change.

Climatic disasters, economic growth, and conflict

Research indicates that economic growth is related to the occurrence of armed conflict. If sudden changes in economic growth increase the risk of armed conflict and weather-related disasters cause negative growth shocks, a logical consequence would be that such disasters can cause armed conflict via their negative impact on growth.

Several empirical studies document that slow economic growth and low income levels are important in predicting which countries will experience a conflict: armed civil conflict is more likely to occur in poor countries than in rich (see, among others, Collier & Hoeffler, 2004; Fearon & Laitin, 2003; Hegre & Sambanis, 2006). This can be the result of frustration and grievances, ease of recruiting rebels when even modest compensations to the rebel and his/her family exceed their present income, and lack of military capabilities and state capacity to prevent and suppress armed conflicts.

Of course, the political and social unrest that frequently precedes the onset of armed conflict often erodes economic institutions, causing economic havoc and making it more difficult to maintain peace. Herein lies a great econometric challenge: the latent start of a conflict may occur long before the unrest qualifies as a conflict onset in traditional conflict datasets such as the UCDP/PRIO Armed Conflict Dataset. This implies a very real endogeneity problem because the low income growth may be as much a result of an approaching armed conflict as of a conflict itself. Many studies point to the importance of economic factors in explaining conflict onset, but only a few provide convincing solutions to this endogeneity problem. Most studies – such as those just mentioned – understandably rely on lagged regressors, and conclude that because low income level and negative income shocks tend to occur before the commencement of civil conflicts, they appear to be likely causes.

Methods of overcoming the simultaneity problem include the use of instrumental variables, as in Miguel, Satyanath & Sergenti (2004), in which the researchers use rainfall in sub-Saharan Africa as instrument for GDP per capita growth. They find that a one percentage point decrease in rainfall raises the likelihood of a country experiencing conflict incidence by about two percentage points and conflict onset by three percentage points. Given that rainfall causes exogenous economic growth shocks, the 2SLS instrumental variable approach shows not only how growth correlates with conflict, but also justifies the causal assertion.

Bernauer et al. (2012) use deviation in temperature and rainfall (from long-run averages) as instruments for economic growth in a global dataset for the period 1980–2004. They find no significant link between climate variability, economic growth, and the risk of conflict onset. This conclusion remains robust for a subsample including only African countries, thus contrasting with the results of Miguel, Satyanath & Sergenti (2004). The Miguel et al. study is further challenged by Ciccone (2011), who shows that a misspecification of rainfall measures may explain the observed negative relation between rainfall and conflict.[3]

Some studies focus solely on the reduced-form relation between climate and the risk of conflict. Burke et al. (2009) study panel data on African countries

[3] The same study shows that Miguel et al. results do not hold when the time series are extended from 1999 to 2009. Brückner & Ciccone (2010) show that the Miguel et al. study is not robust to using year fixed effects.

between 1981 and 2002 by means of fixed-effects transformed models and find that a one degree Celsius increase in temperature will increase the risk of armed civil conflict by as much as 4.5 percentage points within the same year. However, Buhaug (2010) compares different data and model specifications and concludes that climate variability in terms of temperature is a poor predictor of armed civil conflict.

A few studies consider the effects of climate-related disasters[4] on conflict using disaster dummies and frequencies.[5] Studies by Nel & Righarts (2008) and Besley & Persson (2011) find that climate disasters increase the risk of armed conflict. Slettebak (2012), however, finds that if anything, climate-related disasters seem to reduce the risk of armed conflict onset.[6] All three studies are vulnerable to unobserved country heterogeneity in the sense that the distribution of natural disasters across countries probably is non-random. Indeed, the use of fixed-effects transformations in our study is motivated by this econometric challenge.

Although there is strong evidence that slow growth is linked to conflict onset, the other elements in the potential natural disaster to conflict pathway are less studied and understood. Clarifying the effects of natural disasters, particularly climate-related hazards, on the economy and on peace becomes important as we face global warming. Some previous studies indicate that natural disasters can have a negative impact on growth, but there is little research that examines whether these in turn trigger armed conflict. Given the causal pathway from natural disasters to slow growth and to armed civil conflict, the link between climate-related disasters and economic growth on the one hand, and economic fluctuations triggered by nature and armed civil conflict on the other hand, has not yet been investigated comprehensively. This article analyzes these relationships.

Hypotheses

To identify and quantify the short-run causal effects between climatic disasters, income growth, and armed civil conflict, our study proceeds in two stages. Because it is crucial to understand the effect of climate-related natural disasters on economic growth, we have chosen to analyze this relationship separately and in more detail than a mere instrumental variable analysis entails. Therefore, we first study the relationship between climate events and economic growth, and then the effect of disasters and growth on armed conflict onset.

Natural disasters are likely to affect growth immediately through their impact on production inputs: when severe climate-related natural disasters come as sudden and unexpected shocks or events, they cause damage to humans and infrastructure. Floods, winds related to heavy precipitation, unusually strong monsoons, storms, and tropical cyclones destroy crops, kill farm animals, and can postpone the planting or harvesting season, thus having severe effects on people's income and assets. Damage to houses and farm buildings may force people to leave their homes and land, further limiting their income opportunities until they are able to return, rebuild, and plant, and the next harvesting season arrives. Even then, the land or equipment may be damaged to an extent that makes the first harvests unusually small. Disasters may also damage other infrastructure such as roads and factories and cause considerable harm to settlements in villages and cities, as demonstrated by the flooding that occurred in Pakistan in 2010. Even when there is substantial international relief assistance, these shocks alter input stocks that are used to create income and economic growth to the extent that in the short run we expect to see decline in economic growth.

H1: Climate-related disasters have a negative effect on economic growth.

The previous literature on conflict onset has shown that slow economic growth is negatively related to increased risk of conflict onset. We take this as our point of departure and expect that negative economic shocks caused by climate events will increase the risk of armed conflict onset.

H2: Negative income growth shocks caused by climate-related disasters increase the likelihood of armed civil conflict onset.

Even though much of the identification strategy for our second hypothesis relies heavily on arguments similar to those in Miguel, Satyanath & Sergenti (2004) and Bernauer et al. (2012), our approach differs in some important ways. In contrast to these studies on temperature- and rainfall-induced conflict, we investigate disasters that

[4] Variation in temperature and rainfall may reflect climate-related disasters such as droughts and floods, but only indirectly and only when these are large and intense enough to affect the annual figures. These measures may also reflect other variations that are not related to climate shocks and thus fall outside the definition of natural disaster.

[5] By doing so the studies pay equal attention to events affecting 100 people as those affecting 100,000 people, for instance.

[6] In addition to these studies on climate-related disasters, Brancati (2007) and Nel & Righarts (2008) find that earthquakes increase the likelihood of incidence of armed conflict.

Table I. Descriptive statistics for data used in the analysis

Variable	*N*	*Mean*	*Std. dev.*	*Min*	*Max*
Dependent variables					
Conflict onset (> 25 battle deaths)	4,455	0.035	0.183	0	1
Real GDP per capita growth (%)	4,354	1.726	7.415	–65.1	123.3
Climatic disasters					
Large disaster (> 10,000 affected)	4,417	0.171	0.376	0	1
Population affected (%)	4,279	0.448	2.689	0	62.5
Population affected (%), time weights	4,279	0.201	1.388	0	32.2
Affected by floods (%), time weights	4,279	0.110	0.946	0	23.5
Affected by storms (%), time weights	4,279	0.090	1.012	0	32.2
Control variables (all lagged by one year)					
Openness of economy (%)	4,356	77.4	49.1	1.086	456.6
Real investment share of GDP (%)	4,342	20.1	11.8	–18.9	90.3
Real government share of GDP (%)	4,342	19.0	10.0	1.438	83.3
FDI inflow relative to GDP (%)	3,876	3.608	19.7	–82.9	564.9
FDI outflow relative to GDP (%)	3,468	1.129	14.2	–10.4	570.4
Inflation	3,630	46.0	505.3	–100.0	23,773.1
Population size (,000)	4,369	33,444	120,500	149.8	1,313,974
Democracy index	4,065	11.2	7.33	0	20

FDI = Foreign direct investment

come as sudden and more unexpected shocks. While most climatic disasters last for only some days, and so appear as impulses in the time dimension, for temperature and rainfall the variation in annual levels is a rather gradual phenomenon in most countries. Droughts in particular can go on for long periods of time, and this time persistence may lead to expectations; for example, during a drought period a best prediction for the near future is that the drought continues. In this way, rainfall expectations among farmers and potential rebels may affect their willingness to join rebel movements. This in turn, may lead to endogeneity in models where rainfall is used as an instrument for economic growth.[7] By contrast, it is much harder to forecast sudden climatic disasters, as they tend to come more as discrete shocks than as continuous events, making them less predictable. Therefore, climate-related events as defined in this article serve as exogenous events in our second-stage analysis.

Furthermore, rainfall can have very heterogeneous effects on economic performance across countries. For instance, it is likely that agricultural economies in sub-Saharan Africa are affected more heavily by rainfall variation than those in countries that use more advanced cultivation methods or have more diversified economies. Floods, cyclones, and storms, on the other hand, should have a negative impact whenever and wherever they occur. In this way, we find it likely that climate-related disasters perform better as an instrument for economic growth in global panel studies than rainfall and temperature variation do.

Obviously, consequences of sudden natural disasters differ across countries. This may be due to culture, infrastructure, political institutions, etc. Some of these aspects we can control for by including control variables in the analysis while the effects of others on the results are reduced by the inclusion of country fixed effects.

Data

Our panel dataset covers the period 1980–2007 and includes 171 independent countries and 4,455 country-year observations, although some are lost during analysis because of missing control variables (see summary statistics in Table I). We include only the data since 1980 because older disaster data are less reliable (Bureau for Crisis Prevention and Recovery, 2004).

Dependent variable 1: Economic growth

The dependent variable in our growth analysis (Hypothesis 1) is the real GDP per capita growth rate (in terms of purchasing power parity). Data come from Penn World Table Version 6.3 (Heston, Summers & Aten, 2009). As the summary statistics in Table I show,

[7] Such expectations would have direct effects on conflict risk, independent of current economic conditions.

Table II. Climate-related disasters included in the study

Disaster class	*Disaster type*
Floods	General floods
	River floods
	Flash floods
	Coastal floods
	Storm surge
Storms	Tropical storms
	Extra-tropical cyclones
	Thunderstorms/lightning
	Snowstorms/blizzards
	Sandstorms/dust storms
	Generic (severe) storms
	Tornadoes
	Orographic storms (strong winds)

average annual real GDP per capita growth was 1.7% during the period 1980–2007. The data clearly have some extreme values, ranging from –65.1% in Iraq (1991) and –62.4% in Liberia (1990) to 123.3% in Equatorial Guinea (1997). The first two figures are related to conflicts – the first Gulf War in Iraq and civil war in Liberia – and the latter to the discovery of large oil reserves in Equatorial Guinea in the mid-1990s. Despite some extreme values, the variable has approximately a normal distribution and 90% of observations are inside the –8.8% to 10.1% range.

Dependent variable 2: Armed civil conflict

We use armed civil conflict onsets from the annually updated UCDP/PRIO Armed Conflict Dataset (Gleditsch et al., 2002; Harbom & Wallensteen, 2010) as our dependent variable in the conflict analysis. The dataset has a relatively low inclusion criterion (25 annual battle-related deaths), which allows us to include low-intensity conflicts. We include all internal and internationalized internal conflicts in our dataset. We use a dummy variable with a value of 1 when a new conflict emerges, when one of the parties in the conflict has changed completely, or when a conflict that has been inactive for more than two calendar years re-emerges. In total, our dataset has 155 onsets, which comprise 3.5% of all country-year observations (Table I). As an alternative measure for a robustness check, we include a dummy for conflict incidence with a value of 1 for all country-years with conflict. We also construct an onset dummy for conflicts that accumulate more than 1,000 battle-related deaths during the course of the conflict. All data comes from the UCDP/PRIO Armed Conflict Dataset.

As a country with an ongoing armed conflict can experience an outbreak of a new conflict, we include all country-year observations following the conflict onset. This allows us to include all conflict onsets in the dataset. To control for the possibility that a country that is already experiencing conflict, or that recently endured one, may be more likely to experience another conflict, we include a variable that counts the years since the last year of conflict, as suggested by Beck, Katz & Tucker (1998). This also controls for time dependence.

Climate-related disasters

In this study, we use disaster data from the Emergency Events Database (EM-DAT), developed by the Centre for Research on the Epidemiology of Disasters (CRED).[8] EM-DAT is a global dataset that has records on disasters since 1900. To qualify for inclusion in EM-DAT, an event must meet at least one of the following criteria: 10 or more casualties, 100 or more people affected, declaration of a state of emergency, or call for international assistance.

EM-DAT includes both natural and man-made disasters. We focus on climate-related disasters and, because we are especially interested in the exogeneity associated with shock-like natural events, we only include hazards sorting under the disaster classes 'floods' and 'storms' in EM-DAT.[9] They typically have rapid onsets and disappear within one month. An overview of all 13 climate-related disasters included in our analysis is provided in Table II. As long as these events occur as shocks (that is, they last less than one month), they are included in the analysis. EM-DAT includes information on the numbers of people killed and people affected by the event, and the total direct damage (in current US dollars). We use the number of people affected as our main variable of interest.

How a disaster affects national income in any given year is likely to depend on the relative magnitude of the disaster as well as the time elapsed since the event took place. We normalize all disasters in a similar fashion to Noy (2009) in order to take these two factors into account. To account for magnitude, we normalize the size of an event by dividing the size of the affected

[8] EM-DAT is available publicly at http://www.emdat.be.

[9] Previous versions of this article also included *wet mass movements*. These account for only 9% of the 1,758 climatic disaster observations in our data. A robustness check revealed that they are not robustly related to economic growth and that they do not affect our results when excluded. Consequently, we only investigate floods and storms in this article.

population by total country population, using lagged figures for total population to ensure that the effect of the event does not enter into the denominator. Population numbers are taken from United Nations Statistical Data (UNSD, 2010).

With regard to timing, because we measure economic growth on annual basis, we need to correct for event time; an event that happened in January potentially has a larger effect on the current year's income than an event that happened toward the end of the year, which is more likely to affect the following year's growth figure. To address this concern, we weight the time elapsed since the event using the devaluation rate (12–*event month*$_{ijt}$)/12 in which j is a natural disaster in country i in year t. In other words, if an event took place in January (event month is 1), the normalized affected population is multiplied by 11/12. If the event happened in July, the multiplier is 5/12. This time appreciation allows disasters occurring in January this year to have a larger impact on current economic growth than disasters occurring in December this year. If a country has experienced several events during one year, the individual values are aggregated.

The annual, normalized, time-adjusted size of *population affected* over the year is thus calculated as:

$$\sum_{j=1}^{m} x_{ijt} = \sum_{j=1}^{m} \left(\frac{population\ affected_{ijt}}{total\ population_{it-1}} * \frac{12 - Event\ month_{ijt}}{12} \right) \quad (1)$$

where *population affected*$_{ijt}$ is the number of people affected in country i by disaster j at year t, *total population*$_{it-1}$ is the previous year's population size, and (12–*event month*$_{ijt}$)/12 is the imposed time weight. The left hand side of the equation thus represents the aggregated *population affected* over all climate-related disasters during year t.

Table I reports the disaster variable as a percentage – on average less than 0.45% of the population is reported to need immediate assistance because of climate-related natural disasters for a given country-year observation. The variation, though, is considerable. Although 2,960 country-year observations report that no disasters took place, the largest disasters affected up to 62% of the population.[10] For any given event, on average 1.4% of the population is affected (not reported). Table I shows that the time-weighted *population affected* (as defined in Equation 1) is roughly half the size of the non-weighted figure. This confirms that disasters, on a global scale, are distributed equally over the year. The table also shows that floods and storms are very similar in terms of *population affected*.

Control variables: Economic growth model

Controls that we include in the economic growth model follow the literature on natural disasters and economic growth, such as Noy (2009) and Raddatz (2009). All control variables are lagged by one year to minimize the occurrence of reversed causality.

Our first control is lagged GDP per capita growth. Inclusion of lagged growth controls indirectly for omitted variables, at least to the extent that it embodies information on what was important in determining the dependent variable in the previous year (Andersen, 2002). In addition, a lagged growth variable allows us to estimate both the direct effect of the exogenous disaster shocks on current growth and their indirect effect on the following year's growth via lagged growth. Indeed, to the extent that current economic growth is determined by growth last year, natural disasters occurring today can affect future economic growth. The other controls include measures for trade openness (absolute value of imports and exports relative to GDP), inflow and outflow of foreign direct investment (FDI) as a share of GDP, investment share of real GDP, the size of government expenditure relative to real GDP, and (logged) inflation using the consumer price index (CPI).[11] Data for trade openness, investment, and government expenditures come from Penn World Table Version 6.3 (Heston, Summers & Aten, 2009). Data for foreign direct investments and inflation come from World Bank (2010).

Control variables: Armed conflict model

Previous quantitative work on armed conflict has identified several factors that affect the onset of conflict. To keep our regression models as simple and parsimonious as possible in the second stage, we have limited the selection of controls to population size and regime type. Several other factors have been tested as part of the sensitivity assessment, but these do not affect the main results.

[10] Moldova experienced a large-scale storm in November 2000 that affected roughly 2.6 million people (see http://www.emdat.be). The second and third largest disasters (in terms of population affected relative to total population) in our data are the tropical cyclone that hit the Solomon Islands in May 1986 and Hurricane Michelle, which hit Cuba in November 2001. They affected 55% and 53% of the population, respectively.

[11] Inclusion of these variables as controls in growth models is discussed in detail in Barro & Sala-i-Martin (2004: 518–540).

Population data come from Penn World Table Version 6.3. These data are both lagged and logged. We use a lagged Polity IV variable (Marshall & Jaggers, 2009) to measure level of democratization. It varies from 0 to 20, in which 0 denotes the most autocratic and 20 the most democratic state. Following Hegre et al. (2001), we include both the linear and squared measure in the model. The summary statistics for these variables are given in Table I.

Analysis

Climatic disasters and economic growth

To test our first hypothesis, we estimate regression models with different transformations of the relevant explanatory variable, *population affected*.[12] In the analysis we estimate the following two-way error component model:

$$y_{it} = \alpha_0 + \alpha_1 \sum_{j=1}^{m} x_{ijt} + \alpha_2 y_{it-1} + \phi' \boldsymbol{\kappa}_{it-1} + u_{it} \quad (2)$$

where $u_{it} = \boldsymbol{\eta}_i' \boldsymbol{I}_\eta + \boldsymbol{\tau}_t' \boldsymbol{I}_\tau + \varepsilon_{it}$.

For each country i at year t we denote the following: y_{it} is the per capita GDP growth rate; α_1 is the disaster coefficient for the sum of the population affected by all disasters j in that year (as defined in Equation 1); α_2 is the coefficient for lagged economic growth y_{it-1};[13] $\boldsymbol{\kappa}_{it-1}$ is a vector of control variables (we follow the short-run growth literature by lagging them one year); and u_{it} is the error term composed of country-specific, unobserved factors independent of time, $\boldsymbol{\eta}_i$, year-specific, unobserved factors independent of country-characteristics, $\boldsymbol{\tau}_t$, and an idiosyncratic error term ε_{it}. $\boldsymbol{I}_\eta$ and $\boldsymbol{I}_\tau$ are two column vectors of ones.

A valid critique of previous studies is that they ignore time-independent geographic factors such as climate and closeness to the coastline or the equator, which affects the occurrence of natural disasters and economic growth (Gallup, Sachs & Mellinger, 1999). Furthermore, while developed countries may experience less human and infrastructural damage when disasters strike them, developing countries may have a tendency to exaggerate the impact of disasters to attract more aid from abroad (Skidmore & Toya, 2002). To reduce biases caused by these concerns, we estimate country fixed-effects models, that is, with variables transformed to deviations from their country-specific means. This effectively removes time-independent growth-factors, contained in the vector $\boldsymbol{\eta}_i$. We also include fixed-year dummies to control for global shocks, the vector $\boldsymbol{\tau}_t$. Hence, both levels and trends in economic growth are picked up in a non-parametric fashion.[14]

Table III reports the results on the effects of climate-related disasters on per capita economic growth. As an introductory estimation, Model 1 includes a simple dummy variable noting whether a large-scale disaster took place in the country. The model also includes lagged economic growth for the previous year and the other control variables: openness to foreign trade, investment, government expenditure, FDI, and inflation, all lagged by one year. The results show a negative effect on current economic growth, significant at the 10% level.

We next study the effect of our more sophisticated climatic disaster variable that also explores variation in the smaller disasters. Model 2 includes our main variable of interest, the time-weighted *population affected* together with the controls from Model 1.[15] As can be seen from the results, the effect of climatic natural disasters on current economic growth is negative and highly significant. When the weighted *population affected* increases by one standard deviation (0.014), economic growth is predicatively reduced by 0.38 percentage points (26.8*0.014) within the same year. The long-run growth reduction, calculated by evaluating Equation 2 in steady state with y_{it} equal to y_{it-1}, is predicatively 0.46 percentage points (0.38/(1–0.18)).

In Model 3 we include floods and storms separately to compare their impact on growth. The coefficients are similar and highly significant, and an F-test rejects the hypothesis that the marginal effects are different (F-value is 0.31; *p*-value is 0.58). This result holds across all specifications in the article. Thus, we use the combined measure for floods and storms in subsequent models.

We conduct several robustness checks of which some are reported in Table IV. Model 4 in Table IV shows that the results remain similar when all controls except for lagged growth are removed. As a control for other

[12] We also constructed similar measures for *people killed* and *economic damage* in which the number of people killed by the disaster is normalized by the size of total population and the amount of economic damage by GDP. Both measures use the same weight structure as *people affected* (Equation 1). Of these variables, *population affected* was the best predictor of growth. It also renders the other two measures insignificant when all three variables are included in the base models simultaneously (the results are not shown).

[13] Other subsequent growth studies suggest that this AR(1) specification should be used (Raddatz, 2007; Noy, 2009).

[14] As robustness checks, we also include country-specific time trends in the models in Table III. Use of these does not change the results (not shown).

[15] Including other controls such as current account balance, life expectancy at birth, etc. does not affect the results regarding our variable of interest.

Table III. Climate-related disasters and economic growth, 1981–2007

	(1) GDP/capita growth	(2) GDP/capita growth	(3) GDP/capita growth
Population affected (time weights), t		–26.8***	
		(–6.75)	
Affected by floods (time weights), t			–31.0***
			(–3.10)
Affected by storms (time weights), t			–24.0***
			(–4.47)
Climatic disaster (dummy), t	–0.53*		
	(–1.91)		
GDP/capita growth, t–1	0.17***	0.18***	0.18***
	(3.89)	(3.94)	(3.93)
Trade openness, t–1	0.015**	0.014*	0.014*
	(2.00)	(1.92)	(1.92)
Real investment share of GDP, t–1	0.031	0.031	0.031
	(0.75)	(0.76)	(0.76)
Real government share of GDP, t–1	0.025	0.025	0.025
	(0.29)	(0.28)	(0.29)
FDI inflow, t–1	0.36*	0.36*	0.36*
	(1.90)	(1.92)	(1.92)
FDI outflow, t–1	–0.30**	–0.30**	–0.30**
	(–1.98)	(–1.99)	(–1.99)
Inflation (ln), t–1	–0.075	–0.069	–0.068
	(–0.72)	(–0.66)	(–0.65)
Observations	2,940	2,904	2,904
Countries	149	145	145
R-squared	0.18	0.18	0.18

Robust t-statistics, clustered on countries, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Fixed country and year effects are included in all analyses. Models are estimated with STATA 11.

natural disasters, Model 5 shows the results using *earthquakes*, *volcano eruptions*, and *droughts* as additional regressors (earthquakes and volcanos are also measured by the number of people affected while drought is modeled by a dummy for the relevant country-years). Our climatic disaster variable proves robust to these controls and only drought seems to be significantly related to economic growth. Model 6 adds *lagged population affected* to Model 2 from Table III. The lagged disaster variable has a positive sign, but fails to attain a conventional significance level. It does not have any effect on our main variable of interest. Model 7 uses *logged population affected* and returns a strong negative impact on economic growth. Model 8 extends the time series to 1970 (the first year with available population data from UNSD), returning the same results as for the shorter time-span. Model 9 reruns the model with *population affected without time weights*. As expected, we get a negative coefficient about half of the size compared to the time-weighted *population affected*.

So far we have used the fixed-effects estimator to control for time- and country-independent growth factors. Country-years probably also differ with respect to fixed conflict risk factors, so we use this estimator in the section about civil conflicts as well. However, fixed-effects regressions based on Equation 2 might yield biased results because y_{it-1} is correlated with the country-specific *averaged* error ε_i by construction. As a final robustness check we address this concern in Model 10 where the Arellano & Bond (1991) estimator is applied instead.[16] The empirical results confirm our previous findings: an increase in population affected by one

[16] The estimator builds on a GMM-framework. It is obtained by differencing Equation 2 once, using all past values of economic growth in *levels* as instruments for present values in *first-differences* (this generates 71 instruments). Country-specific effects are eliminated by the differentiation, and the instruments remove correlation between lagged growth and error terms.

Table IV. Climate-related disasters and economic growth – Robustness tests

	(4) GDP/capita growth	(5) GDP/capita growth	(6) GDP/capita growth	(7) GDP/capita growth	(8) GDP/capita growth	(9) GDP/capita growth	(10) GDP/capita growth
Population affected (time weights), *t*	–22.6***	–26.5***	–26.6***		–25.7***		–32.8***
	(–4.27)	(–6.65)	(–6.71)		(–6.56)		(–5.12)
Population affected (time weights), *t*–1			4.72				
			(0.91)				
Population affected (ln) (time weights), *t*				–0.55***			
				(–4.14)			
Population affected (no time weights), *t*						–12.4**	
						(–2.28)	
Earthquakes (time weights), *t*		–3.11					
		(–0.31)					
Volcanoes (time weights), *t*		–25.0					
		(–0.10)					
Droughts (dummy), *t*		–0.62*					
		(–1.94)					
GDP/capita growth, *t*–1	0.16***	0.18***	0.18***	0.17***	0.18***	0.17***	0.18***
	(2.79)	(3.93)	(3.96)	(3.92)	(4.28)	(3.91)	(3.47)
Trade openness, *t*–1		0.014*	0.014*	0.014*	0.013*	0.014*	0.034
		(1.91)	(1.93)	(1.88)	(1.67)	(1.91)	(1.26)
Real investment share of GDP, *t*–1		0.031	0.031	0.032	0.023	0.032	–0.042
		(0.76)	(0.76)	(0.78)	(0.60)	(0.77)	(–0.46)
Real government share of GDP, *t*–1		0.024	0.025	0.025	0.015	0.023	0.052
		(0.28)	(0.29)	(0.29)	(0.20)	(0.26)	(0.26)
FDI inflow, *t*–1		0.36*	0.36*	0.36*	0.34*	0.36*	0.053
		(1.92)	(1.91)	(1.92)	(1.82)	(1.91)	(0.61)
FDI outflow, *t*–1		–0.30**	–0.30**	–0.30**	–0.29*	–0.30**	–0.050
		(–1.99)	(–1.99)	(–1.99)	(–1.88)	(–1.99)	(–0.68)
Inflation (ln), *t*–1		–0.071	–0.072	–0.055	–0.041	–0.069	0.15
		(–0.68)	(–0.68)	(–0.52)	(–0.40)	(–0.65)	(0.77)
Observations	4,210	2,904	2,904	2,904	3,256	2,904	2,731
Countries	162	145	145	145	145	145	143
R-squared	0.07	0.18	0.18	0.18	0.18	0.18	–
Time period	1980–2007	1980–2007	1980–2007	1980–2007	1970–2007	1980–2007	1980–2007

Robust t-statistics, clustered on countries, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Fixed country and year effects are included in all analyses. Models are estimated with STATA 11.

standard deviation now corresponds to a total growth reduction of 0.56 percentage points.[17]

In total, the work presented so far provides quantitative evidence of a negative causal effect on short-run economic growth from the number of people affected by climatic disasters. The respective coefficients are significant and the results are robust to different model specifications and control variables used in the economic literature. If anything, these results can be taken as support for the argument that climate-related disasters alter factors that are important for production and income, and hence reduce overall economic performance.

Armed civil conflict

The second goal of this study is to analyze how growth changes triggered by climatic disasters determine the risk of armed civil conflict onset. Previous studies have shown that low income levels and slow economic growth increase the risk of armed civil conflict onset. From this, it follows that climate-related disasters may increase the likelihood of conflict through their negative impact on income growth. Analytically, we can define civil conflicts as a function of economic growth, and economic growth as a function of climatic disasters. According to advocated postulations and the chain rule, the dynamics are then given by:

$$\frac{\partial \mathit{Conflict\ onset}}{\partial \mathit{Clim.\ disasters}} = \frac{\partial \mathit{Conflict\ onset}}{\partial \mathit{Economic\ growth}} * \frac{\partial \mathit{Economic\ growth}}{\partial \mathit{Clim.\ disasters}} > 0 \quad (3)$$

The first term on the right-hand side of Equation 3 can be understood as a structural equation describing the growth effects on conflicts. It is empirically specified as:

$$c_{it} = \beta_0 + \beta_1^{IV} \hat{y}_{it} + \boldsymbol{\gamma}' \boldsymbol{\delta}_{it-1} + \upsilon_{it} \quad (4)$$

For each country i at time t we denote the following: c_{it} is a dummy variable equal to one for all observations with new armed civil conflict onset; ${\beta_1}^{IV}$ is the coefficient for the instrumented income growth $\hat{y}_{it}$;[18] $\boldsymbol{\gamma}$ is the coefficient vector for a vector of lagged control variables $\boldsymbol{\delta}_{it-1}$; and υ_{it} is the error term.[19] Because the dependent variable is binary, the model in the second stage is a linear probability model. The parameter of interest in the structural equation is ${\beta_1}^{IV}$.

Table V summarizes key results from our instrumental variable analysis. First, we check how robust the disaster–growth relation is to commonly used conflict determinants. Model 11 includes controls for population size, regime type, and length of peace prior to the onset. The key explanatory variable as defined in Equation 1 is unchanged. The results confirm that our measure for climatic disasters is robust. The estimated growth reduction is 0.18 percentage points per percentage point increase in the disaster variable. The computed F-value is 11.48 (p-value < 0.001). In other words, climatic disasters seem to be strongly relevant for short-term growth fluctuations in GDP per capita, even when controlling for typical conflict variables.

As well as being relevant for income growth in the first-stage equation, climatic events should be exogenous in the second stage. A potential problem is that climate-related disasters might affect the risk of conflict through channels other than income. If this is true, we could get biased coefficients in the second-stage regression. Theoretically, weather-related disasters may affect conflict propensity in ways other than through income growth. For instance, if such events destroy communication and transportation systems, they may affect the mobility of the military and potential rebel groups. Net consequences of these mobility constraints are in theory ambiguous. On the one hand, climate-related disasters might separate conflict parties from each other and thereby temporarily postpone an onset. On the other hand, if government forces depend more heavily on roads and conventional communication systems, climatic disasters might shift the conditions to wage war asymmetrically and thereby increase conflict risk as potential rebels' opportunity to emerge and survive may increase.

Thus, it is not feasible to rule out the possibility that sudden climatic disasters determine the probability of new conflicts only through income, a requirement for the instrument to be valid. Nevertheless, a reduced-form specification can at least provide some hints about the general relation between climate-related events and armed civil conflict. Model 12 in Table V reports results from a reduced-form equation, that is, the (short-run) effect from climate-related disasters on conflict onset. Current economic growth is also included in order to

[17] Arellano-Bond tests (in first differences) suggest that the error term follows an AR(1) process (p-value is 0.000), but not an AR(2) (p-value is 0.337). The Hansen test of overidentifying restrictions does not reject the null hypothesis (p-value is 0.275). All these numbers provide support for our model specification. The system GMM-estimator initially developed by Arellano & Bover (1995) gives similar results (not shown).

[18] The 'hat' above y indicates that we use the instrumented rather than the observed values.

[19] Again we estimate country and time fixed-effects models.

Table V. Climatic disasters, economic growth, and armed civil conflict, 1980–2007

	(11) *GDP/capita growth*	*(12)* *Conflict onset*	*(13)* *Conflict onset*
GDP/capita growth, *t*		–0.0011**	0.0035
		(–2.01)	(0.65)
Population affected (time weights), *t*	–18.02***	–0.083	Instrument
	(–3.39)	(–0.84)	
Population (ln), *t*–1	–2.02	0.053	0.062*
	(–0.98)	(1.65)	(1.74)
Democracy index, *t*–1	0.055	0.0052	0.0049
	(0.32)	(1.14)	(1.04)
Democracy index (squared), *t*–1	–0.0020	–0.00020	–0.00019
	(–0.25)	(–0.94)	(–0.87)
Observations	3,894	3,894	3,894
Countries	153	153	153
R-squared	0.05	0.03	–
F-test of instrument	–	–	11.48***

Robust z-statistics (t-statistics in first stage columns), clustered on countries, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Fixed country and year effects are included in all analyses. Coefficients for time since last onset and cubic splines are not shown. Models are estimated with STATA 11.

illustrate the typical negative growth effect found in previous studies.[20] As the model shows, climate-related disasters have no significant direct effect on the risk of conflict onset in our data. In fact, the average relation between population affected and conflict onset is negative (point estimate equal to –0.083), that is, the opposite of our *a priori* hypothesis.

The other results presented by Model 12 are similar to the results in a number of previous studies. Economic growth is negatively linked to the risk of conflict onset: when economic growth increases by one percentage point, the risk of armed civil conflict onset is predicatively reduced by 0.11 percentage points. This result is significant at the 5% level. While all control variables have their expected signs, none of them are significant at the 10% level. In total, we find no support in our data for the view that climatic disasters affect conflict onset other than through income fluctuations.

Model 13 shows results from the 2SLS analysis (Model 11 provides the first-stage results). Here, the link between current growth and conflict onset has changed from being negative and significant to being (positive and) clearly insignificant. In other words, growth changes caused by climatic disasters do not seem to affect the likelihood of experiencing a conflict onset. This is a further indication that changes in economic growth triggered by climatic disasters do not affect the probability of conflict onset.

To test sensitivity of the results, we run several alternative specifications. Table VI reports some of these: Model 15 repeats the baseline specification (Model 13 in Table V) with country-specific time-trends in addition (Model 14 shows results from the first stage). While the instruments gain in strength (F-value is 17.7), the second stage results remain unchanged. In Models 16 and 17 we use the two disaster classes 'floods' and 'storms' as separate instruments.[21] As expected, the results are almost identical to Models 14 and 15, although the statistics suggest weaker identification in the first stage. The same is the case with Models 18 and 19 that use the natural logarithm of *population affected* as the instrument. Model 21 substitutes the onset variable with a dummy for conflict incidence to test whether disaster-triggered growth shocks affect the likelihood of conflict presence (the reduced form is provided in Model 20; the first stage is the same as Model 11 in Table V). Models 22 and 23 examine onset of war (conflict onset that accumulated at least 1,000 battle-related deaths during the course of conflict). As earlier, the second-stage

[20] We also estimated conflict models with one and two year time lags for economic growth, but these did not affect the conflict propensity.

[21] We cannot reject the null hypothesis that both instruments are valid (Hansen J-statistic equal to 0.18; *p*-value is 0.67). Country-specific time trends are included here as well to gain power in the first stage.

Table VI. Armed civil conflict – Robustness tests

	(14) GDP/capita growth	*(15) Conflict onset*	*(16) GDP/capita growth*	*(17) Conflict onset*	*(18) GDP/capita growth*	*(19) Conflict onset*	*(20) Conflict incidence*	*(21) Conflict incidence*	*(22) War onset*	*(23) War onset*
GDP/capita growth, *t*		0.0045		0.0045		0.0020	–0.0020***	–0.012	–0.00025	–0.0020
		(0.96)		(0.96)		(0.29)	(–2.67)	(–1.28)	(–1.55)	(–0.90)
Population affected	–20.1***	Instrument					0.18	Instrument	0.031	Instrument
(time weights), *t*	(–4.20)						(1.10)		(0.82)	
Affected by floods			–20.4**	Instrument						
(time weights), *t*			(–2.21)							
Affected by storms			–19.7***	Instrument						
(time weights), *t*			(–4.40)							
Population affected (ln)					–0.38***	Instrument				
(time weights), *t*					(–2.70)					
Population (ln), *t*–1	–14.9**	0.065	–14.9**	0.065	–2.04	0.059*	0.045	0.025	0.0032	–0.00025
	(–2.05)	(0.43)	(–2.05)	(0.43)	(–0.99)	(1.66)	(0.75)	(0.35)	(0.46)	(–0.03)
Democracy index, *t*–1	–0.24	–0.0054	–0.24	–0.0054	0.059	0.0050	0.010	0.011	0.0029**	0.0030**
	(–1.02)	(–0.93)	(–1.02)	(–0.93)	(0.35)	(1.07)	(1.22)	(1.30)	(2.04)	(2.14)
Democracy index	0.012	0.00031	0.012	0.00031	–0.0023	–0.00019	–0.00056	–0.00058	–0.00013**	–0.00013**
(squared), *t*–1	(1.07)	(1.18)	(1.07)	(1.17)	(–0.28)	(–0.89)	(–1.42)	(–1.47)	(–2.06)	(–2.13)
Observations	3,894	3,894	3,894	3,384	3,894	3,894	3,894	3,894	3,894	3,894
Countries	153	153	153	153	153	153	153	153	153	153
R-squared	0.13	–	0.13	–	0.05	–	0.27	–	0.01	–
F-test of instrument	–	17.65***	–	13.87***	–	7.31***	–	11.48***	–	11.48***
Country-specific year trend	Yes	Yes	Yes	Yes	No	No	No	No	No	No

Robust z-statistics (t-statistics in first stage columns), clustered on countries, in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Fixed country and year effects are included in all analyses. Coefficients for time since last onset and cubic splines are not shown. Models are estimated with STATA 11.

results are insignificant. Taken together, the *a priori* expected negative effect from current economic growth on the risk of armed civil conflict onset is not present in our 2SLS models.[22]

These results differ from those in the empirical studies of Collier & Hoeffler (2004) and Miguel, Satyanath & Sergenti (2004), who find significant negative effects from economic growth on the risk of civil conflict onset. Our results support the view that economic growth, when instrumented by climatic phenomena, does not relate systematically to armed civil conflict onset (Bernauer et al., 2012). This finding, however, may be specific to climate-related natural disasters and does not necessary rule out growth impacts on conflict in general.

Conclusions

Climate change may well be the most serious and wide-ranging future challenge facing our planet. Changes in temperature and precipitation may change the living conditions for people and animal and plant life on a permanent basis. Moreover, climate change may also increase the number or intensity of various climate-related disasters. To explore how these latter changes may play out for countries affected by such disasters, this article examines how climate-related disasters affect economic growth and armed civil conflicts during the period 1980–2007.[23]

Our results show that an increase by one standard deviation in the number of people affected by sudden climatic disasters leads to a total aggregate income growth reduction of about 0.5 percentage points. Arguably, storms and floods adversely affect people and production inputs such as land, infrastructure, and factories, which in turn have a negative impact on the aggregate economy. Interestingly, these negative income shocks do not increase the risk of armed civil conflict as predicted by prominent studies in the field (Collier & Hoeffler, 2004; Fearon & Laitin, 2003; Miguel, Satyanath & Sergenti, 2004). However, our results primarily justify assertions about income changes caused by climatic disasters. It might still be the case that growth shocks caused by rainfall (see Miguel, Satyanath & Sergenti, 2004) change the likelihood of civil conflicts in ways other than growth shocks caused by sudden floods and storms, although analyses conducted on a more local scale indicate that short-term variations in climate do not seem to provoke land-related conflicts (Benjaminsen et al., 2012) and that drought periods see fewer episodes of violent cattle raiding (Adano et al., 2012).

There could be several possible reasons for our findings, based on historical data, that economic downturn caused by climatic hazards does not seem to come with increased conflict risk on a year-by-year basis. First, it may matter what has caused economic hardship in the country. A natural disaster may be viewed by the population as outside the government's control, and thus the economic consequences are not blamed on the government. Second, people hit by such a disaster may consider economic consequences as transitory; after the houses have been rebuilt and the next harvest is in, life is expected to return to normal in economic terms. Third, as disasters can have unifying effects on the population that divert attention from other grievances, they might, at least transitionally, reduce the likelihood that a rebel movement emerges (Slettebak, 2012).

Finally, our results may indicate that economic growth and income level may not be such important sources of conflict as previous studies imply. We find our results appealing because the traditional economic approach, with rebels as rational utility-maximizing individuals, does not necessarily yield a negative income–conflict relationship. Indeed, higher income growth could make it more attractive to take up arms as long as higher national income means that there is more to grab. In other words, the argument that higher growth represents higher alternative costs associated with rebellion is not as straightforward as generally thought, even if one accepts the rather restrictive definition of rebels as rational and utility-maximizing individuals. This is in line with economic theory that suggests a positive relationship between economic growth and crime rates (Mehlum, Moene & Torvik, 2004).

Hence, our insignificant 2SLS estimates might be an indication that the linkage between economic conditions and conflict risk is far more complex or heterogeneous than suggested by earlier country-year analyses. When it comes to climate change and increased frequency and severity of climate disasters, our study indicates that in the past, the *short-term* negative effect of climate-induced disasters on economic growth does not increase the risk of conflict onset in the following two-year period. Thus, there is a need for studies that look at the

[22] As further robustness checks, we run several alternative specifications of the base model: generalized least squares models without country fixed effects, logit models, expand the time period to 1970–2007, and add other controls. None of these change the result.

[23] For an attempt to predict the future, see Devitt & Tol (2012), who simulate a model with climate change, civil war, and development.

long-term economic effects of disasters and how these relate to the risk of armed civil conflict.

Replication data

The dataset and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets. All analyses were done using Stata 11.

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Don't blame the weather! Climate-related natural disasters and civil conflict

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Abstract

The issue of climate change and security has received much attention in recent years. Still, the results from research on this topic are mixed and the academic community appears to be far from a consensus on how climate change is likely to affect stability and conflict risk in affected countries. This study focuses on how climate-related natural disasters such as storms, floods, and droughts have affected the risk of civil war in the past. The frequency of such disasters has risen sharply over the last decades, and the increase is expected to continue due to both climate change and demographic changes. Using multivariate methods, this study employs a global sample covering 1950 to the present in order to test whether adding climate-related natural disasters to a well-specified model on civil conflict can increase its explanatory power. The results indicate that this is the case, but that the relation is opposite to common perceptions: Countries that are affected by climate-related natural disasters face a lower risk of civil war. One worrying facet of the claims that environmental factors cause conflict is that they may contribute to directing attention away from more important conflict-promoting factors, such as poor governance and poverty. There is a serious risk of misguided policy to prevent civil conflict if the assumption that disasters have a significant effect on war is allowed to overshadow more important causes.

Keywords

armed conflict, climate change, natural disasters

Introduction

The academic, policy, and popular discussions that surround the issue of climate change predict changing weather patterns to increase natural disasters. Hurricane Katrina, which hit the city of New Orleans in 2005, has given much impetus to this discussion. Tropical cyclones, floods, heat waves (even cold spells), and droughts are apparently likely to be more destructive and carry higher consequences for humans in the future because rising temperatures (global warming) is expected to increase the frequency and intensity of these events (Aalst, 2006; IPCC, 2007a,b). Many even expect these disasters to increase the risk of violent conflict, which would create double burdens to states and societies trying to cope and adjust to climate change. In this article, I investigate whether there is a systematic tendency that climate-related natural disasters[1] cause civil conflict to arise, or re-ignite, within the same or the following year.

In order to assess whether natural disasters have any real effect on the risk of armed conflict, an existing, well-tested model should be used as a starting point. Only if natural disasters can add explanatory power to such a model might one be able to be confident in the proposition that disasters also increase the risk of armed conflict. I will use one candidate for such a model, developed by Fearon & Laitin (2003), to test how disasters affect the risk of civil war onset, when controlling for the most important other relevant factors. Dixon (2009)

[1] Unless otherwise specified, I use the term 'disaster' to refer to climate-related natural disasters (storms, droughts, floods, landslides, extreme temperatures, and wildfires).

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finds that the model used by Fearon & Laitin (2003) has fared very well, as the academic community has achieved some level of consensus on the role of all the variables they found to be significant. Hence, the scope of this study is limited to violent security issues (Goldstone, 2001), which may possibly be a consequence of the non-violent security challenges brought about by natural disasters. By studying how climate-related natural disasters have affected the likelihood of civil war in the past, this article aims to increase knowledge about to what extent future disasters, possibly exacerbated by the effects of climate change, can be expected to affect the likelihood of outbreaks of civil war. Thereby, this study may also contribute to informing governments about response strategies for managing the potential double impacts of natural disasters.

What is a natural disaster?

A climate-related natural disaster occurs when a natural hazard affects a vulnerable population so forcefully that it causes substantial death and/or damage. 'Natural disaster' can thus be broken down into three components: hazard, exposure, and vulnerability. The hazard is a natural phenomenon, such as strong wind, heavy rainfall, or extreme temperatures, while exposure and vulnerability are mainly human. Exposure refers to whether settlements are placed in locations that are exposed to natural hazards, while vulnerability is to what extent people and settlements are physically and institutionally prepared to withstand the damaging effects of natural hazards. Hence, apart from the very strongest hazards which always can be expected to cause severe damage, where and when natural disasters occur is highly contingent on human preparations (Birkmann, 2006; Wisner et al., 2004). For example, a sturdy, storm-proof building may escape damage from cyclones that would devastate fragile slum-dwellings. Similarly, constructing dikes along flood-prone rivers and avoiding construction of houses in areas that are at risk from becoming flooded can contribute to reducing the risk of disastrous floods.

The examples above also illustrate that natural disasters mainly affect poor people who cannot afford storm-proof buildings, who have no choice but to build their homes in the most exposed areas, and who subsist by what they are able to grow themselves. These problems are mainly related to poverty and, often, poor governance, not nature. Failure to adapt to and anticipate potential natural hazards will result in disaster sooner or later. At times, environmental degradation, such as deforestation, even moves societies in the opposite direction, making them more vulnerable. Similarly, uncontrolled urbanization may cause exposed, risky areas (such as steep hills and low-lying, flood-prone areas) to become densely populated – a recipe for disaster in the long run.

Even if weather conditions do not change, the number of climate-related disasters will increase if human habitations are placed in exposed areas without sufficient protection. Climate change projections indicate that many areas will face increasing exposure from climate-related hazards in the future. This, combined with current trends in urbanization, indicates that the significance of this issue is likely to increase. Without improving the resilience of affected societies substantially, an increased number of disasters will follow. This is highly unsettling in itself, but if claims that natural disasters increase the risk of conflict are correct, there is far more to worry about.

Why do disasters matter for conflict?

The debate on security implications of climate change has contributed to increasing the attention to how environmental factors may affect the risk of armed conflict. Environmental shocks generate insecurity, frustration, scarcity of important resources, and weakened enforcement of law and order, which are frequently suggested to increase the likelihood of outbreaks of armed violence (Brancati, 2007; Burke et al., 2009; Homer-Dixon, 1999; Miguel, Satyanath & Sergenti, 2004; Nel & Righarts, 2008). While no one debates that severe environmental shocks cause suffering and destruction, there is no consensus on how humans should be expected to respond to these challenges. On the contrary, sociological research on post-disaster behavior has reached the opposite conclusion of the popular perception, finding that the likelihood of anti-social behavior tends to drop during and after disasters.

The roots of sociological research on disaster behavior can be traced at least back to Durkheim (1952[1897]), who found that great social disturbances and wars tend to increase social integration, thereby reducing the risk of anti-social behavior. Prince (1920) is credited with the first study aimed specifically at studying human behavior when faced with catastrophic events. Prince studied victims of the Halifax Explosion in December 1917, finding – as would be expected from Durkheim's observations – that the disaster had contributed to increased social cohesion in the affected community.

The first large-scale systematic studies of human behavior in disaster were conducted by US researchers in the aftermath of World War II. The research projects were motivated by two main factors: worries about how the population could be expected to respond to a nuclear attack and an interest in how to cause maximum disruption to an enemy during war (Fritz, 1961). With only two cases of nuclear bombing to study, the researchers turned to natural disasters and conventional bombing during World War II in order to increase knowledge about human behavior in disaster situations. The initial expectation was that bombing and natural disasters would cause massive panic and a breakdown of law, order, and social norms, but this was strongly contradicted by the findings. Summarizing the results of more than 16,000 interviews and questionnaires conducted after 144 peacetime disasters in the USA and among victims of Allied bombing in Germany and Japan (Disaster Research Group, 1961; US Strategic Bombing Survey, 1947a,b), Fritz (1996: 10) wrote that

> Even under the worst disaster conditions, people maintain or quickly regain self control and become concerned about the welfare of others.... antisocial behavior, such as aggression towards others and scapegoating are rare or nonexistent. Instead, most disasters produce a great increase in social solidarity among the stricken populace, and this newly created solidarity tends to reduce the incidence of most forms of personal and social pathology.

The article was written in 1961, but not made publicly available until 1996.[2] Although this is an old work, Fritz states in his 1996 introduction that he has not seen anything in more recent studies that would change the basic framework of his analysis (Fritz, 1996: 17).

Fritz suggests that the importance of cultural and individual differences diminish in disaster situations, as people are forced to confront similar dilemmas under similar conditions, irrespective of class or ethnicity (Fritz, 1961: 655). Further, such group identities are reported to be superseded by a common identity among the disaster victims, a 'community of sufferers', as they are united by an external threat that is common to all. The emergence of such communities is posited as a universal feature of disasters where the survivors are permitted to interact freely and to make an unimpeded social adjustment to the disaster (Fritz, 1996: 28).

A core implication from disaster sociology is, then, that disasters should reduce the likelihood of violent conflict through generating a sense of unity among the victims and reducing the importance of divides that might otherwise be conducive to conflict. This is starkly opposed to the suggestion that disasters increase the likelihood of conflict due to relative deprivation, ethnic security dilemmas, or fighting over diminishing resources. While the theory focuses mainly on the people directly affected by the disaster, one may speculate that the unifying effect may spread to the rest of the population as well – the frequent desire of outsiders to help in disaster situations is well known.

Within this theory, there are some important caveats to consider. First, if disasters are to trigger violent conflict, this is expected to happen in poor, unstable countries, not in the well-organized industrial countries where the cases cited by Fritz were located. Therefore, the theory must be tested on a representative sample of countries in order to assess its explanatory power relative to other theories – which is part of the rationale for this article. Second, Fritz's theoretical argument is founded on the assumption that disaster victims are allowed to make an unimpeded adjustment to the disaster situation (Fritz, 1996: 28). He does not specify this assumption in detail, but it appears to have been fulfilled in the cases he builds his conclusions on – which includes wartime Germany and Japan. Authoritarian regimes may be suspected of having an interest in preventing the formation of any group capable of collective action – including disaster communities. This appears even more likely when considering that disasters may increase the likelihood for demands for social and political change, which may be highly unpopular among authoritarian leaders (Fritz, 1996: 55).

Within the current debate on how environmental factors may affect the risk of conflict, scarcity of important resources holds a prominent place. Acute scarcities, caused by reduced supply, increased demand or skewed distribution, are suggested as a significant current and future source of violent conflict (Homer-Dixon, 1999). Most natural disasters occur relatively abruptly (the main exception is drought), but the after-effects may linger on for a long time, causing or exacerbating scarcities similar to those described by Homer-Dixon. From the perspective of disaster sociology, however, this is where the similarities end. Of the three main theoretical connections between scarcity and conflict risk suggested by Homer-Dixon (1999: 136f), two are directly contradicted by disaster sociology, while the third is at least partially contradicted.

The two first connections suggested by Homer-Dixon are frustration-aggression theories and group identity

[2] It was originally intended to be part of an edited book on disaster topics edited by Charles Fritz and Harry Williams. However, both changed jobs before the book was finished, and Fritz's chapter was left out of the book after what appears to be mainly editorial disagreements. For a fuller description, see Fritz (1996: iii-iv).

theories. Frustration and relative deprivation as well as political leaders' exploitation of ethnic and social identity by pitting different groups against each other are proposed as plausible connections at the individual and group levels. Homer-Dixon's third connection is located at the systemic level: environmental scarcities are expected to reduce constraints facing insurgents, for example through weakening state institutions, thereby increasing the opportunity for rebellion. Homer-Dixon (1999: 142f) expects that the combination of relative deprivation, increased intergroup segmentation, and perceptions of a weakened state is likely to cause insurgency.

The first two suggested connections run directly counter to Fritz's arguments that disasters reduce the relevance of group identities and the likelihood of aggressive behavior, thereby also reducing the risk of group-identity-driven conflict. With respect to the weakening of state institutions, disaster sociology expects the increased sense of solidarity among disaster victims to arise in the absence of any overarching authority. Increased levels of conflict due to this are therefore not expected. However, the findings summarized by Fritz are from countries with strong systems of governance, so it is unlikely that insurgent organizations should be able to exploit temporary reductions in state capacity. Such a scenario appears far more realistic in many of the countries that are already among the most vulnerable to natural disasters.

Natural disasters will, almost by definition, overstrain governments' capacities in affected areas for a certain amount of time. However, it is not straightforward that this should increase the opportunities for insurgency. First, the insurgents may be set back by the disaster as well. Second, a time when potential insurgents and their families are busy trying to survive and recover from a disaster may not be the best period to attempt to instigate a rebellion. Also, if disasters contribute to reducing grievances and group differences, the foundation for an insurgency may be severely undermined.

A more serious objection against disaster sociology can be derived from the argument of how disaster victims are unified by their common experiences. Even if this is generally true, it begs the question of who become victims. Disasters generally do not select their victims at random – the poorest and most vulnerable are most likely to be affected. These groups usually live in the least disaster-resistant habitations, in the most exposed areas, and are generally less able to secure the resources needed for quick and effective recovery (Wisner et al., 2004). If disaster damages follow ethnic or social divides, this may be suspected to increase the likelihood of conflict, while damage – and aid efforts – across such divides may reduce it.

A potentially important difference between Homer-Dixon's scarcity perspective and disaster sociology is the time frame. Environmental degradation is a slow and gradual process while a disaster, which by definition is a severe exception from everyday life, has a shorter duration. Although a drought can linger on for months and years, most natural disasters pass in a matter of days or weeks. Reconstruction, however, may take substantially longer. This raises the question of how long after a disaster the reduced likelihood of conflict is likely to last, and whether it can be expected to be replaced by increased friction during the reconstruction process.

Quarantelli & Dynes (1976) find that conflicts related to the allocation of blame or the distribution of resources tend to arise in the reconstruction process after disasters. As their analysis is limited to non-violent conflict in USA, it is less clear how this should be expected to play out in other countries. Goldstone (2001) suggests that the political outcomes of disasters hinge on how they are handled; poorly managed disasters in developing countries are argued to increase the risk of political unrest and violence, while competent disaster management may actually increase the support for the government. This argument is mirrored by Olson & Gawronski (2010), who find that disasters may cause governments' popularity to rise or fall, depending on whether they are able to demonstrate competence in their management and concern for the victims. A case study of the different effects that the 2004 Tsunami in the Indian Ocean had on the conflicts in Sri Lanka and Aceh (Enia, 2008) offers further support for this contention by illustrating how governments and insurgents in both conflicts attempted to use the situation to advance their own goals, with very different outcomes.

Initially, one would expect the 'best' disaster management to be found in rich, Western countries. However, this is also where the expectations are likely to be highest. Disaster management must, at least in this case, be gauged relative to people's expectations. This means that governments with a weaker absolute performance may still perform better relative to the population's expectations, and therefore emerge with strengthened legitimacy after a disaster. Therefore these findings do not suggest a systematic effect of disasters on the risk of conflict. To address this question, large-scale systematic research seems necessary. This need is further underscored by the criticism that prominent research within both environmental security and disaster sociology may not have used sufficiently representative cases (see, for example, Gleditsch, 1998). This study is an attempt to move in that direction.

One of the first cross-national quantitative studies aimed at investigating the relation between natural disasters and the risk of violent conflict was conducted by Drury & Olson (1998). They find a positive relation between disaster severity and the level of political unrest, using a sample of the 12 countries that experienced one or more disasters that killed at least 1,500 persons[3] between 1966 and 1980. Country-years from two years before the first disaster until seven years after the last are included in the analysis. They find a positive association between disaster severity and the risk of post-disaster conflict and present six cases where severe natural disasters have been followed by conflict. Although pathbreaking at its time, the study suffers from a sample that is limited both in time and in the number of countries included. The model also lacks important controls. The findings are highly interesting, but would benefit from a revisit with an improved and expanded model that incorporates a broader sample and sufficient control variables. This study proceeds in this spirit.

Brancati (2007) finds that earthquakes are significantly related to an increased risk of violent conflict. She argues that among natural disasters, earthquakes are particularly likely to trigger conflict due to their rapid and unpredictable onsets. Although earthquakes are not climate-related, mechanisms that connect them to an increased risk of conflict can be expected to be relevant for rapid-onset climatic disasters as well, despite the differences between climate-related and geological disasters just mentioned. Brancati tests three different dependent variables[4] and finds that the relationship is strongest for low-level violence.

Although the author claims that 'earthquakes can actually stimulate intrastate conflict by producing scarcities in basic resources, particularly in developing countries where the competition for scarce resources is most intense' (Brancati, 2007: 715), there is no variable measuring this in her models. One should be cautious about drawing conclusions about causal connections on such a weak basis, in particular within an area with so many plausible causal mechanisms (for an overview, see Buhaug, Gleditsch & Thiesen, 2010). While the dependent variable of this study is the *onset* of armed conflict, Brancati uses *incidence* in the models aimed at analyzing earthquakes' effect on civil war. The factors explaining why a conflict broke out are not necessarily the same as those explaining why it keeps going (Fearon, 2004). While we can discuss which measure should be used, replication reveals that earthquakes lose their explanatory power when onset is used as a dependent variable. This indicates that Brancati's results are not valid for *outbreak* of civil war. Onset seems like the appropriate measure here, since incidence per definition follows after an onset that may or may not have been caused by a disaster.

The most extensive cross-national analysis focusing specifically on natural disasters to date was undertaken by Nel & Righarts (2008). Using a sample of 183 political units covering the period 1950–2000, they find a positive relationship between natural disasters and the risk of armed conflict. They test measures for geological disasters and climate-related disasters and a measure combining all natural disasters on dependent variables of minor violent civil conflict onset (less than 1,000 killed), major conflict onset (more than 1,000 killed), and a variable including both these. Their findings indicate that disasters increase the risk of conflict onset in the same year and following year. Climate-related disasters are found to follow this pattern, except that they do not appear significantly related to minor conflict.

The indicator for disasters used by Nel & Righarts is the number of disasters per capita for each country-year. Although this approach has some merit as a proxy for the share of a population that may be affected by disasters, I am skeptical for two main reasons. First, it reduces the weight of disasters that affect large populations. A disaster does not get diluted by hitting a large population – if anything, it becomes more severe. Second, this approach is used instead of including population size as a control variable in the model. Large populations are, *ceteris paribus*, more likely to experience both natural disasters and armed conflict. Not including population size in the models may therefore cause the effect of disasters on conflict risk to become confounded with the effect of population size.[5]

The increased risk of disasters is mainly due to the fact that large populations hold more potential victims of natural hazards. This makes natural hazards turn into disasters more often, and the death toll is likely to be

[3] These countries are Bangladesh, China, Guatemala, Honduras, India, Iran, Nicaragua, Nigeria, Pakistan, Peru, the Philippines, and Turkey

[4] These are conflict events, level of rebellion, and incidence of civil war.

[5] The number of people affected by disaster could be used as a control variable, but the high share of apparently non-randomly distributed missing information on the variable provided by EM-DAT (CRED, 2007) would diminish and potentially bias the sample.

higher. With regard to conflict, a large population size is among the few factors that appear robustly related to an increased risk of civil war (Dixon, 2009; Hegre & Sambanis, 2006). Despite the robustness of the relation, the causal link is open to several interpretations. One is that large populations are more difficult to administer, thereby making it harder for governments to detect and prevent insurgencies (Fearon & Laitin 2003). A second possibility is that large populations hold more potential insurgents, as well as larger groups of potential sympathizers and recruits. This suggestion is supported by Raleigh & Hegre (2009), who find that the frequency of conflict events in Africa tends to be proportional to the population size of the area in question. Large populations are also likely to be more heterogeneous, indicating that a larger number of identity groups may be used for mobilizing conflict. On average, the number of members in each group can be expected to be greater in large populations. If conflict that involves identity groups starts in such countries, the sheer size of the groups increases the likelihood of a larger number of persons being killed, thereby also increasing the likelihood that a conflict is recorded in armed conflict databases.

If population size is not included in a regression model aiming to explain the occurrence of armed conflict, and some other phenomenon that occurs more often in large populations is included in the model, this phenomenon is likely to capture some of the explanatory power of population size. Above, I argued that, *ceteris paribus*, large populations experience more natural disasters and more armed conflict. This means that without population size in the model, the effect disasters have on conflict risk is likely to be overestimated. This may be what happens in the model used by Nel & Righarts. As shown in Table I, a replication of their models on climate-related disasters shows that the results are not robust to the inclusion of population size.[6]

The environmental security literature and disaster sociology reach opposite conclusions regarding how disasters should be expected to affect the risk of armed conflict. The middle road offered by Goldstone (2001), Enia (2008), and others complicates matters further. The quantitative studies presented offer support for the environmental-security perspective, but the robustness of the findings have been called into question. On the positive side, two theories pitted against each other offer an interesting opportunity for empirical testing, which is attempted in this article.

Table I. Accounting for civil conflict: Replication of Model 11 in Nel & Righarts (2008) and model with population size included

	Replication	*Population size included*
Number of climatic disasters per capita	1.113***	0.348
	(0.310)	(0.386)
Infant mortality rate $_{t-1}$	0.0230***	0.0231***
	(0.00566)	(0.00566)
Infant mortality rate squared $_{t-1}$	–7.80e–05***	–7.57e–05***
	(2.68e–05)	(2.71e–05)
Mixed regime	0.524***	0.447***
	(0.155)	(0.156)
GDP growth	–0.0671***	–0.0773***
	(0.0197)	(0.0198)
Brevity of peace	0.900***	0.621***
	(0.162)	(0.176)
Total population (ln)		0.250***
		(0.0394)
Constant	–5.139***	–7.206***
	(0.251)	(0.402)
Observations	7,829	7,829

Relogit regression coefficients with robust standard errors in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Interactive effects between disasters and other phenomena?

Theoretical interest and the strong effect of population size in the Nel & Righarts (2008) study indicate that the relation between disasters and population size should be examined in greater detail. Logically, countries with a large population will experience more disasters, because there are more potential victims and because these countries tend to have a larger area. However, disasters happen only where people live, so severe weather events in uninhabited areas will not turn into disasters.[7]

What happens, then, if a large population with all its potential insurgents is hit by a natural disaster? If disasters, as has been suggested, produce feelings of relative deprivation, increase frustration with the government,

[6] Geological disasters, on the other hand, remain significantly related to conflict risk after the inclusion of population size in the model, indicating that climate-related and geological disasters may affect the risk of conflict differently.

[7] Area does not contribute significantly in a model where population size is included.

and cause fighting over diminishing resources, the conflict-instigating effect should be larger in a country with a large population. If, on the contrary, disasters contribute to increased societal cohesion, an increased sense of unity in the face of adversity, or simply a widespread interest in maintaining fragile stability, disasters should reduce the individual propensity to engage in rebellion. This, in turn, should lead to a decrease in the risk-increasing effect of population size for some period of time after a disaster. The inclusion of an interaction term between disaster and population size (Model 6, below) constitutes a significant improvement of the model and reinforces the impression that disasters reduce the risk of conflict.

Weak, semi-authoritarian countries are frequently found to face a greater risk of civil war than authoritarian and democratic countries (Hegre et al., 2001). Often corrupt and ineffective, without strong incentives to aid the population in times of crisis, but also lacking the ability to quash nascent rebellions by force, these regimes may also plausibly be expected to be more at risk from disaster-induced uprisings. An interaction between disasters and semi-authoritarian regime, measured as country-years scoring between –5 and 5 on the Polity IV scale, was tested. The inclusion of this measure did not constitute a significant improvement of the model (not shown).

Poverty is one of the main predictors for civil war and poor countries are also, in general, less able to prevent severe weather events from turning into disasters. In a similar vein as the semi-authoritarian regimes, these countries may also be expected to be less able to prevent unrest from escalating once it has started. This was tested by running an interaction between natural disasters and a dummy that takes the value of 1 if a given country-year has among the 25% lowest GDP per capita. This measure contributed to a weak improvement of the overall model (not shown).

Data

The issue of how to define and measure disasters deserves some extra comments, as it is not straightforward. Two main ways of defining natural disasters are used in the literature on environment and security. One focuses on 'physical' measures, such as millimeters of precipitation, temperature, or score on the Richter scale for earthquakes.[8] These will be referred to as 'force-based' measures. The alternative emphasizes human consequences rather than physical effects. Here, disasters are coded by the damage they cause to humans rather than their 'objective' force. This definition-type is the basis for the EM-DAT database (CRED, 2007) and is used for example by Nel & Righarts (2008), as well as in this study. While these two methods will often yield similar results, there are some important differences.

An obvious attractiveness of the force-based measures is that they appear precise and exogenous to human affairs. While the decision of what qualifies as a 'disaster' may vary in different contexts, temperature and precipitation can be measured accurately – to the extent that there are measurement stations in the relevant areas.[9] Also, unlike their social consequences, these measures are independent of the political situation in the areas where they occur. Further, they are less dependent on media coverage than consequence-based measures, although both types of information may be difficult to obtain from poorly developed or strongly authoritarian countries.

While the activities of political actors are indeed unlikely to affect wind speeds, temperatures, or precipitation, I argue that for research on how natural factors may influence the risk of conflict, these factors are not what matter. Although the two are closely related, humans react to the consequences of natural forces, not the forces in themselves. These consequences are shaped by the interplay of hazard, exposure, and vulnerability, as outlined above. Theories on how environmental factors may cause people to fight are based on the level of adversity and pressure people face rather than some objective force of hazard events. Thus, the most relevant measure is the level of adversity resulting from a severe weather event, not the force of the weather event in itself. Another important advantage of using a consequence-based measure is that it takes adaptation to natural hazards into account endogenously. Experience with facing such hazards as well as societal and technological development can be translated into practices that reduce vulnerability, so that the hazards do not become disasters. Such adaptation to environmental factors is not captured by analyzing only physical effects, which implicitly assume a time- and place-invariant vulnerability to severe weather events.[10]

[8] For some examples of these types of measures, see Miguel et al. (2004), Burke et al. (2009), or Brancati (2007).

[9] For some examples on problems with such measures, see for example Tiedemann (1984), Knutson et al. (2010), and Landsea et al. (2006).

[10] As an illustration one may consider the Bhola Cyclone, which killed several hundred thousand people in Bangladesh in 1970 and the more powerful Yasi Cyclone, which did not lead to direct fatalities when it struck Australia in 2010.

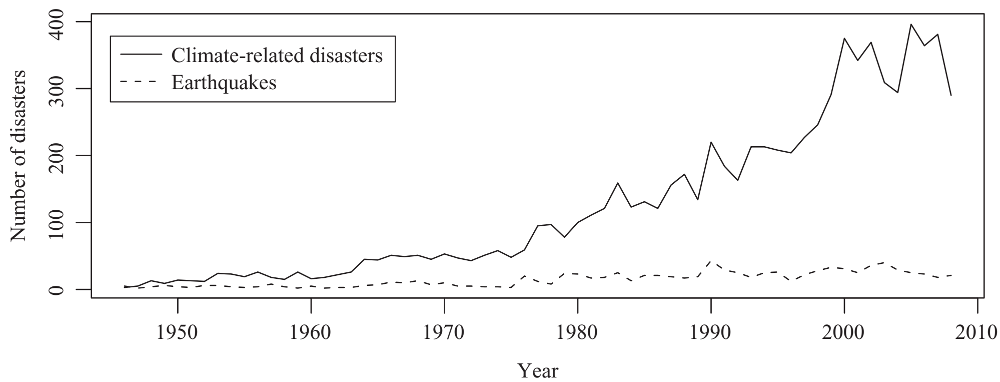

Figure 1. Number of recorded climate-related natural disasters and earthquakes, 1946–2008
Source: CRED (2007).

One weakness of the consequence-based measures is that the likelihood that a severe event translates into a disaster depends on both the situation in the affected area and, to some extent, the practices of how and when calls for international assistance are issued or states of emergency are declared. However, among the available data, I consider that this is the best choice for analyzing the relation between natural disasters and conflict risk. Since my area of interest is the consequences of climate change, I include only natural disasters that are expected to be affected by climate change. These are storms, floods, droughts, extreme temperatures, wildfires, and landslides.[11] The data come from the EM-DAT database (CRED, 2007). In order to be included in the database, an event must fulfill at least one of the following criteria: ten or more people reported killed, 100 or more reported affected, a declaration of a state of emergency, and/or a call for international assistance. In this study, disasters have been coded at the country-year level. This means that a single disaster that has affected two countries is recorded as one disaster for each country. As illustrated in Figure 1, the number of recorded climate-related natural disasters has increased substantially since the mid-1970s. This trend alone illustrates why the question of natural disasters and conflict is relevant, regardless of the discussion about climate change. While some of this increase is likely to be driven by increased access to information, the distribution of earthquakes has not undergone a similar change. This indicates that the increase in climate-related disasters is not driven only by increased reporting.[12] A total of 7,833 disasters are included in this study.

In addition to the increase across time, there is substantial variation between countries. Clearly, this is largely due to the distribution of hazards, vulnerability, and exposure, but it also appears likely that some of the variation is caused by different reporting practices. The United States stands out clearly among the most disaster-prone countries,[13] as it has experienced an annual number of five or more disasters 38 times since 1945. As illustrated by Figure 2, the most common is zero disasters, while only a small minority experience five or more.

Figure 3 illustrates geographical distribution of disasters in the period analyzed. The three most disaster-affected countries are the United States (699 disasters), China (462 disasters), and India (445 disasters). The high prevalence of disasters in the United States gives some reason for concern that the trends are driven by changes in US disaster-reporting practices. However, the trends displayed above, as well as the overall results of this study, are largely unaffected by excluding any or all of these countries from the analysis.

As outlined above, my starting point for analyzing the relation between climate-related natural disasters and the risk of civil war is the model developed by Fearon & Laitin (2003). However, their original dependent variable only runs until 1999. For this reason, and also

[11] EM-DAT distinguishes between 'wet' and 'dry' mass movements. The 'dry' are considered as geophysical events originating from solid earth. As these are not climate-related, they are not included. For more on the disaster classifications, see http://www.emdat.be/classification.

[12] The results presented in this study are robust to excluding the earlier parts of the time period.

[13] The three most disaster-prone country years, with 32, 33, and 35 disasters were all in the United States (1998, 1997, and 1991, respectively). Of 26 country-years experiencing 20 or more disasters, 16 were in the United States, 6 in China, three in India, and one in the Philippines.

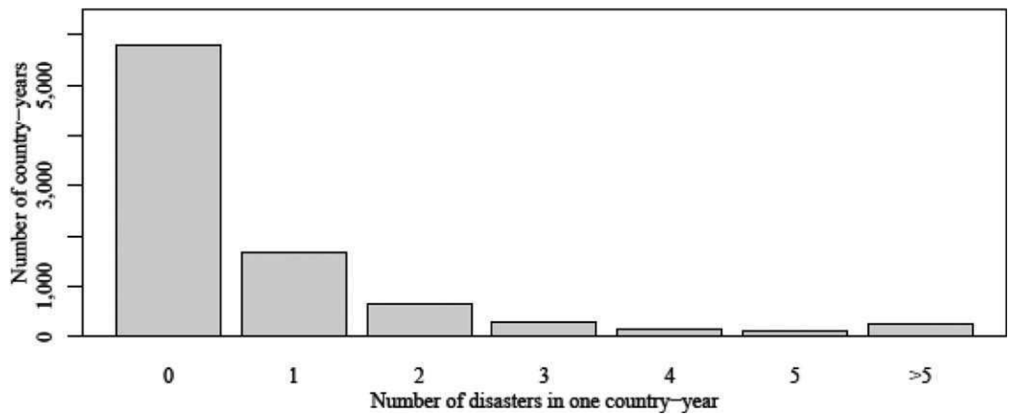

Figure 2. Number of climate-related natural disasters per country-year, 1946–2008
Source: CRED (2007).

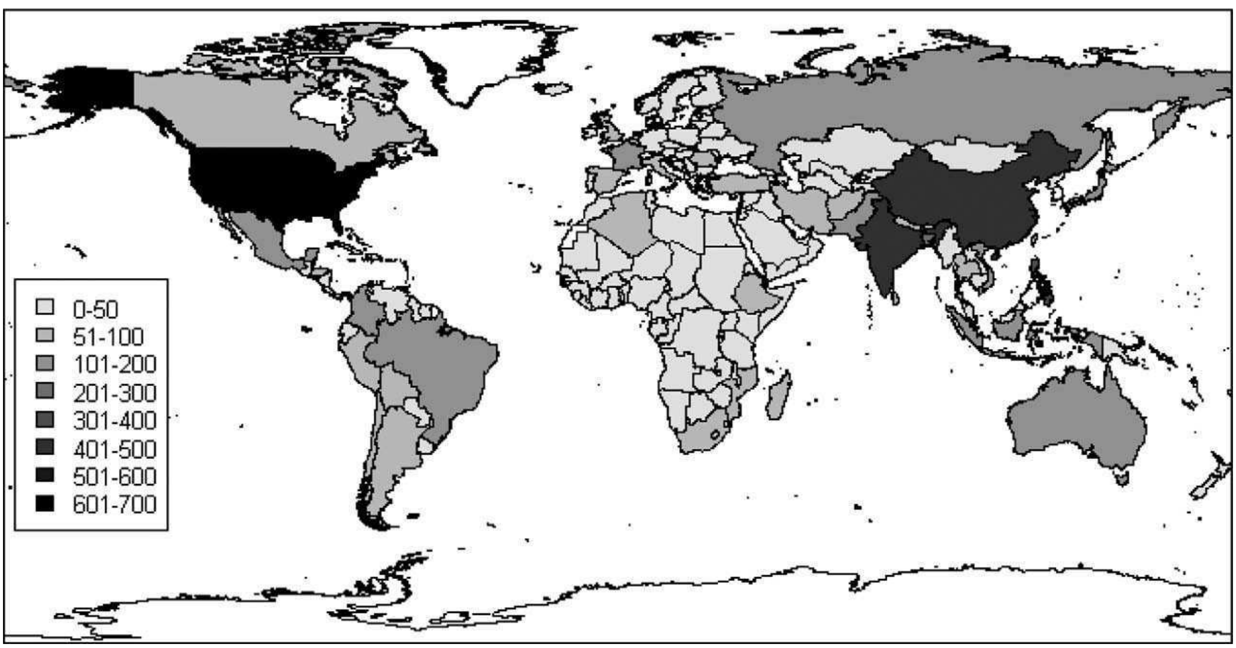

Figure 3. Geographical distribution of recorded climate-related natural disasters, 1946–2008

because I want a dependent variable that captures lower-level conflict as well, I use onset data from the UCDP/PRIO Armed Conflict Dataset (Gleditsch et al., 2002; Strand, 2006). This dataset covers conflicts that cause at least 25 battle-related deaths in a calendar year. For robustness testing and increased consistency with previous studies, I also test a dependent variable with a threshold of 1,000 battle-related deaths. In order to control for temporal dependency, an indicator of whether or not a conflict was ongoing in the previous time period is included.

In order to extend the time period analyzed by Fearon & Laitin (2003), their time-invariant variables (percentage rough terrain, noncontiguous state, ethnic and religious fractionalization) are extrapolated, while other variables are replaced with similar data. The Penn World Tables (Heston, Summers & Aten, 2009) are used for retrieving information on GDP per capita while population size is derived from Banks (2009). Both these variables are log-transformed in the analysis and lagged one year to reduce the risk of picking up effects from conflict onsets. Data on oil exports are obtained from the World Bank (2007). These data are sample-constraining due to missing information and are therefore not used in all the models. This exclusion has a minimal effect on the other coefficients.

The time frame for the variables that indicate whether a state has recently joined the international system or has experienced instability in the system of governance (defined as whether or not the country experienced a change in score on the Polity IV index during the three years prior to the year in question) is extended using data from the Correlates of War Project (2008) and the Polity IV dataset (Marshall & Jaggers, 2009), respectively. Information on the level of democracy was also retrieved from Polity IV, but here I deviate from the procedure used by Fearon & Laitin (2003). Their main measure of level of democracy is a linear measure of score on the Polity scale (lagged one year). However, as the semi-authoritarian regimes in the middle of the Polity scale have been found to be substantially more at risk, I use a dummy variable instead. This variable takes the value of 1 if a country-year scores between –5 and 5 on the Polity IV scale, 0 otherwise.

In line with Fearon & Laitin (2003), I include a variable measuring whether a country had an ongoing conflict in the previous year. The main variables of interest, disasters and conflict, may trend upwards without being causally connected, thereby giving a false impression of a causal relation. In order to control for this, the models are run with year-fixed effects (individual year dummies not shown in the model outputs). I also cluster the analysis by country, where I assume that the observations within countries are not independent whereas they are across countries. Clustering on units also allows the computation of standard errors that are robust to heteroskedasticity.

Results

The first model in Table II replicates Fearon & Laitin's (2003) Model 1, and is included as a basis of comparison for the other models. Model 2 is run using the UCDP/PRIO dependent variable with 25 battle-related deaths as the inclusion criterion. The main change is that the variables indicating whether a conflict was ongoing in the previous time period and whether states are noncontiguous lose significance. Ethnic fractionalization, on the other hand, becomes significant with a positive sign. Also, as others have reported, semi-authoritarian rule is significantly related to an increased risk of conflict. Oil exporters are also at higher risk of conflict, but this variable is sample-constraining and the other variables perform quite similarly with and without it. This variable is dropped from Model 3 onwards in order to increase the number of observations.

Including a count measure of the number of disasters that has affected a country in a given year does not contribute significantly to explaining the occurrence of civil war onsets. Nor is the overall performance of the model significantly improved.[14] The same conclusion holds if a squared term is added in order to control for a curvilinear relation (not shown). Model 4, on the other hand, is a significant improvement. Here, the count measure is replaced with a binary variable that takes the value of 1 in country-years that have experienced one or more disasters and 0 in years that have not. This variable is significantly negatively related to the onset of civil conflict. When running the model with only rapid-onset or destructive disasters included (not shown), the results for count and binary measures are similar in direction but generally somewhat weaker in significance than the results shown in Model 4. Thus, these results indicate that disasters do not raise the risk of conflict; on the contrary, they appear to lower it.

In Model 5, the binary disaster variable is replaced by the number of disasters of each type that have affected a country in a year (landslides, wildfires, heat and cold waves not shown). The number of droughts is negatively related to conflict onset and statistically highly significant, a result that goes against one of the most consistently-argued propositions about climate change and the consequences from the lack of water. None of the other types of disasters are statistically significant. When using single disaster types, there is less difference between the count and binary measures (binary not shown); the significance of droughts is reduced to just outside the 5% significance limit while the other types remain insignificant.

In sum, Model 4, where a binary measure of natural disasters is used, is the model where the disaster variable has the strongest effect. When keeping all other variables at their means, the risk of conflict is estimated at 4.0% when the disaster dummy is fixed at 0, while it drops to 2.9% when the disaster dummy is fixed at 1. The effect is similar but slightly stronger when using a disaster variable that is lagged one year, indicating that experiencing natural disasters limits the risk of conflict in the same year and in the following year.[15] This suggests that the conflict-inhibiting effect tends to last beyond the immediate aftermath of the disasters. Also, it improves confidence in the results, as the risk that they are

[14] The likelihood-ratio tests were run on models without robust standard errors, as the test does not handle this method.

[15] A binary disaster measure lagged two years was tested, but did not come close to contributing significantly to the model.

Table II. Accounting for civil conflict: Replication of Model 1 in Fearon & Laitin (2003) and with models with natural disasters included

Dependent variable	*(1)* *F&L onset*	*(2)* *Onset*	*(3)* *Onset*	*(4)* *Onset*	*(5)* *Onset*	*(6)* *Onset*
Conflict previous year	–0.954***	–0.047	–0.133	–0.116	–0.154	–0.152
	(0.314)	(0.264)	(0.268)	(0.260)	(0.270)	(0.271)
GDP/cap, lagged	–0.344***	–0.411***	–0.449***	–0.441***	–0.452***	–0.445***
	(0.072)	(0.087)	(0.095)	(0.094)	(0.096)	(0.095)
Pop. size (ln), lagged	0.263***	0.243***	0.241***	0.285***	0.231***	0.154**
	(0.073)	(0.059)	(0.053)	(0.056)	(0.055)	(0.076)
Rough terrain	0.219***	0.134**	0.109*	0.124**	0.114*	0.134**
	(0.085)	(0.064)	(0.062)	(0.061)	(0.063)	(0.061)
Noncontiguous state	0.443	0.299	0.340	0.387	0.347	0.338
	(0.274)	(0.232)	(0.259)	(0.254)	(0.255)	(0.258)
Oil exporter	0.858***	0.540**				
	(0.279)	(0.254)				
New state	1.709***	1.324***	1.293***	1.298***	1.295***	1.246***
	(0.339)	(0.353)	(0.357)	(0.360)	(0.357)	(0.352)
Recent instability, lagged	0.618***	0.166	0.117	0.125	0.122	0.143
	(0.235)	(0.193)	(0.189)	(0.189)	(0.190)	(0.191)
Level of democracy,[1] lagged	0.021	0.419**	0.505***	0.494***	0.491***	0.533***
	(0.017)	(0.189)	(0.185)	(0.181)	(0.184)	(0.183)
Ethnic fractionalization	0.166	1.080***	1.133***	1.143***	1.127***	1.139***
	(0.373)	(0.323)	(0.327)	(0.328)	(0.321)	(0.322)
Religious fractionalization	0.285	–0.511	–0.704*	–0.759*	–0.661	–0.770*
	(0.509)	(0.443)	(0.415)	(0.411)	(0.421)	(0.413)
Disasters, count			0.016			
			(0.033)			
Disasters, binary				–0.333**		–2.908***
				(0.161)		(0.998)
Storms					–0.027	
					(0.050)	
Floods					0.092	
					(0.065)	
Droughts					–0.554**	
					(0.268)	
Disaster * Population						0.264***
						(0.099)
Constant	–6.731***	–5.312***	–4.955***	–5.443***	–4.863***	–4.261***
	(0.736)	(1.450)	(1.435)	(1.436)	(1.433)	(1.495)
Observations	6327	6444	6954	6954	6954	6954
Pseudo R^2	0.108	0.119	0.113	0.115	0.117	0.119

[1] Model 1: score on Polity IV scale; all other models: anocracy dummy.
Robust standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.
Fearon & Laitin's (2003) original dependent variable is used in Model 1, while the dependent variable in the other models is from UCDP/PRIO Armed Conflict Dataset (Gleditsch et al., 2002; Strand, 2006). All models but the original one from Fearon & Laitin are run with robust standard errors and year-fixed effects (year dummies not shown). The results are robust to a wide range of robustness and specification tests.

influenced by endogeneity or reverse causality is further diminished.

The results are robust to a wide range of specification tests and robustness checks, such as excluding single disaster-prone countries such as India, China, and the United States, as well as excluding the countries that constitute the highest GDP per capita quartile in each year. Excluding the lowest quartile, on the other hand,

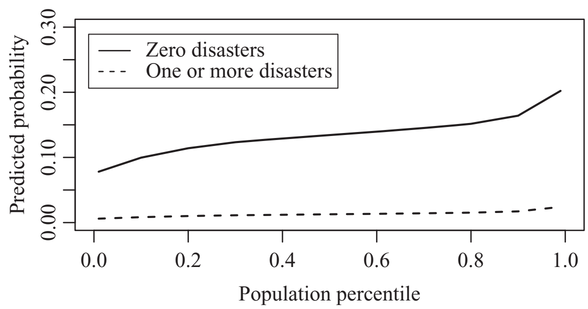

Figure 4. Predicted probabilities of onset with interaction between population size and disasters

weakens the effect of the disasters, but the negative sign is retained. However, it also reduces the number of onsets from 268 to 150. Running the analyses on a dependent variable that only includes conflicts that caused 1,000 or more battle-related deaths gives similar but somewhat weaker results (not shown).

Interactions

The interaction between natural disasters and population size in Model 6 significantly improves the model. Conflict risk increases substantially with increasing population, but it increases more rapidly at zero disasters than at any positive disaster count (tests of disaster count measures not shown). When the interaction term is introduced, the difference between zero and one or more disasters is further increased. In other words, when the interaction term is added, positive disaster counts strongly counterweigh the increased risk of conflict caused by increased population size. For country-years with zero disasters, on the other hand, the risk of conflict grows substantially steeper with increased population size than in a model without the interaction term between population size and disasters.

While the interaction term between disasters and population size significantly improved the model, the proposition that disasters have stronger effect on conflict risk in semi-authoritarian countries is not supported by the data. The interaction between poverty and disasters fares somewhat better; the model is improved, but significant only at the 10% level. An interaction with GDP per capita was also tested, but it did not contribute significantly to the model (not shown).

Discussion and conclusion

I set out to test whether natural disasters can add explanatory power to an established model of civil conflict. The results indicate that they can, but that their effect on conflict is the opposite of popular perception. To the extent that climate-related natural disasters affect the risk of conflict, they contribute to reducing it. This holds for a measure of climate-related natural disasters in general, as well as drought in particular. While this finding contradicts recent debate, it is consistent with a large amount of research, in particular research carried out in the 1950s and 1960s, on the relation between disasters and the risk of anti-social behavior.

An important weakness of these studies is the lack of variation in important factors such as political system, economic level, and cultural conditions. Despite this, Fritz (1996: 15) argues that disaster victims have a striking similarity in behavior across space, time, and culture. The results presented in this article support his argument; the effect of climate-related natural disasters appears robust and cross-nationally valid. An important question is the dependence of specification: while the binary measure is robust, other specifications such as a pure count of disasters, checks for a curvilinear effect, and various ordinal measures were tested but performed more poorly. The main difference is between those who experience disasters and those who do not: the number of disasters that occur within a country-year appears less important. This finding also underscores the importance of being cautious about assuming that adversity will automatically translate into increased levels of conflict – a perception that appears frequent among a number of vocal actors in the debate around the political consequences of climate change.

One explanation of the interaction effect between population size and natural disasters may be that the unifying effect described among others by Fritz (1996) may reduce the willingness to join insurgent organizations. Another possible effect relates to Goldstone's (2001: 46) suggestion that disasters provide an opportunity for governments to display both their competence and incompetence. The negative effect of disasters on conflict risk may be read as that governments tend to improve their popularity – the population in affected areas (and perhaps other areas as well) may be left with a more positive impression of the government than they had before the disaster. This should in itself contribute to reducing the pool of potential recruits for insurgent organizations. A third, less optimistic alternative is that disasters simply overstrain societies and would-be insurgents to such an extent that they contribute to limiting rather than expanding the window of opportunity for insurgents.

For further research, investigating the mechanisms connecting disasters to reduced conflict risk could possibly provide interesting avenues towards reducing conflict in general. While the country-year-level analytical approach holds merit in studying aggregate country-level effects, such as the absence or presence of civil war or natural disasters within a country, it appears less suited to capturing specific causal effects between them. Both are commonly limited to specific geographic areas, which means that future studies aimed at investigating in greater detail the relation between natural disasters and conflict risk are likely to benefit from geographically disaggregated designs.

One cannot read into these results that climate change is not dangerous. Even if climate-related natural disasters do not appear to increase the risk of armed conflict, people are still likely to suffer. However, adversity and suffering do not necessarily translate into severe violence. Citizens as well as investors and developers in poor countries seem to have scant reason to fear that climate change-driven disasters will cause armed unrest, even though climate-related natural disasters may cause increasing rates of death and destruction in years to come. Also, while this is the main trend, it is not unlikely that there will be exceptions, that a single disaster incident may be followed by an outbreak of armed conflict. These, like most other armed conflict onsets, should be expected in poor countries with low level of development and weak, inefficient regimes. Despite climate change, economic and political variables remain the most important predictors of conflict. Rather than over-emphasizing conflict as a result of climate change, I would recommend keeping the focus on societal development, including building resilience against adverse effects of climate change. While this promises the possibility of alleviating the danger of climate change, it can also lead to strengthened societies in the face of natural disaster and civil war.

Replication data

The dataset, codebook and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets. All analysis was done using Stata 11.1.

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Could climate change precipitate peace?

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Abstract

Growing interest in the social consequences of climate change has fueled speculation that global warming could lead to an increase in various forms of political violence. This article examines the effects of climate change on international conflict subsequent to the onset of European industrialization. Surprisingly, analysis at the system level suggests that global warming is associated with a *reduction* in interstate conflict. This naive relationship is suspect, however, as the increased consumption of carbon-based fuels is itself associated with changing patterns of politics and prosperity. In particular, economic development has been viewed as a cause of both climate change and interstate peace. Incorporating measures of development, democracy, cross-border trade, and international institutions reveals that systemic trends toward peace are actually best accounted for by the increase in average international income. The results imply that climate change, which poses a number of critical challenges for citizens and policymakers, need not be characterized as fundamentally a security issue, though climate change may have important security implications on the periphery of world politics. The analysis here also suggests that efforts to curb climate change should pay particular attention to encouraging clean development among middle-income states, as these countries are the most conflict prone. Ironically, stagnating economic development in middle-income states caused by efforts to combat climate change could actually realize fears of climate-induced warfare.

Keywords

climate change, democracy, economic development, global warming, intergovernmental organization, international conflict, militarized interstate dispute

Introduction

An evolving consensus that the earth is becoming warmer has led to increased interest in the social consequences of climate change. Along with rising sea levels, varying patterns of precipitation, vegetation, and possible resource scarcity, perhaps the most incendiary claims have to do with conflict and political violence. A second consensus has begun to emerge among policymakers and opinion leaders that global warming may well result in increased civil and even interstate warfare, as groups and nations compete for water, soil, or oil. Authoritative bodies, leading government officials, and even the Norwegian Nobel Committee have added their voices to inchoate concerns that climate change will give rise to an increase in heated confrontations as communities compete in a warmer world.

Where the basic science of climate change preceded policy, this second consensus among politicians and pundits about climate and conflict formed in the absence of substantial scientific evidence. While anecdote and some focused statistical research suggests that civil conflict may have worsened in response to recent climate change in developing regions (c.f. Homer-Dixon, 1991, 1994; Burke et al., 2009), these claims have been severely criticized by other studies (Nordås & Gleditsch, 2007; Buhaug, Gleditsch & Theisen, 2010; Buhaug, 2010).[1]

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[1] Sutton et al. (2010) critiques Burke et al. (2009). Burke et al. (2010) offers a reply.

In contrast, the few long-term macro statistical studies actually find that conflict increases in periods of climatic chill (Zhang et al., 2006, 2007; Tol & Wagner, 2010).[2] Research on the modern era reveals that interstate conflict has declined in the second half of the 20th century, the very period during which global warming has begun to make itself felt (Goldstein, 2011; Hensel, 2002; Levy, Walker & Edwards, 2001; Luard, 1986, 1988; Mueller, 2009; Pinker, 2011; Sarkees, Wayman & Singer, 2003).[3] While talk of a 'climatic peace' is premature, assertions that global warming is injurious to world peace must be evaluated in light of countervailing evidence and contrasting causal claims.[4]

To understand why global warming can coincide with a reduction in interstate conflict, it will be useful to recall that the contemporary situation differs from earlier eras of climate change to the degree that warming is a product of human activity. Human beings burn fossil fuels that produce greenhouse gases that lead to global warming. These same fossil fuels propel economic and political systems that appear less inclined to certain forms of violent conflict (Gartzke & Rohner, 2010, 2011). Industrialization leads to economic development and democracy, each of which has been associated with peace. Prosperity also encourages international institutions and stabilizing global and regional hierarchies. Thus, global warming may coincide with peace, while not actually inhibiting warfare.

This study explores the relationship between climate change, liberal processes fueled by industrialization (development, democracy, international institutions), and interstate conflict. Previous studies of liberal peace have not paid much attention to climate change. Climatic peace may be yet another benefit purchased by all but accruing mostly to the developed world. At the same time, there might be trade-offs to consider in terms of the pace of development and the environment. The curvilinear relationship between development and interstate peace reported here and elsewhere (Boehmer & Sobek, 2005) suggests important advantages to increasing the pace of development, rapidly moving states through the 'danger zone' of partial industrialization. If efforts to combat climate change cause nations to stagnate economically, then the world may unintentionally realize the worst fears of pundits and politicians for climate-induced conflict.

While the findings reported below clearly indicate that the rise in global temperatures has not (yet) led to increased interstate conflict, there remains room for debate about whether global warming has other deleterious, or even beneficial, effects. Under some conditions climate change appears to reduce the frequency of interstate disputes, though there is no compelling rationale for why this should be the case, even as this particular relationship is not robust with respect to the broadest set of coincident explanations. It may be too soon to provide a definitive answer to whether warming increases, reduces, or has no effect on interstate conflict, though of course waiting for more data also poses trade-offs. Conversely, the consequences of global warming may well differ across countries and regions. Some states may become more violent under pressure from a warmer planet, even as other states or regions find greater cause for cooperation. For now, I focus on detailing global patterns of climate change and interstate conflict, a necessary first step.

Conceptualizing climate and conflict

Research on climate change has generated tremendous interest. Initial debate focused on whether the climate is changing. Consensus has since evolved that the earth is getting warmer. Controversy then shifted to whether human beings are responsible for climate change. The third, most prolonged stage of the climate-change debate involves deciding what actions states and other actors should take to address consequences of global warming.

These numerous and varied effects of climate change could conceivably be considered separately from their causes, provided the two are not directly related. We need not put to rest all controversy about the causes of global warming to understand a bit about what climate change will do to the world we all occupy. Yet, to the degree that climate change is attributable to industrialization, it may make sense to consider whether these processes also interact directly or indirectly with specific consequences of global warming. To determine whether a warmer planet will be a more violent one, we need to ascertain both that: (a) rising temperatures increase conflict globally (not just in a few possibly atypical cases),[5]

[2] A 1974 report from the Central Intelligence Agency warned of the dangers of a cooler climate, affecting agriculture and political stability (Central Intelligence Agency, 1974).

[3] Battle deaths in war also declined (Lacina, Gleditsch & Russett, 2006; Lacina & Gleditsch, 2005).

[4] 'Future global warming is not likely to lead to (civil) war between (within) European countries' (Tol & Wagner, 2010: 77). Zhang and co-authors find similar results for China (2006) and for the world at large (2007). These findings were widely misrepresented in popular media as evidence that global warming is associated with increased violence.

[5] General tendencies can fail to characterize phenomena in particular times or places.

and (b) the causes of climate change do not themselves dissipate conflict in a way that might limit, or even counteract, the direct (negative) effects of global warming.

Research has begun to offer plausible linkages between climate change and an increase in some forms of conflict, such as insurgency and civil war. Barnett & Adger (2007: 639) note that 'direct and indirect impacts of climate change on human security may in turn increase the risk of violent conflict'. The authors ignore the opposite possibility, that the causes of climate change are thought to have largely benign effects on interstate conflict. Looking for harmful effects of climate change does not provide an accurate picture unless global warming is only associated with harmful effects. Indeed, a rich body of research suggests that the likely cause of climate change is also capable of mitigating conflict.

Whatever its contribution to climate change, classical liberal political economists see the forces of industrialization as fundamentally pacifying (Cobden, 1903[1867]; Bastiat, 1995[1848]; Angell, 1933; Hobson, 1938[1905]). A number of scholars argue that the emergence of modern nationalism (Knorr, 1966; Gilpin, 1981), the reduction in the economic value of land (Kaysen, 1990), or changes in the nature of global production (Brooks, 1999) have decreased the benefits that can be had from conquest and hence have made war among developed nations obsolete (Mueller, 2001). Economically developed countries have increasingly become 'trading states' (Rosecrance, 1985), or even 'virtual states' (Rosecrance, 1996), substituting economic cooperation for military conquest.

Yet, the drumbeat of war has repeatedly drowned out expectations of a simple linear relationship between development and peace. Angell (1933) argued that war no longer paid economically, but high costs failed to prevent fighting in 1939. Early quantitative studies found little evidence that economic development inhibited warfare (Wright, 1942; East & Gregg, 1967; Rummel, 1967), while later research offered little more support (e.g. Bremer, 1992; Reuveny & Thompson, 2002). At best, development appeared to amplify the effects of liberal politics (Hegre, 2000; Mousseau, 2000). Lacking evidence, scholars discounted development as a cause of interstate peace, focusing instead on democracy.[6]

Some research has begun to unpack the economic determinants of conflict and peace. Boehmer & Sobek (2005) find that economic development has non-linear effects on conflict at the state level. Poor countries cannot project power, while the rich tend to be satisfied and secure. The most disputatious states are those that are partially developed. Gartzke & Rohner (2010) distinguish between conflicts over private (resources, territory) and public goods (political stability, globalization), demonstrating formally and then empirically that capital accumulation shifts conflict away from conquest and toward compellence. Initial increases in prosperity allowed states to project power and engage in conquest abroad (Gartzke & Rohner, 2011). Subsequent development reduced the utility of territorial conquest, but further improved power projection, so that developed states could still fight over foreign policy goals, when and where differences occur.

Returning to the issue of climate and conflict, scholars have sought to identify relationships over long swaths of human history. For example, Zhang et al. (2007) show that cooling is associated with a variety of harmful social effects over a 500-year period. The authors intentionally omit the period of Western industrialization. Similarly, Tol & Wagner (2010) use data on warfare in Europe over roughly half a millennium to show that the results of an earlier study by Zhang et al. (2006) are robust to different regions. Cold appears to precipitate conflict in the temperate zone, at least in the pre-modern era.

In contrast, a growing number of studies covering much more brief temporal and spatial domains offer a pessimistic picture of the effects of warming on conflict. Burke et al. (2009), for example, provide evidence that higher annual temperatures in sub-Saharan Africa are associated with significant increases in civil conflict. While these findings match existing pessimism concerning the destabilizing effects of global warming, they lack important controls and are not robust (Buhaug, 2010). Even this evidence does not demonstrate that conflict will become worse everywhere. We do not yet know whether climate change can make the world more violent *on balance*. Given past patterns of social and political inequality, it would be surprising if prosperous regions suffered to an equal extent. Indeed, the more common pattern is externality; as with pollution, resource exploitation, the brain drain, and many other processes, the developed world may benefit in security terms from climate change, while other regions experience negative effects.

Climate and conflict: Through the lens of a theory of war

If climate change influences conflict, it does so through the processes responsible for war and peace. These

[6] Poverty is linked to civil conflict (Fearon & Laitin, 2003; Hegre & Sambanis, 2006).

processes are in turn complex, multiple in origin and effect, and weakly conceptualized and defined, even as they are critical to understanding how climate affects conflict. Still, much has been learned about the logic of war that can be applied here.

Actors must typically possess substantial disagreements for fighting to occur. Some experts view national interests as inherently incompatible, as all states seek power (Mearsheimer, 2001; Schweller, 1998) or security (Waltz, 1959). Others argue that interests vary (Organski & Kugler, 1980; Bueno de Mesquita, 1981). Still others view national interests as constant, but argue that structure can change, affecting the feasibility of pursuing objectives peacefully (Snyder & Diesing, 1977; Russett & Oneal, 2001).

Whatever the origin of difference, warfare remains a costly, messy, apparently inefficient way of settling social tensions. Communities benefit if members resolve their differences nonviolently. The problem, of course, is that individuals can prefer to fight, especially when the stakes are high. Yet, even under anarchy, disagreements are typically resolved peacefully. Leaders haggle, compromise, negotiate, bluster or threaten, but do not fight. War is then the result of incompatible interests and whatever factors or forces leave some adversaries unable to arrive at compromise agreements, even as most others can (and do).

Bargains are generally available under relatively mild assumptions (war must be costly, and competitors must be able to divide up issues freely) (Hicks, 1963; Fearon, 1995).[7] States or other actors can be unable to identify or forge bargains when competitors conceal weakness or feign strength (Blainey, 1973), or when changes in the balance of power or interest make the weaker party prefer to renege on agreements in the future.

The effects of climate change can thus propagate conflict either by making interests less compatible, or through increased bargaining failures. The former is the main approach in the literature, but climate change could also increase conflict simply because it is change. This can happen in two ways. First, rapid change can lead to uncertainty about property rights or the disposition of resources, which in turn can lead to conflict. Second, global warming may produce predictable long-term, secular changes in power relationships that force declining powers into action or oblivion. If for example agricultural patterns are affected, so that some nations become more fertile while others bake or desiccate, then beneficiaries may be able to convert new resources into influence that will rise over time. A declining state may have incentives to 'use or lose' existing military advantages to carve out concessions from opponents, or acquire resources affected by climate change.

Of the two possibilities, the former appears more general than the latter. The majority of historical contests arguably derive from uncertainty (asymmetric information), rather than from power transitions (commitment problems). Precisely because commitment problems are difficult to resolve, resulting wars tend to be large and intractable, but also, for this same reason, rare. To the degree that climate change affects the causes of war in ways that parallel historical root causes of competition and conflict, we should not expect the 'mix' of informational and commitment problem contests to become much different.

If anything, it seems likely that the mix will shift away from commitment problems and toward uncertainty as a cause of (often minor) contests. The kinds of resources that will be made scarce by global warming are already scarce or unavailable in certain regions. These regions are often more peaceful than the places where such resources are abundant. Singapore cannot feed itself. Much of Asia and Europe import all or most of their fuel needs. Scarcity, in and of itself, is not a reason for warfare, especially when resources are cheap relative to the cost of fighting. Intensive producers of commodity agricultural or mineral resources may benefit or be harmed by global warming. It does not follow that they will possess the martial might to impose their will on others, especially when the consumers of such resources include powerful nations more intent on profit than plunder.

While these possibilities are intriguing, all imply some change in the macro tendency for war. I will examine the possibility that climate volatility produces uncertainty and political instability in future research. For now, it will make sense to address existing perspectives on climate change and conflict directly, as this will do more to inform the evolving debate than by simply charting additional possible correlates of climate change.

Fighting over the weather

Violent conflict occurs wherever human beings inhabit the globe. Disputes require some mechanism for resolution, whether this involves force or persuasion. When the stakes are high, the temptation to resort to violence as the final arbiter must remain strong. State monopolies on

[7] Fearon discounts indivisibilities as a cause, as states can make side payments. Others see indivisibilities as important, particularly in civil conflicts (Toft, 2003; Walter, 2003).

force do not refute, but instead reflect the logic of political competition. Of course, the fact that politics involves violence does not make all politics violent. The possibility of punishment or coercion is itself available to deter or compel, and therefore often prevents the exercise of force. Common conjecture about the eventuality of conflict 'shadows' political discourse, often making behavioral violence redundant. Political actors can anticipate when another actor is incentivized to violence and can choose to avoid provocation (Leeds & Davis, 1997). Alternately, ignorance, indifference or an inability to act can result in political violence. Scholars must thus view context, motive, and information to determine whether certain situations make force more or less likely.

Climate change could generate or exacerbate tensions in the world (cf. Homer-Dixon, 1991, 1994, 1999; Stern, 2007; Burke et al., 2009). The general argument is one of resource scarcity precipitating conflict (Percival & Homer-Dixon, 1998; Kahl, 2006).[8] Elsewhere, scholars focus on local abundance of globally scarce resources as motive for (Collier & Hoeffler, 2004), or means to finance (Le Billon, 2001), conflict.

A large accompanying literature has sought to unravel possible empirical correlates of scarcity, climate, and conflict. Hauge & Ellingsen (1998) offer one of the first systematic studies to substantiate resource scarcity arguments in the context of civil conflict, while Hendrix & Glaser (2007), for example, argue that better evidence exists in climatic variance, rather than long-term trends.[9] Critics challenge the empirical validity of the connection between resource scarcity and conflict (Raleigh & Urdal, 2007; Theisen, 2008). Salehyan (2008) notes of this literature that there is no consensus about a general connection between climate change and conflict, but that this does not preclude such a relationship from occurring in particular places, times, or indeed in future research.

Parallels within and between nations are too strong to assume that the logic of resource scarcity will not also apply to international politics. Indeed, the origins of contemporary arguments may be traced to earlier studies of scarcity among states. Choucri and North (1975, 1989), for example, argue that 'lateral pressure' driven by population growth can lead to predatory interstate behavior. More recently, Tir & Diehl (1998) offer evidence for a connection between population (but not population density) and interstate conflict. Stalley (2003) examines the effect of environmental scarcity on militarized interstate disputes (MIDs), finding that population density and soil degradation are associated with an increase in MIDs, while fish and water scarcity and resource 'vulnerability' have no significant impact on whether states fight.[10] This special issue contains some of the first studies to focuses on possible connections between climate change and interstate conflict.

One area in which intrastate and interstate conflict overlap involves water. De Stefano et al. (2012) model the evolution of competition among riparian states, citing the greatest risks in, and among, countries in North Africa and the Middle East. Feitelson, Tamimi & Rosenthal (2012) assess implications of climate change for already heavily constrained aquifers supplying Israelis and Palestinians. They find that climate change is not as critical in *altering* water tensions as it might seem. Tir & Stinnett (2012) offer a similarly optimistic interpretation of the power of interstate institutions (treaties) to manage tensions over boundary rivers.

Perhaps the most obvious reason for the lack of attention to interstate relations in studies of climate and conflict is the conviction that answers already exist. Warfare among states has declined in roughly the same period during which climate change has begun to make itself felt (cf. Buhaug et al., 2010: 14). However, the presence of an apparently counter-intuitive negative association between climate and interstate conflict cannot in itself be an argument for ignoring the subject. Buhaug et al. (2010) argue that this negative relationship must be spurious, though they do not demonstrate this to be the case.

Any relationship between climate and interstate conflict is possible, but a clear prediction can be inferred from the resource scarcity literature. This prediction should be carefully evaluated, especially since the expectations of two different bodies of theory are at odds. To the degree that climate change leads to tensions among populations over scarce resources, and populations exist within states, one should expect that states will engage in more frequent (or vigorous) conflict. An increase in

[8] Tensions could arise in other ways besides resource scarcity, such as shifting borders (rivers) or coastlines (arctic sea melt). However, these processes are still at least partially about scarcity, since it is presumably the supply of territory, or its value, that is at stake.

[9] Climate change at the poles may have larger effects on interstate conflict (Haftendorn, 2010). Yet, international resource grabs have been surprisingly peaceful (Bennett, 2010).

[10] Angell (1936) rejects claims of resource- or population-induced conflict.

conflictual interstate behavior should in turn translate into increased aggregate (i.e. systemic) conflict. Indeed, it is important to assess claims of climate-induced conflict at the system level in order to determine overall tendencies. Climate change is holistic, affecting the globe without reference to borders, suggesting that civil- or state-level behavior could be misleading.

> *Hypothesis 1:* Systemic conflict should increase with rising average annual temperature.

Yet, whether climate change generates a ripeness for war depends not just on whether scarcity increases the opportunity for conflict, but also on whether leaders and populations are more inclined to fight. Alternatives to force are typically available, if not always exercised. Whether war or peace ensue depends on whether warfare is expensive relative to the value of goods at stake or, alternately, if other options, such as diplomatic or deliberative mechanisms, facilitate compromises that make warfare redundant. The efficacy of these political or diplomatic mechanisms is not fundamentally tied to resource allocation or climate change. Scarcity can increase the value of resources, but since it also decreases quantity, the total value of a pool of resources is ambiguous. Scarcity, in and of itself, does not motivate political violence until the total value of disputed resources or prerogatives exceeds the anticipated 'production cost' of capturing assets through military force. Localized scarcity may generate political tensions, but it can also yield technological or social innovations that manage any tendency toward conflict. Goods can be traded from regions of abundance to regions of scarcity. Governments, firms or individuals may re-allocate labor or capital. Opposing tendencies can cancel or dissipate. Whether polities resort to war given new challenges depends on how actors manage information, constraints, and opportunities, and on how actors interact.

What are these 'opposing forces'? Even if global warming causes more conflict, the precipitants of climate change have already contributed to peace in some regions. Industrial and post-industrial societies are much less inclined to use force against one another. Some argue that industrialization has led to trade that makes war more costly or less efficient (Polachek, 1980; Oneal & Russett, 1997).[11] Others focus on how economic development creates economies that are difficult to profitably coerce through force (Angell, 1933; Rosecrance, 1985). Still others claim that globalization of production networks is critical (Brooks, 2005). A final set of arguments focuses on the effect of prosperity on factor endowments; wealthy societies that fight must use expensive labor to pursue relatively cheap inputs to production (Gartzke & Rohner, 2010, 2011).

While highly developed states are arguably less prone to fight, at least with each other, the effects of development are probably non-monotonic. Economic development has at least two different effects on civilization, initially increasing state capacity and the ability to project power, but later diminishing the value of conquest to developed economies (Boehmer & Sobek, 2005; Gartzke, 2006). Increasing ability and diminishing interest form a concave function as development progresses. Initially, increased state capacity allows states to project power. As industrial economies mature, however, incentives to trade and to fight begin to cancel each other out. For developed states, it is the declining utility of conquest that prevails. The rate at which peace predominates may also conform to the intensity of contests. Development should discourage larger disputes more quickly than minor confrontations that involve relatively little expenditure of effort and more often involve policy rather than territory. Thus, while the curvature and slope of the function will vary with conflict intensity, the overall trend should be for the world to experience fewer disputes as development and, by extension, global warming increase.

Other liberal variables coincide with economic development and industrialization. The most prominent of these is democracy. Democracies seldom or never fight each other, though democracies appear no less prone to fight in general (Maoz & Russett, 1993; Oneal & Russett, 1997). Systemic democratic peace advocates attempt to broaden the liberal peace by arguing that democratization is producing a world in which even non-democracies are more peaceful (Huntley, 1996; Wendt, 1999; Mitchell, 1997, 2002). However, it is actually quite difficult to reconcile systemic claims with the dyadic finding (Gartzke & Weisiger, 2012). Liberal peace scholars also point to the role of international organizations in inhibiting conflict (Oneal & Russett, 1999). Yet, evidence for the pacific effect of international organizations is weak and subject to controversy (Boehmer, Gartzke & Nordstrom, 2004). Intergovernmental organizations are as much a reflection of cooperation as they are a cause. Trade is another process often pointed to as a cause of peace (Polachek, 1980), though again there is reason to question the strength of this association (Beck,

[11] Development could also have an indirect effect on interstate conflict through creating conditions ripe for democracy (Przeworski et al., 2000; Boix, 2003; Epstein et al., 2006).

Katz & Tucker, 1998; Morrow, 1999). While all of these relationships are incorporated in the analysis, the link between economic development and conflict appears most salient in assessing the effects of climate change on interstate conflict behavior. I therefore offer a hypothesis on development, while also measuring the impact of other liberal variables:

> *Hypothesis 2:* Systemic conflict should decrease with rising economic development.[12]

The effects of climate change on interstate conflict

This section tests the hypotheses by comparing temperature variation with other putative covariates of systemic conflict. I contrast the pessimistic view gaining traction in policy circles (Hypothesis 1) with the possibility that global warming could diminish interstate conflict. I then focus on development as a more persuasive cause of peace (Hypothesis 2).

Before forging ahead, it will be useful to explain why I explore these linkages between climate and conflict at the system-level. First, there is every reason to suspect that system-level analysis is sufficient to test the hypotheses outlined above. Without specific expectations about how the effects of climate on conflict vary from place to place, there is no *a priori* reason to favor a more fine-grained analysis. Indeed, the best place to begin an inquiry of this type is at the system level. State or dyadic analysis would allow for the inclusion of additional covariates, but the research community has yet to posit ways that these variables might relate to climate change. The relationships that have been hypothesized are most likely to manifest at the system level. The approach here thus provides answers and insights without encumbering the empirical domain for future tests.

Second, a system-level analysis of basic relationships is necessary. Regardless of whether additional tests are proposed (and conducted) involving states or dyads, researchers will still need information about the overall tendency of climate change to affect (or fail to affect) interstate conflict. An important source of ambiguity follows from the fact that we know very little about the pervasiveness of tendencies that have begun to be identified and debated in the literature. Predictions about climate change in more discrete units of ocean or territory are less reliable, suggesting claims about the effects of climate change on conflict are themselves most reliable when made where confidence about the nature and impact of temperature anomalies is least in doubt. The analysis here is meant to complement additional, more fine-grained analysis. Identifying systemic relationships should help to define and propel examination of additional, more geographically varied correlates of climate change. I investigate climate and conflict at the system level as an initial step, in the expectation that future research will fill in or possibly revise many missing details.

Research design and data

The system-level analyses conducted here involve counts of militarized disputes or fatal militarized disputes. I use negative binomial logit to evaluate a count dependent variable. Key independent variables and additional 'control' variables are all discussed below.

The Correlates of War (COW) Militarized Interstate Dispute (MID) dataset is the most widely referenced measure of interstate conflict (Gochman and Maoz, 1984; Ghosn, Palmer & Bremer, 2004). MIDs consist of militarized threats, displays, or uses of force up to and including war among internationally recognized states, 1816 to 2000. I sum MIDs annually.

Annual average temperature data are reported as 'anomalies'. First, researchers at the NASA Goddard Institute for Space Studies provide the GISS Surface Temperature Analysis (GISTEMP) time series beginning in 1880, with a base time period 1951–80 (Hansen et al., 2006, 2010).[13] Second, data from the United Kingdom Meteorological Office Hadley Centre and the Climatic Research Unit, University of East Anglia, offer annual observations from 1850, with a base period of 1961–90 (Brohan et al., 2006).[14]

Measures of regime type come from the Polity IV project (Gurr, Jaggers & Moore, 1989; Marshall & Jaggers, 2002). *Democ* measures three institutional attributes of democracy: popular suffrage, constraints on the executive, and civil liberties. *Autoc* codes restrictions on political participation. The indexes are routinely combined into an ordinal measure.

Data on IGO membership come from COW. These data report membership at five-year intervals for all but the most recent few decades. I construct a count of the

[12] As noted, this relationship may be curvilinear (Boehmer & Sobek, 2005).

[13] These data were obtained from the GISS NASA website at: http://data.giss.nasa.gov.

[14] The HadCRUT data are available at: http://www.cru.uea.ac.uk/cru/data/temperature/.

international organizations per year and replace missing values with a previous year's observation.

Gross domestic product (GDP) per capita is the standard measure of development. GDP data for the bulk of the world's countries come from Gleditsch (2002). GDP data are only available for recent decades. Historical research involving economic development must thus rely on proxies. Per capita energy consumption correlates very highly with GDP per capita (cf. Burkhart & Lewis-Beck, 1994) and has the added value of actually measuring consumption of fossil fuels. I use per capita energy consumption in tests reported here.

Most research on liberal peace has focused on trade dependence rather than economic development. Development is the more appropriate indicator here, as it is more closely linked to industrialization/pollution and climate change. I also argue that development is generally more salient than trade for mitigating conflict. It seems appropriate and practical, however, to include a measure of world trade in some regressions to confirm that the effects attributed to development are not the result of economic interdependence. Data on economic openness (monadic trade) is included in the Gleditsch data.

I add several variables to address possible confounding factors. *# Countries* is a count of the number of internationally recognized nation states by year. The number of countries grows tremendously over the period covered in the analysis. *Population* measures the number of humans on earth. Systemic structural changes could also bias estimates of the effect of climate or other variables. I add a dummy for US hegemony (1945–present), and for the post-Cold War period (1992–present) to address system structure effects.

Carter & Signorino (2010) offer a simple technique to address temporal dependence that uses a count for the year, plus quadratic and cubic versions of the count variable. This approach is well suited to the analysis conducted here. I also add a count variable for the number of countries that are members of the international system in a given year in some regressions. Additional details are discussed as they arise in reviewing the analysis.

Analysis

Figure 1 reports the annual onset of MIDs, weighted by the number of dyads in the world system. As the quadratic trend line indicates, the number of MIDs per annum rose during the 19th and early 20th centuries, peaking in two world wars. However, the post-World War II period has been more peaceful, a pattern even more pronounced for the sample of fatal MIDs or wars.

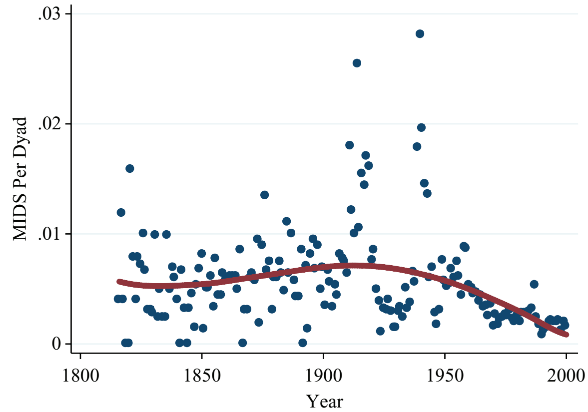

Figure 1. Frequency of MID onsets per year (weighted by number of dyads)

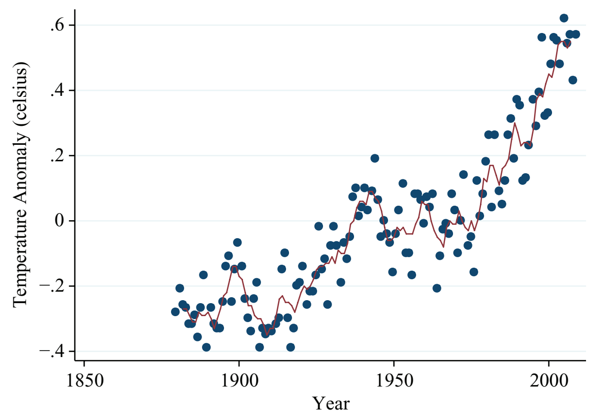

Figure 2. Global temperatures [annual averages and five-year moving average], 1880 to 2007 (plotted values are temperature anomalies relative to the base period 1951–80)

The incidence of MIDs has dropped at roughly the same time that the effects of climate change become apparent. Figure 2 details average annual global temperature anomalies and a five-year moving average.[15] Climate change appears to correlate with the decline in interstate conflict. Yet, other processes co-trend in this period. The most eligible processes are liberal economic and political variables. Figure 3 depicts average democracy, the number of IGOs, and per capita energy consumption from 1816 and 2000. Values are normalized by variable means.

Table I lists eight regressions comparing the effects of climate, democracy, development, and IGO membership on an annual count of worldwide MIDs. Model 1.1 contains only average annual temperature anomalies,

[15] See Hansen et al. (2006). These data are available at: http://data.giss.nasa.gov/gistemp/graphs/Fig.A2.txt.

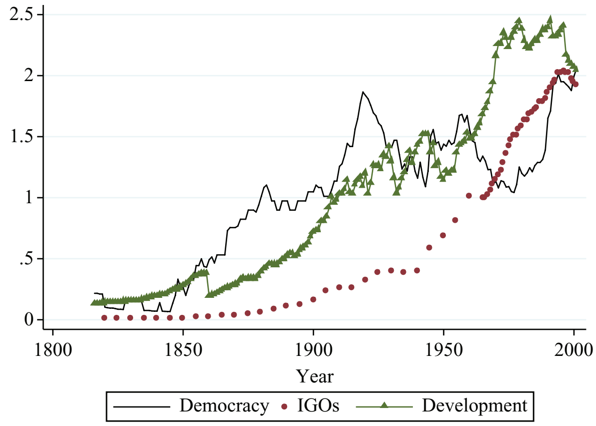

Figure 3. Global historical trends in liberal variables (values normalized)

world population, a count of countries, and the intercept. Temperature anomalies correlate positively with the count of MIDs, appearing to confirm the suspicion of many that global warming may increase interstate conflict.

Model 1.1 is almost certainly under-specified. The negative relationship between climate and conflict probably reflects the non-linear function identified in Figure 1. Model 1.2 adds the squared temperature anomaly variable. While the coefficient on the linear term remains insignificant, the quadratic variable is negative and highly significant. Given that the mean for the linear variable is negative and the quadratic mean is positive, the combined effect is negative. Higher annual temperatures still appear to reduce conflict.

Model 1.3 adds a measure of the proportion of democracies in the world.[16] Systemic democracy actually appears to increase conflict, though at the 10% significance level.

Democracies may be less warlike toward each other, but the most disputatious dyads involve one democracy and one non-democracy (Ray, 1993; Gleditsch & Hegre, 1997). As the number of democracies in the world increases, initially the bulk of dyads created are heterogeneous, theoretically increasing ecological conflict. For this reason, I add a quadratic regime type variable to Model 1.4. The results appear at first to support the curvilinear argument. Both regime type variables are highly significant in opposite directions. However, a plot of the relationship (not shown) reveals that the function trends downward, curving in the opposite direction anticipated, convex to the origin, with a minimum number of MIDs at about 85% of the maximum proportion of democracy.

Models 1.5 and 1.6 explore the effects of economic development on interstate disputes. Model 1.5 adds the linear development variable, while Model 1.6 introduces the quadratic term. By itself, the linear impact of development is positive and modestly statistically significant. The climate and regime type variables also become smaller and less statistically significant. The quadratic development variable in Model 1.6 greatly increases the significance and substantive impact of development on conflict. The democracy variables become statistically insignificant. The quadratic term on the climate anomaly variable remains significant at the 1% level. Climate still appears to diminish interstate conflict. The final pair of regressions in Table I add the linear and quadratic IGO variables. Neither of the IGO variables is statistically significant, though they slightly reduce the statistical significance and impact of the climate anomaly variables.

A pitfall inherent in the analyses in Table I is that most of the variables involved are non-stationary. Variables that trend over time will tend to correlate regardless of whether they are related causally. The results in Table I would be much more credible if it could be demonstrated that they did not result from the co-trending of key variables. Before correcting for the non-stationarity of the variables directly, I first address the time trend common to all of the variables. Model 2.1 in Table II adds linear, quadratic, and cubic count variables for years since 1816 to Model 1.8 from Table I. The time trend variables are all highly statistically significant. They appear to be capturing relationships that are not explained by the other variables. The effect of the year count variables is to make the climate variables statistically insignificant, while democracy and IGOs are significant. Economic development remains statistically significant. However, this approach is somewhat heavy-handed. While there is no *a priori* reason to oppose these measures, they contain limited theoretical content and should be interpreted with care. Note for example that both IGOs and democracy now appear to be harmful to interstate peace

A separate concern involves the coding of militarized disputes (I will return to the issue of non-stationarity in Table III). MIDs often involve relatively minor acts of conflict that could overwhelm relationships at higher conflict intensities. While potentially useful for capturing subtle effects of climate on conflict, minor MIDs may also incorporate trends that are unrelated to climate, globalization, or the rise of global democracy. Model 2.2

[16] I also examined average democracy level and found that results are equivalent.

Table I. Predicting the number of systemic militarized interstate disputes with temperature anomalies, democracy, development and IGOs (negative binomial regression, annual MID counts 1880–2000)

Model: MID Onset	*1.1 Coeff. (S.E.)*	*1.2 Coeff. (S.E.)*	*1.3 Coeff. (S.E.)*	*1.4 Coeff. (S.E.)*	*1.5 Coeff. (S.E.)*	*1.6 Coeff. (S.E.)*	*1.7 Coeff. (S.E.)*	*1.8 Coeff. (S.E.)*
Temperature	0.947†	0.461	0.361	0.369	0.231	–0.104	–0.100	–0.058
	(0.526)	(0.443)	(0.472)	(0.475)	(0.415)	(0.341)	(0.340)	(0.323)
Temperature^2		–4.526***	–4.821***	–3.305***	–2.810***	–2.408**	–2.433**	–2.224*
		(0.749)	(0.692)	(0.887)	(0.854)	(0.780)	(0.790)	(0.929)
Democracy			1.315†	20.65***	13.40†	–6.770	–6.231	–7.245
			(0.792)	(6.361)	(7.155)	(8.758)	(9.085)	(9.097)
Democracy^2				–27.84**	–17.37†	8.038	7.345	9.003
				(8.880)	(10.05)	(11.89)	(12.22)	(12.37)
Development					0.581*	3.298***	3.274***	3.082***
					(0.250)	(0.629)	(0.637)	(0.905)
Development^2						–1.022***	–1.006***	–0.939**
						(0.202)	(0.223)	(0.302)
Intergov. Org.							–0.788	0.712
							(4.557)	(6.162)
Intergov. Org.^{2}								–3.686
								(8.794)
Population	0.191	0.640*	0.535*	0.413	0.457†	0.694**	0.737*	0.730*
	(0.293)	(0.250)	(0.262)	(0.266)	(0.271)	(0.222)	(0.350)	(0.351)
No. Countries	0.002	–0.011	–0.008	–0.003	–0.011	–0.014†	–0.014†	–0.014*
	(0.009)	(0.008)	(0.008)	(0.008)	(0.009)	(0.007)	(0.007)	(0.007)
Intercept	2.081***	2.447***	1.956***	–1.477	–0.441	1.484	1.371	1.611
	(0.274)	(0.255)	(0.448)	(1.231)	(1.346)	(1.369)	(1.464)	(1.499)
ln(α)	–1.412***	–1.669***	–1.682***	–1.756***	–1.799***	–2.098***	–2.096***	–2.095***
	(0.177)	(0.218)	(0.219)	(0.247)	(0.229)	(0.261)	(0.263)	(0.265)
N	122	122	122	122	122	122	122	
Log-likelihood	–422.49	–412.25	–410.76	–407.00	–404.12	–394.46	–394.45	–394.37
$\chi^2_{(8,8,8)}$	121.21***	173.08***	187.46***	273.40***	340.55***	389.27***	390.30***	398.76***

Significance levels:† 10%;* 5%;** 1%;*** 0.1%.

focuses on fatal MIDs. The higher dispute intensity moves the curvilinear relationship identified in Table I prior to the beginning of the sample in 1880. Thus, a simpler model specification with no non-linear terms is used.[17] I also introduce two additional variables. First, economic development could reflect the effect of trade on conflict. For this reason, I add a measure of total global trade (Oneal & Russett, 2005). Second, US hegemony could account for changes in conflict patterns attributed to climate change.[18] However, neither the *World trade* nor the *US hegemony* variables are statistically significant.

Interstate politics became more peaceful after the Cold War, even as climate change began to make itself felt. In Model 2.3, I add another dummy for the post-Cold War period. Climate change is just short of statistical significance at the 10% level. IGO counts are marginally significant and positive, while development remains significant.

Figure 4 details the effects of climate change on fatal MIDs based on Model 2.2 in Table II. I used the Clarify software in Stata to calculate the predicted probabilities and confidence intervals reported in the figure (Tomz, Wittenberg & King, 2003). Introducing US hegemony and post-Cold War forces the climate anomaly variable to compete for covariance over the portion of the relationship with the dependent variable where the confidence intervals are tightest. Again, statistical blunt objects must be applied to counteract the negative relationship between global warming and fatal MIDs.

Figure 5 again uses Clarify to plot the effects of development on conflict (Model 2.2). The robust relationship is reflected in tight confidence intervals around estimated values.

[17] Democracy and IGO membership are not significant in any version of Model 2.1.

[18] Colonialism is captured by the *hegemon* dummy and the *# countries* count variable.

Table II. Predicting the number of systemic MIDs with temperature anomalies, democracy, development, and IGOs (negative bin. regression, annual MID counts 1880–2000)

Model:	*2.1*		*2.2*		*2.3*	
MID Onset	*All MIDs*		*Fatal MIDs*			
	Coeff.	*(S.E.)*	Coeff.	*(S.E.)*	*Coeff.*	*(S.E.)*
Temperature	0.077	(0.360)	−2.814*	(1.403)	−2.393	(1.498)
Temperature^2	−1.398	(1.087)				
Development	6.549***	(1.219)	−1.796***	(0.547)	−1.652**	(0.547)
Development^2	−2.026***	(0.369)				
Democracy	−17.89*	(8.629)	0.457	(1.385)	−0.677	(1.945)
Democracy^2	24.85*	(11.93)				
Intergov. Org.	−25.93*	(10.27)	8.975	(5.650)	10.03 †	(5.969)
Intergov. Org.^{2}	64.53***	(20.15)				
World Trade			0.588	(2.121)	−0.0275	(2.186)
US Hegemony			−0.760	(0.538)	−0.772	(0.563)
Post Cold War					0.582	(0.548)
Population	2.168***	(0.549)	0.498	(0.909)	1.073	(1.185)
No. Countries	−0.024**	(0.008)	−0.002	(0.011)	−0.010	(0.013)
Year	−0.560***	(0.114)	−0.151	(0.178)	−0.177	(0.184)
Year^2	0.005***	(0.001)	0.002 †	(0.001)	0.002	(0.002)
Year^3	−0.000***	(0.000)	0.000	(0.000)	0.000 †	(0.000)
Intercept	21.00***	(4.338)	1.629	(6.815)	2.362	(7.016)
ln(α)	−2.347***	(0.293)	−16.46***	(0.924)	−15.97***	(0.739)
N	122		120		120	
Log-likelihood	−384.74		−208.95		−208.16	
$\chi^2_{(3,4,5,6,7,8,9,10)}$	545.06***		178.64***		179.38***	

Significance levels : † 10%;* 5%;** 1%;*** 0.1%.

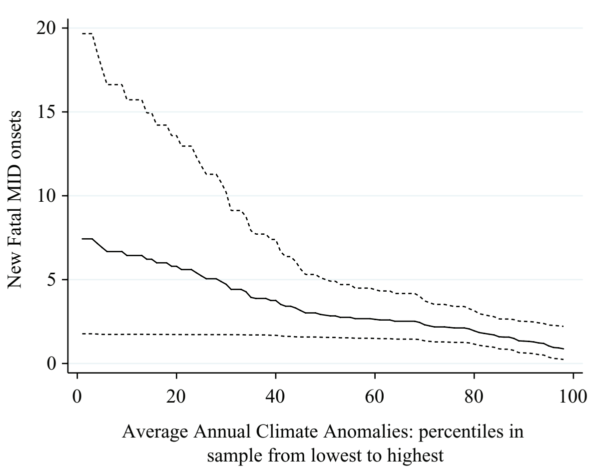

Figure 4. Global average annual temperature anomalies

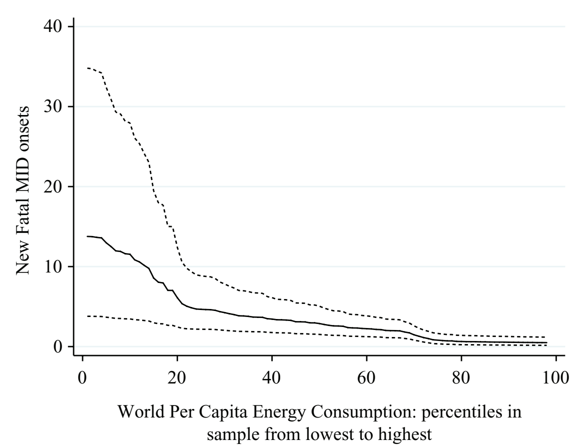

Figure 5. World per capita energy consumption

While Table II examines possible confounding temporal trends among key variables, I have still to address non-stationarity within these variables. The probability distribution of a stationary variable does not change when shifted in time or space (Hamilton, 1994). Table III offers three regressions in which the key variables have been corrected for non-stationarity. The steps involved in correcting each variable were slightly different, given differences in these data. In each case, I used plots and diagnostic tools such as the Dickey-Fuller test to identify appropriate corrections. The regime type variable serves as an example. A unit root test (Dickey-Fuller) and a plot of values of the variable

Table III. Predicting the number of systemic MIDs with stationary variables [corrected] and a second climate data source (negative binomial regression, annual MID counts 1850–2000)

Model	*3.1*		*3.2*		*3.3*	
	GISTEMP		*HadCRUT*			
MID Onset	*All MIDs*				*Fatal MIDs*	
	Coeff.	*(S.E.)*	*Coeff.*	*(S.E.)*	*Coeff.*	*(S.E.)*
Temperature ($n-1$)	0.441	(0.511)	0.540	(0.564)	0.659	(0.629)
Temperature^2 ($n-1$)	6.406*	(3.005)	3.269	(3.337)	7.671	(4.168)
Development (ln, $\bar{x}$, $n-1$)	–2.306	(1.226)	–3.639**	(1.374)	–3.686*	(1.756)
Development^2 (ln, $\bar{x}$, $n-1$)	–42.81**	(15.40)	–7.547***	(2.138)	–6.187*	(2.698)
Democracy ($\bar{x}$, $n-1$)	–3.554	(3.780)	–5.625	(4.018)	–5.963	(4.979)
Democracy^2 ($\bar{x}$, $n-1$)	172.4	(131.3)	182.1	(113.0)	129.4	(139.3)
Intergov. Org. (ln, $\bar{x}$, $n-1$)	4.357	(2.690)	3.597	(2.184)	3.693	(3.825)
Intergov. Org.^{2} (ln, $\bar{x}$, $n-1$)	–18.27*	(7.596)	–15.49**	(5.657)	–16.27	(13.16)
Intercept	2.839***	(0.116)	2.682***	(0.109)	0.868***	(0.127)
ln(α)	–0.754***	(0.125)	–0.509***	(0.101)	–0.361	(0.200)
N	121		151		151	
Log-likelihood	–454.19		–550.11		–313.06	
$\chi^2_{8,8,8}$	36.72***		62.08***		16.73***	

Significance levels : † 10%;* 5%;** 1%;*** 0.1%.

against time showed that the variable was not stationary. I first subtracted the variable mean, centering the variable about zero. I then first-differenced the variable to remove the apparent linear trend. The resulting variable exhibited no trend and had a mean of zero with constant variance. *Development* and *Intergov org* had non-linear trends. I logged each variable and then followed the steps above to produce stationary versions of the variables. First differencing was sufficient to correct the climate change variables.

Model 3.1 contains corrected versions of the eight key variables, but omits other 'control' variables. The results suggest some impact for climate and development on conflict, though only for the quadratic term. Interestingly, temperature anomalies now appear to exacerbate MID behavior, while development decreases disputes. International organizations also appear to inhibit conflict. I examined versions of the regressions in Table III that included corrected stationary versions of *Population*, *# Countries*, and other variables, but these variables were generally insignificant and tended to weaken results for key variables. Since all of the variables in these models are de-trended, the value of controls meant to capture the effect of certain trends is considerably reduced.

One of the limitations of the analysis is the limited temporal domain over which data are available on climate change. Reaching back earlier in time is useful because it places the beginning of the analysis more firmly in the pre-industrial or early-industrial period. Model 3.2 uses the HadCRUT data, which adds 30 observations to the econometric time series. These data are corrected in the same manner as the CISTEMP data used exclusively in Tables I and II. Introducing the longer time series to the stationary variables has two important effects. First, it leads the climate change variables to become statistically insignificant. Second, it strengthens the statistical significance of both *Development* variables. *Intergov org* also becomes more robustly significant.

The final model in Table III again looks exclusively at fatal disputes. The results are substantially the same as in Model 3.2, though levels of statistical significance are generally lower. The IGOs variable is no longer statistically significant, while the development variables are significant at a lower threshold level. Still, both development variables are statistically significant, despite the data contortions necessary to produce stationary variables and despite the presence of other plausible determinants of peace and conflict. What initially looked to be a product of climate is perhaps most convincingly explained by the precipitants of climate change, in particular economic development.

In addition to counts of MIDs and fatal MIDs, it is possible to examine the effects of climate on aggregate casualty counts. Lacina, Gleditsch & Russett (2006) argue that casualty counts may be a better measure of trends in human conflict.[19] Lacina & Gleditsch (2005) offer the best available casualty data. I replicated the regressions from Tables I and II, replacing the dependent variable with casualty counts or logged casualty counts. Because they provide relatively few new insights and in order to save space, I do not report these results here. The climate anomaly variable is never statistically significant, either by itself or in conjunction with its square. Economic development is always positive and usually statistically significant, suggesting that casualty levels are increasing with modernity. While this result contrasts with the findings using MIDs and fatal MIDs, one cannot infer that developed states experience more casualties, as developed countries could be inflicting more casualties on other states. Alternately, developing countries may have higher casualties once international arms markets can supply more lethal military technologies. Finally, there is a strong curvilinear relationship between casualties and democracy or IGOs. This appears to be an accident of history more than a causal relationship. Democracy and IGOs have increased in the 20th century, while the mid-century is notable for extraordinary contests involving massive casualties. Logging casualty counts leads the IGO variable to become insignificant, while democracy remains modestly significant and negative at the 5% level in most regressions.

Conclusion

It thus appears that the processes that are widely seen by experts as responsible for global warming are themselves key contributors to the decline in global warfare. Prosperous nations are not fighting each other, even if they are polluting the planet. Obviously, this poses important dilemmas for policymakers and others. On the one hand, economic growth is inherently appealing. Prosperity solves many of the problems that plague the developing world. We must add to the advantages of economic development that it appears to make countries more peaceful. On the other hand, climate change imposes significant environmental costs. These trade-offs lack easy solutions. Indeed, we must ask whether environmental objectives are modified by the prospect that combating climate change could prolong the process of transition from warlike to peaceful polities.

[19] Casualties are an effect of warfare. Leader choice might well be affected by concerns about casualties, but leaders may not accurately anticipate casualties early in a contest.

Climate change may be one of the most important issues facing human civilization, or perhaps even life on earth. The effects of climate change are generally viewed as negative. Reasonable speculation also links climate to interstate conflict. However, the evidence provided here suggests reasons for cautious optimism. Interstate warfare is not generally inflamed by higher temperatures. Instead, economic development contributes to both global warming and interstate peace. Development creates nations that are no longer interested in territorial conquest, even if occasionally they continue to use force in punitive ways, or to police the growing global commons, coercing non-compliant states, groups, or leaders. In a somewhat ironic twist, the same forces that are polluting our planet and altering the climate also have beneficial effects on international conflict.

Replication data

Data and an automated do-file replicating all aspects of the empirical analysis can be found at http://www.prio.no/jpr/datasets.

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Climate change and the institutional resilience of international river basins

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Abstract

In the existing 276 international river basins, the increase in water variability projected by most climate change scenarios may present serious challenges to riparian states. This research maps the institutional resilience to water variability in transboundary basins and combines it with both historic and projected variability regimes, with the objective of identifying areas at potential risk of future hydropolitical tension. To do so, it combs existing international treaties for sources of institutional resilience and considers the coefficient of variation of runoff as a measure of past and future water variability. The study finds significant gaps in both the number of people and area covered by institutional stipulations to deal with variability in South America and Asia. At present, high potential risk for hydropolitical tensions associated with water variability is identified in 24 transboundary basins and seems to be concentrated mainly in northern and sub-Saharan Africa. By 2050, areas at greatest potential risk are more spatially dispersed and can be found in 61 international basins, and some of the potentially large impacts of climate change are projected to occur away from those areas currently under scrutiny. Understanding when and where to target capacity-building in transboundary river basins for greater resilience to change is critical. This study represents a step toward facilitating these efforts and informing further qualitative and quantitative research into the relationship between climate change, hydrological variability regimes, and institutional capacity for accommodating variability.

Keywords

climate change, freshwater treaties, resilience, river basin organizations, transboundary, water variability

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Introduction

Transcending political boundaries, river basins shared by two or more countries pose particularly challenging management problems. In transboundary basins, the unifying principles of integrated watershed management clash with the forces of state sovereignty. While the interdependence exemplified by sharing a river may result in interstate conflict and dispute, it could likewise result in cooperation (Elhance, 1999). To date, studies have shed much light on this relationship considering how physical, economic, and political factors may affect conflict and cooperation (e.g. Lowi, 1993; Hensel, Mitchell & Sowers, 2006). In its most extreme form, the water–conflict relationship has been expressed in the water-wars thesis (Starr, 1991). While the great majority of academic studies have criticized this alarmist claim as sensationalist at best (Wolf & Hamner, 2000), others have challenged these more sobering and optimistic accounts by speculating about the effects of climate change on international water (Working Group II, n.d.).

Overall, climate change is expected to intensify security concerns within or between countries or within river basins (Nordås & Gleditsch, 2007; Gleick, 1993). According to Barnett (2003: 9), climate change may have indirect negative effects that can undermine the legitimacy of governments, undermine individual and collective economic livelihoods, and affect human health through reduced availability of food and increased exposure to new disease vectors. A report written by a group of retired senior military officers attests that one of the most destabilizing impacts from climate change will be reduced access to freshwater, which could lead to conflict in certain areas (CNA, 2007: 13–16). Pertaining to the phenomenon of water variability, a 2008 Technical Report of the Intergovernmental Panel on Climate Change has claimed that increased precipitation intensity and variability is projected to increase the risks of flooding and drought in many areas, which will affect food stability as well as water infrastructure and practices (Bates et al., 2008: 3–4).

As climatic variability around the world is expected to change, the resilience of social-ecological systems in the face of these shifts could be influenced by the existence and make-up of international institutions. Resilience is described here as the ability of a system to absorb perturbations without altering the fundamental structure, functions, and feedbacks of both its ecological and social components (Adger et al., 2005; Walker et al., 2006). Such 'second-order resources' enhance the abilities of society to deal with environmental change (Ohlsson & Turton, 2000). Formal management regimes governing shared river basins, in the form of international water treaties (including specific stipulations such as water allocation, conflict resolution, and variability management) and river basin organizations, can be particularly instrumental in managing or defusing likely disputes among fellow riparians when faced with climatic change and water variability (Drieschova, Giordano & Fischhendler, 2008). In their assessment of the Ganges Water Treaty, for example, Salman & Uprety (2002: 177–186) find that the 1996 Ganges River Treaty may have incorporated important stipulations such as water allocation yet ignored others, including water augmentation (or variability management) and flood mitigation. Having little recourse to deal with water variability has contributed to political tensions between India and Bangladesh.

The study presented here aims to increase our understanding of the global distribution of treaties and the institutional mechanisms they contain. This article uses the geographical approach of risk-mapping based on the vulnerability expressed by presence of treaties and river basin organizations, juxtaposed with the respective basin's exposure to hydrological variability. The objective is to identify which basins may be ill-equipped to deal with climatic change and water variability. Our working assumption is that the existence of these treaty stipulations and organizations will enhance resilience specifically in river basins predicted to experience high variability in the future.

With this mapping analysis we are then able to identify specific basins that may merit further study in light of their potential risk of hydropolitical stress. The study shows that institutional coverage is unevenly distributed across continents and across basins. North America, Europe, and Africa have the highest coverage of spatial extent, while South America and Asia have significant gaps in both the number of people and the spatial extent covered. The majority of high potential risk associated with low institutional coverage and present water variability is found in northern and sub-Saharan Africa. Considering future water variability, our study suggests that this high potential risk may also affect other areas of the globe (e.g. in Central Asia or Eastern Europe), many of which are currently not under scrutiny. By identifying these areas at the global scale, we can contribute to efforts aimed at anticipating and addressing future challenges in transboundary water management posed by climate change.

The outline of this article is as follows. We briefly discuss the linkage between climate change, water variability, and stability within international river basins. We then review the institutional sources of resilience to climate change, particularly treaties, and the mechanisms they embody, as well as river basin organizations that are described in the literature and are considered in this research. We then provide a brief description of the data and methodology we used to classify and combine vulnerability and exposure to hazard. Next, the results of a risk classification are presented along with basins that merit further study due to their high potential risk levels. We conclude by discussing the main findings of this study and suggest further research.

Climate change, water variability, and stability in international river basins

Climate change affects precipitation patterns and river runoff, thus increasing the vulnerability of certain regions and communities to changes in water availability and hydrological extremes (Bates et al., 2008). The historical records of many river basin flows suggest that significant variability and changes in mean flows have already been observed (Milly, Dunne & Vecchia, 2005; Milliman et al., 2008; Dai et al., 2009), and the predicted effects of climate change may render future river flow variability outside the bounds of previously observed runoff events (IPCC, 2007: 31; Milly et al., 2008). The IPCC notes that as drought-affected areas are projected to increase, adverse impacts on multiple sectors (such as agriculture, water supply, energy production, and health) will likewise rise. Increased flood risk will also pose challenges to society pertaining to physical infrastructure and water quality (IPCC, 2007: 49).

In international river basins, these direct and indirect changes may alter current hydropolitical balances and evidence suggests that the likelihood of political tensions is related to the interaction between variability or rates of change within a basin and the institutional capacity to absorb that change (Wolf, Stahl & Macomber, 2003; Stahl, 2005; Yoffe, Wolf & Giordano, 2003; Yoffe et al., 2004). Consequently, regions and basins not governed by treaties or water-related institutions and facing current and future variability may be more vulnerable to tension and conflict. In regions that are already governed by treaties, climate change and variability could affect the ability of basin states to meet their water treaty commitments and effectively manage transboundary waters, especially if such treaties are not suited to dealing with variability and new hydrological realities (Ansink & Ruijs, 2008; Goulden, Conway & Persechino, 2009). Variability may thus raise serious questions about the adequacy of many existing transboundary arrangements, even in areas that have exemplified cooperation in the past (Cooley et al., 2009: 28).[1]

Given the links between climate change, water variability, conflict, and cooperation in international river basins, the existence of institutions and river basin organizations seems paramount. Beyond the mere existence of these institutions is their make-up and robustness. Such institutional mechanisms may confer additional resilience onto international treaties.

Institutional sources of resilience to climate change

Recent research has found that while an international water agreement may not necessarily prevent the emergence of country grievances, these grievances usually result in negotiations (or peaceful management) when an agreement already governs the basin (Brochmann & Hensel, 2009). Institutions such as international water treaties can contribute to transparency, decrease the transaction costs of cooperation, and clarify expectations among the parties, thus stabilizing hydropolitical relations (McCaffrey, 2003: 157).

While a handful of empirical works have studied the general phenomenon of water treaty signature (Espey & Towfique, 2004; Song & Whittington, 2004; Tir & Ackerman, 2009; Dinar, Dinar & Kurukulasuriya, 2011), less research has examined the institutional components such treaties embody in a global context (Stinnett & Tir, 2009). The presence (absence) of institutional stipulations may further reflect on the resilience of treaties, given water variability and climatic change (Gleick, 2010). The international relations and hydropolitics literature has shed insight into which mechanisms could possibly enhance treaty resilience and cooperation.

Guided by the availability of global data as to the existence of particular stipulations and buttressed by existing analysis in the literature, we consider the presence of (a) water allocation mechanisms, (b) variability management mechanisms, (c) conflict resolution mechanisms, and (d) river basin organizations. While we have elected to concentrate on only four major stipulations, we recognize that additional stipulations may add to resilience. Side-payments and issue-linkage, for example, may act as a contract enforcing mechanism specifically in asymmetric contexts (LeMarquand, 1977; Bennett, Ragland & Yolles, 1998; Dinar, 2006). Our underlying

[1] However, Dinar et al. (2010) demonstrate that variability can motivate countries to set up new international agreements so as to deal with changes in runoff and precipitation.

assumption is that the existence of these four institutional stipulations provides a valid first approximation at the global scale of the institutional resilience of transboundary basins to present and future climate change-induced water variability. Below we discuss these four major components. While these stipulations are quite distinct, in some cases one single treaty provision can include information on two different stipulations. For example, it is possible that an allocation mechanism also includes specific stipulations for variability management. In that case we will consider the mere presence of an allocation mechanism as one positive feature of the agreement, and the existence of explicit references to flow variability management as another asset of the treaty.

Allocation mechanism

The presence of allocation mechanisms in agreements pertaining to water quantity and even hydropower may suppose greater certainty in the water sharing among riparian countries (as opposed to allocation uncertainty), which could be preferable in the context of climate uncertainty. Drieschova, Giordano & Fischhendler (2008), for example, enumerate a variety of stipulations including direct and indirect allocation mechanisms and general principles for allocation. Direct allocation includes stipulations that divide specific water quantities among the protagonists (see, for example, Cooley et al., 2009). Indirect allocations can include such stipulations as consultations or prioritization of uses, while general principles can include stipulations such as equitable utilization or needs-based approaches (Drieschova, Giordano & Fischhendler, 2008; Wolf & Hamner, 2000). Many of the above-cited authors seem to agree that in light of climatic change, treaties that exhibit *flexibility* are likely to be more suitable for dealing with water variability. Nevertheless, the authors all seem to have slightly different definitions of how flexibility may be operationalized in an international treaty.

Drieschova, Giordano & Fischhendler (2008) suggest that a more flexible water allocation mechanism is one that divides water by percentage (as opposed to fixed amounts). Despite the advantages of this more flexible mechanism, Drieschova, Giordano & Fishhendler recognize that any direct allocation mechanism is sometimes buttressed with additional indirect mechanisms that also have some built-in flexibility, because they implicitly recognize that water availability may change and therefore establish the process for which allocations will be determined. McCaffrey (2003) argues that flexible allocation mechanisms are those that recognize that water allocations may have to be reduced due to water availability in particular circumstances. Finally, Cooley et al. (2009) emphasize allocations that specify that an upstream riparian deliver a minimum flow to a downstream riparian and, like McCaffrey, praise mechanisms that permit countries in specific situations to make up owed water allocations in a future period when more water is available.

Because treaties may include a range and combination of stipulations that jointly achieve flexibility (in a context of water variability), it is often difficult to assess agreements for their flexibility in a uniform fashion. Moreover, the effectiveness of the particular allocation mechanisms can vary widely due to the influence of local context and hydrological regime, making it difficult to establish a general rule on which specific allocation stipulations are more suitable (relative to others) to deal with water variability. For these reasons, we assume that it is the general presence of allocation stipulations, as opposed to treaties that neglect to codify any allocation division at all, that may contribute to institutional resilience of a basin in light of water variability.

Variability management

Variability management stipulations are designed to deal with climatic extremes such as droughts and floods or other specific variations. Such extreme events inflict severe damage on the environment and populations resulting in both tangible and intangible effects (Bakker, 2006). Variability thus increases the demand for infrastructure development and the need to manage water demand and supply (Global Water Partnership, 2000). The mere existence of such stipulations implies that the treaty parties not only acknowledge the temporal variability of water availability but may also better prepare basin states to deal with extreme events.

The literature points to a number of specific treaty mechanisms that enhance resilience to drought. Combined with some of the allocation mechanisms discussed above, authors have pointed to immediate consultations between the respective states, stricter irrigation procedures, water allocation adjustments, specific reservoir releases, and data sharing (McCaffrey, 2003; Turton, 2003). Examples of treaties that have stipulated these mechanisms in some form include the 1996 Ganges River Agreement, the 1997 Cuareim River Agreement, the 1970 Lake Lanoux Agreement, and the 1989 Vuoksi River/Lake Saimaa Agreement.[2]

[2] These treaty examples (and others provided further below) can be located in the International Freshwater Treaties Database of the Transboundary Freshwater Dispute Database (TFDD).

Pertaining to flood issues, the establishment of specific flood-control mechanisms is likewise important. Examples of specific stipulations to mitigate floods include transboundary warning systems, information exchange, the construction of reservoirs and levees, floodwalls, channelization, and the regulation of land use (Rossi, Harmancioğlu & Yevjevich, 1994). In her study of transboundary flood and institutional capacity, Bakker (2009) finds that, on average, death and displacement tolls were lower in the basins with flood-related institutional capacity (which included flood-related treaty mechanisms).

Based on the above discussion, we expect that treaties that stipulate specific variability management mechanisms (whether they are intended for drought or flood mitigation), as opposed to those that do not stipulate such mechanisms, will bode better for treaty resilience, especially in the context of variability.

Conflict resolution

Conflict resolution mechanisms, such as third-party involvement or arbitration, could prove invaluable, especially when there are conflicting interpretations of the agreement or when the actions of one country are perceived to negate the agreement's conditions (Global Water Partnership, 2000). Conflict resolution mechanisms also provide a forum for discussing resource and environmental changes not envisioned in the treaty (Drieschova, Giordano & Fishhendler, 2008). The extent to which a treaty stipulates how disputes are to be resolved among the parties relates to the level of confidence the parties may have that their concerns will be met in a fair and safe environment. The 1992 Agreement between South Africa and Swaziland pertaining to the Maputo and Incomati Basins, for example, stipulates three stages of dispute resolution including direct negotiations between the parties, an arbitral tribune, and a United Nations appointed arbitrator.

As mentioned before, historically, extreme events of conflict over water have been statistically somewhat more frequent in regions characterized by high interannual hydrologic variability. Therefore, the existence of established conflict resolution mechanisms can be crucial for assuaging tensions that may arise during extreme climatic events and in a context of climate uncertainty.

River basin organizations

Joint commissions, governing councils, directorates, or river basin organizations (which we herein refer to collectively as RBOs) may also contribute to resilience. According to Chasek, Downie & Brown (2006) *regime effectiveness* may be at the heart of the success of treaties and institutions. Effectiveness, according to Haas, Keohane & Levy (1993), implies that there exists a hospitable contractual environment (among other necessary conditions). This environment, in turn, provides states with the ability to negotiate with reasonable ease, comply with the treaty's tenets without fear that others are cheating or free-riding, monitor each other's behavior, and enforce decisions (see also Susskind, 1994). Depending on their form and function, RBOs can provide such a medium for achieving effectiveness and an appropriate environment for facilitating cooperation (Dombrowsky, 2007).

In addition to being mandated with implementing any treaty obligations and proposing future water plans, projects, and models (Cooley et al., 2009), the RBO is often entrusted with a monitoring mandate (e.g. 1995 Agreement over the Mekong River). As implied above, monitoring stipulations are particularly important since states often fear that fellow states to an agreement may cheat or free-ride (Keohane & Martin, 1995). A conflict resolution mandate, while more often delegated to an external agency (see above), is sometimes consigned to the RBO at least as a first phase of dispute settlement (e.g. 1998 Agreement over the Zarumilla River). Enforcement mechanisms, when they are directly present in a given water treaty, are also undertaken by the RBO (e.g. a Governing Council in the case of the 1973 Agreement between Brazil and Uruguay over the Parana River).

In her study of the Indus Basin, for example, Zawahri (2009) finds that the joint commission established has essentially played an invaluable role in the Indus Waters Treaty's implementation since 1960. According to Zawahri, it is in large part due to the overwhelming success of the joint commission to negotiate, monitor, and manage the Indus regime that stable cooperation over water has existed between the two riparians since the treaty's inception. Along the lines of this example, we expect that basins equipped with a transboundary RBO will deal better with present and projected water variability.

Methods, data, and analysis

This research followed a sequence of five steps to combine institutional and climate-related information about basin-country units. First, we refined the Transboundary Freshwater Dispute Database (TFDD; Yoffe, Ward &

Wolf, 2000) by increasing the spatial resolution from river basin to basin-country unit (BCU) and populating this database with a content analysis of all available transboundary water treaties. We then categorized the vulnerability of each BCU by rating international water treaties according to their potential resilience to hydrological variability (based on the presence of the above stipulations) and by the presence of a RBO. Next, we classified exposure to hydrological variability based on the absolute variability in the past and on the projected relative change in hydrological variability for each BCU. We then classified BCUs by combining maps of hydrological exposure and vulnerability. Using these classifications, we identified basins of significant interest for future study due to their potential risk.

The basin-country unit spatial database

The TFDD contains tabular and spatial information on 276 transboundary freshwater river basins and more than 400 international, freshwater-related agreements worldwide. Recent work expanded the breadth of the collection, adding 240 agreements to the database, as well as its depth through a content analysis of over 40 dimensions such as enforcement, conflict resolution, non-water linkages, etc. Previously, all treaty data in the TFDD were linked to basins and countries separately, and part of this research involved shifting to the basin-country unit for analysis. We define the basin-country unit as the spatial portion of a basin that is within a single country, such that, for example, the Chira basin shared between Peru and Ecuador, is analyzed separately as the Chira-Peru BCU and the Chira-Ecuador BCU. This resolution with a clear spatial reference of transboundary agreements allows the identification of gaps in the spatial extent of existing treaties. The combination of 276 transboundary basins and 148 riparian countries yielded 747 BCUs covering a total of 61.962 million km^2 of the earth's surface and hosting a total of approximately 2.748 billion people.

To better represent the spatial extent of treaty documents, the concept of the territorial treaty application was introduced and defined as the set of present-day BCUs to which the treaty applies. This allowed water agreements signed by colonial powers or nation-states that no longer exist in their present configuration to be mapped and analyzed consistently. Though the influence or existence of these countries may change in a given place over time, agreements signed by these parties may still influence water management in these areas, as established under the 1969 Vienna Convention on the Law of Treaties. To determine the territorial treaty application, treaties that referenced non-existent countries were identified and then examined using a variety of data sources on boundary delineations (Anderson, 2003) and the political history of territorial change (Tir et al., 1998).

Treaty and river basin organization capacity

We considered the capacity of each BCU to deal with current and climate change-driven water variability by recording five components that were then additively combined to give the treaty-RBO score. The first component is the presence of a treaty. Relevant treaties included those with a focus on water as a scarce or consumable resource, a quantity to be managed, or an ecosystem to be improved or maintained (Hamner & Wolf, 1998). This kept the focus on mechanisms directly related to management of water resources, and resulted in 405 treaties being scored while 283 treaties were excluded. Further scores are given for the presence of water allocation mechanisms, flow variation management provisions, and conflict resolution mechanisms. In addition, a score was given to BCUs that had a river basin organization or joint water management commission present (Table I). While data on the first four components were obtained by using the TFDD database, for the fifth component we consulted a number of sources (official agreements, secondary literature, internet, and contacts with international agencies) to find evidence of the actual existence of RBOs. The final list of RBOs was also cross-checked with the extant literature (e.g. Dombrowsky, 2007; Wirkus & Boege 2005; and various UNESCO-IHP publications such as Burchi & Spreij, 2003).

Once these attributes were evaluated, the final step was to add them together for each BCU. One point was given to a BCU for each treaty and RBO component present on that BCU, provided the BCU had at least one treaty present, resulting in a treaty-RBO score ranging from zero to five. Finally this score was grouped into vulnerability levels for each BCU, with 'low' representing a treaty-RBO score of four or five, 'medium' representing a score of two or three, and 'high' representing a score of zero or one. We quantified vulnerability in this way for each of the 747 BCUs.

Exposure to hydrological variability and future change

For each BCU, we used the coefficient of variation (CV) in annual runoff as the key hydrologic indicator of inter-annual variability. CVs for the 1961–90 World

Table I. Criteria used to evaluate treaties and river basin organizations

Criterion	*Description*
Presence of a water treaty	A formal agreement between sovereign nation-states substantively referring to water as a scarce or consumable resource, a quantity to be managed, or an ecosystem to be improved or maintained (Hamner & Wolf, 1998). Geographic scope must be specific enough to identify that, at minimum, the treaty applies to all waters shared between signatories.
Water allocation	Mechanisms for allocating water for water quantity and/or hydropower uses.
Variability management	Mechanism(s) for facing flood and/or drought events or other specific variation in flow.
Conflict resolution	Mechanism(s) specified to address disagreements among the signatories, including arbitration, diplomatic channels, a commission, third-party involvement, and/or a permanent judicial organ.
River basin organization	A bilateral or multilateral body of officials representing participating governments in dialogue about coordinated management of international water bodies.

Meteorological Organization climate normal period (referred to as 'present') and for the time slice 2045–55 ('2050') were derived for each BCU. The CV data were obtained from the World Bank's Water and Climate Change project (World Bank, 2009). The historic runoff data were simulated with the global hydrologic model CLIVAR driven with historic climate data from 1961 to 1990. The future projections of runoff were derived by driving the same hydrological model with the climate data modified according to the precipitation and temperature changes projected by Global Climate Models that assumed the IPCC AR4 A1B emissions scenario. From the many climate models available, only three models were kept and available to this study. They span all impact levels ('wettest', 'middle', and 'driest') based on the change in a climate moisture index for each World Bank Region.

We created two classifications of hydrological hazard for each BCU, one based on the present variability and one based on a combination with projected change in variability by 2050. Following Vörösmarty et al. (2005), the absolute CVs characterizing the 'present' were grouped into three levels: 'low' ($CV < 0.25$), 'medium' ($0.25 \leq CV \leq 0.75$) and 'high' ($CV > 0.75$) variability. The relative change in variability was calculated as the percentage change from the present CV. The 'worst case', that is, the largest relative (future) change among the three available models was selected. The future hazard level for a BCU was determined by taking the present variability level and increasing it by a step if the projected increase in variability was greater than 15%. The one exception was when the present hazard level was already high. In that case, the future hazard level would remain high regardless of the level of change in variability. Hazard levels were calculated for only 735 BCUs because modeling constraints prevented historic and future variability regimes from being simulated for 12 small BCUs.

Combining treaty-RBO capacity with variability and variability change

Following the definition of risk as a combination of exposure to a hazard and vulnerability (e.g. Crichton, 1999), we defined potential risk levels by combining the exposure to hydrological variability (hazard) with the treaty-RBO score (vulnerability). The BCUs with the highest risk are those with the lowest treaty-RBO score (high vulnerability) and the greatest exposure to hydrological variability (high hazard). An application of this model is demonstrated in the online Methodology Codebook.

As a final step, we identified basins that may deserve further study by focusing on those BCUs with the highest present or future risk. To this group, we applied a filter that assessed the relative importance of each BCU to its entire basin in terms of mean annual discharge from the sub-basin, population, irrigation, or area. If a BCU has a significant share of any of these elements, institutional mechanisms to deal with variability appear more relevant than in other BCUs with the same level of potential risk but a small share of the basin. For instance, pressure to improve institutional capacity may be higher in densely populated areas as opposed to scarcely populated areas. Equations and terms used to implement this filtering process can be found in the online Methodology Codebook.

Table II. Basin-country units with individual treaty-RBO components by continent (%)

	Basin continent					Global
Individual treaty and RBO components	*Africa*	*Asia*	*Europe*	*N. America*	*S. America*	*Total*
At least one water treaty	50	40	69	64	32	52
Allocation	25	25	33	42	14	28
Variability management	20	18	34	15	6	21
Conflict resolution	35	25	49	44	15	35
At least one RBO	40	19	32	56	22	33
Number of BCUs	204	163	192	95	93	747

A single treaty can have multiple components, thus the percentages may exceed 100 for each continent. Each BCU may have one or several treaties with any of these mechanisms. Such possible repetitions are not represented.

Results

Vulnerability: Treaty and river basin organization capacity

The treaty-RBO scoring analysis of the 747 BCUs yielded a variety of findings. Table II shows the number of BCUs with at least one treaty-RBO component.

Beyond the presence of a water treaty, conflict resolution was the most frequent component while variability management was the least frequent component globally. The distribution of particular mechanisms by continent shows some patterns in overall coverage as well as the presence of specific mechanisms. Europe and North America consistently emerged as having the highest proportions of coverage, while South America and Asia often had many BCUs without a particular mechanism. RBO distributions differed slightly, but showed similar patterns. The global distribution of treaty-RBO scores by BCU is shown in Figure 1. Overall, almost half of the BCUs in the world had a score of zero and those found in Africa and Asia made up half of this group.

Breaking down the distribution of these different scores in terms of the area covered and the population affected in each continent (Figure 2) provided further interesting insights and can be helpful towards an assessment of their implications and importance. For example, the percentages of total BCUs by region shown in Figure 2a revealed that half of all African BCUs and nearly two-thirds of all Asian and South American BCUs had treaty-RBO scores of zero, and more than 20% of BCUs in each continent were not covered by high treaty-RBO scores. The distributions of scores differed remarkably when represented using area and population coverage, as shown in Figures 2b and 2c. Nearly all of the population and area in North America are covered by high treaty-RBO scores. Similar compressions of the low treaty-RBO score shares are seen for all continents except for Asia, where about one-third of the continent area has no treaty coverage. Interestingly, nearly one-third of the population in European and South American transboundary basins is covered by treaty-RBO scores of two or less. Furthermore, close to 20% of Asia's transboundary basin population has no treaty-RBO coverage, indicating concentrations of poor treaty-RBO coverage where many people may be affected.

A number of basins with large disparities among constituent BCUs were found (disparity being defined as the range between the lowest and highest vulnerability of BCUs of a particular basin). The reason for disparity is that not all riparian states may be signatories of a treaty. The detected disparities are an example of the value of using a BCU approach instead of the river basin approach used in most global-scale analyses of transboundary basins. In some cases, a high disparity may be irrelevant, such as when a certain country comprises a small portion of a transboundary basin. In other cases it may reveal that important actors are absent from the institutions managing a transboundary basin. Of the eight basins that had a disparity of five, the Ganges-Brahmaputra-Meghna and Indus basins are particularly interesting as China is not party to any variability-related treaties and constitutes significant portions of these basins. These two basins together cover 2.768 million km^2 and 872.0 million people. Of the nine basins that had a disparity of four, the Congo/Zaire, Danube, Har Us Nur, Niger, Okavango, and Struma basins stand out because of the significant size or population coverage of their high-vulnerability constituent BCUs. These six basins together encompass 253.8 million people and 7.477 million km^2. Seven additional basins had a disparity of three for their constituent BCUs, while many basins had disparities of one or two.

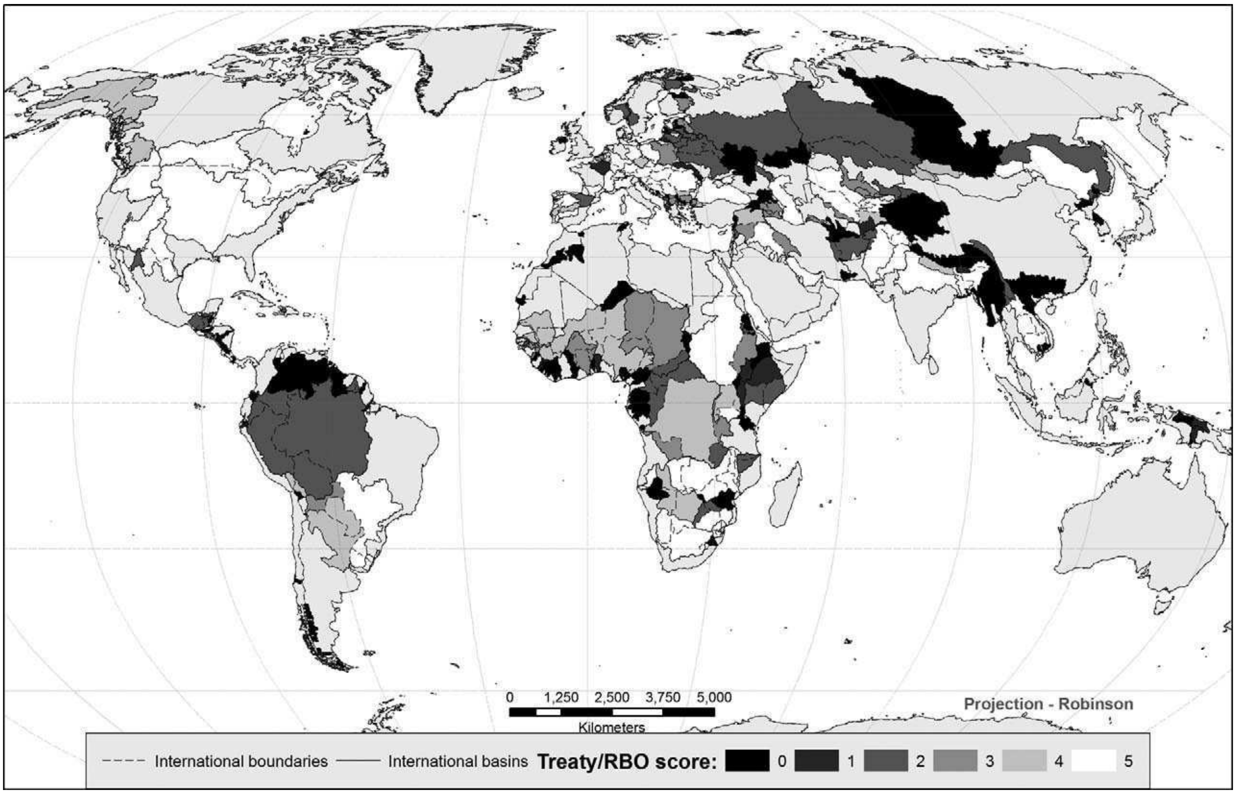

Figure 1. Global distribution of treaty-RBO scores aggregated to each basin-country unit.

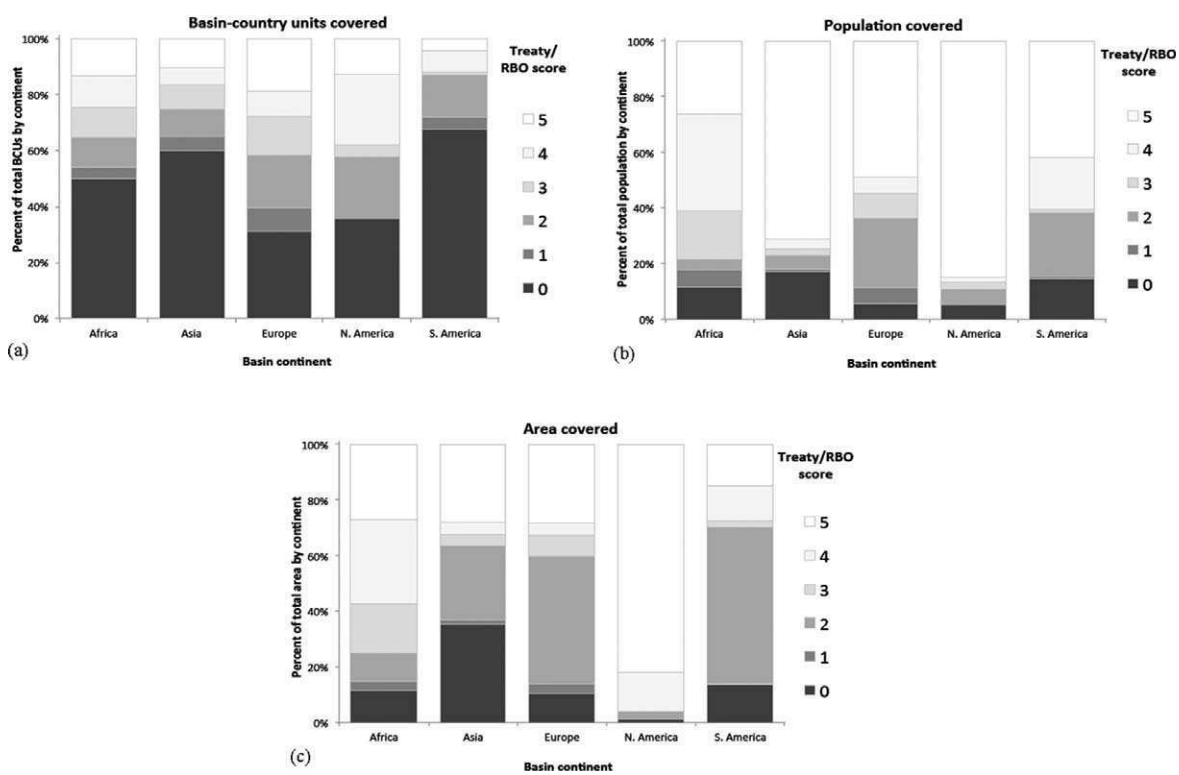

Figure 2. Percentage of coverage by each treaty-RBO score for each continent.

Hazard: Exposure to hydrologic variability and future change in variability

Figure 3 shows the global distributions of hazard classes for present and future. For present hazard, clear spatial patterns can be identified, with the highest degree of variability generally found in transitional climate zones such as the outer tropics and sub-tropics, while core areas of the polar and tropical climate regions experience low variability. Africa stands out as the continent with the largest share of exposure to high hazard, since it hosts 66% of all BCUs and 97% of the population found in this class globally.

The majority of BCUs is predicted to experience increases in runoff variability by 2050. In total, 110 BCUs increase from medium present hazard to high future hazard. This means that the total share of BCUs in the highest hazard level increases from 8.7% in the present to 23.4% by 2050. The changes by continent are fairly even and Africa still stands out with high hazard levels. In terms of population exposure to hazard, at present, nearly half the world's transboundary population is in the lowest hazard level, but in the future, only 30% is projected to be in the lowest hazard level, while 62% will be in the medium hazard level. The share of the world's population found in the highest hazard level increases from presently 3% to 8% in the future.

Potential risk: Combining treaty and RBO capacity with exposure to variability

Table III displays the count of BCUs in each combination of vulnerability and hazard classes. Of particular interest are the cases where a high degree of hazard from exposure to variability is coupled with high vulnerability in the institutional regime (bold entries in Table III). There were 41 BCUs (distributed in 24 international basins that, together, host 332 million people) at high risk under present variability conditions, while 94 BCUs are at high risk when incorporating future variability (encompassing 56 million inhabitants – 2% of the world's transboundary population – in 61 international basins that, together, cover 415 million inhabitants). Since we did not simulate possible changes in institutional arrangements, changes in risk between the present and 2050 are solely due to climate change-induced shifts in runoff variability.

There were clear spatial concentrations of BCUs at highest risk for the present period. Out of a total of 41 high-risk BCUs, 25 were located in Africa (primarily in northern and sub-Saharan Africa), seven were in Asia (primarily in the Middle East and south-central Asia), and nine were found in South America (primarily small basins along the Andes). Conversely, the lowest-risk BCUs were found primarily in western and central Europe, along the USA–Canada border and in Southeast Asia.

The distribution of potential risk by 2050 shows significant concentrations of BCUs at the highest risk in Africa (46 BCUs). African BCUs with over 1 million people that move to the highest risk class include: Ethiopia's shares of the Awash and Lake Turkana basins, which together account for 31 million people, the Moroccan portion of the Dra (1.07 million people), and the Zimbabwean portion of the Sabi (2.89 million people). While for the present period high risk in Asia was concentrated entirely in the Middle East, by 2050 several basins in Central Asia are at high risk, such as the Kura-Araks basin between Georgia and Turkey (3.43 million). Seven European basins, mostly in central and eastern Europe, are in the highest risk level by 2050. Beyond these, many small Central American basins are found to be at high risk in the future, as well as the Catatumbo basin in South America, shared between Columbia and Venezuela (1.26 million people).

The last step of our study identified high-risk units that merit further study: 24 BCUs, distributed in 14 transboundary basins, encompassing 505,000 km^2 and 11.91 million people (Table IV). One-third of the basins identified have all constituent BCUs in the highest risk group, indicating that there is a significant risk of basin-wide impacts from climate change.

The picture portrayed by these data is two-fold. First, there are those well-known basins that are currently at high risk, such as the Congo/Zaire, the Niger, and Lake Chad. Secondly, there are basins with a medium present variability that are projected to experience substantial increases in variability, such as the Catatumbo basin shared by Venezuela and Colombia. Some of the BCUs in this latter group have very high population densities, such as the Turkish portion of the Asi/Orontes (101 people/km^2), which could exacerbate the human impacts of climate change. It is interesting to note that, with two exceptions, all the basins identified which merit further study due to present variability (eight in total) are in Africa. Conversely, by 2050, only half of the basins identified are in Africa, the rest being distributed between Latin America and Eastern Europe/Western Asia.

Discussion and conclusions

International water agreements and RBOs are considered important instruments for dealing with changes in

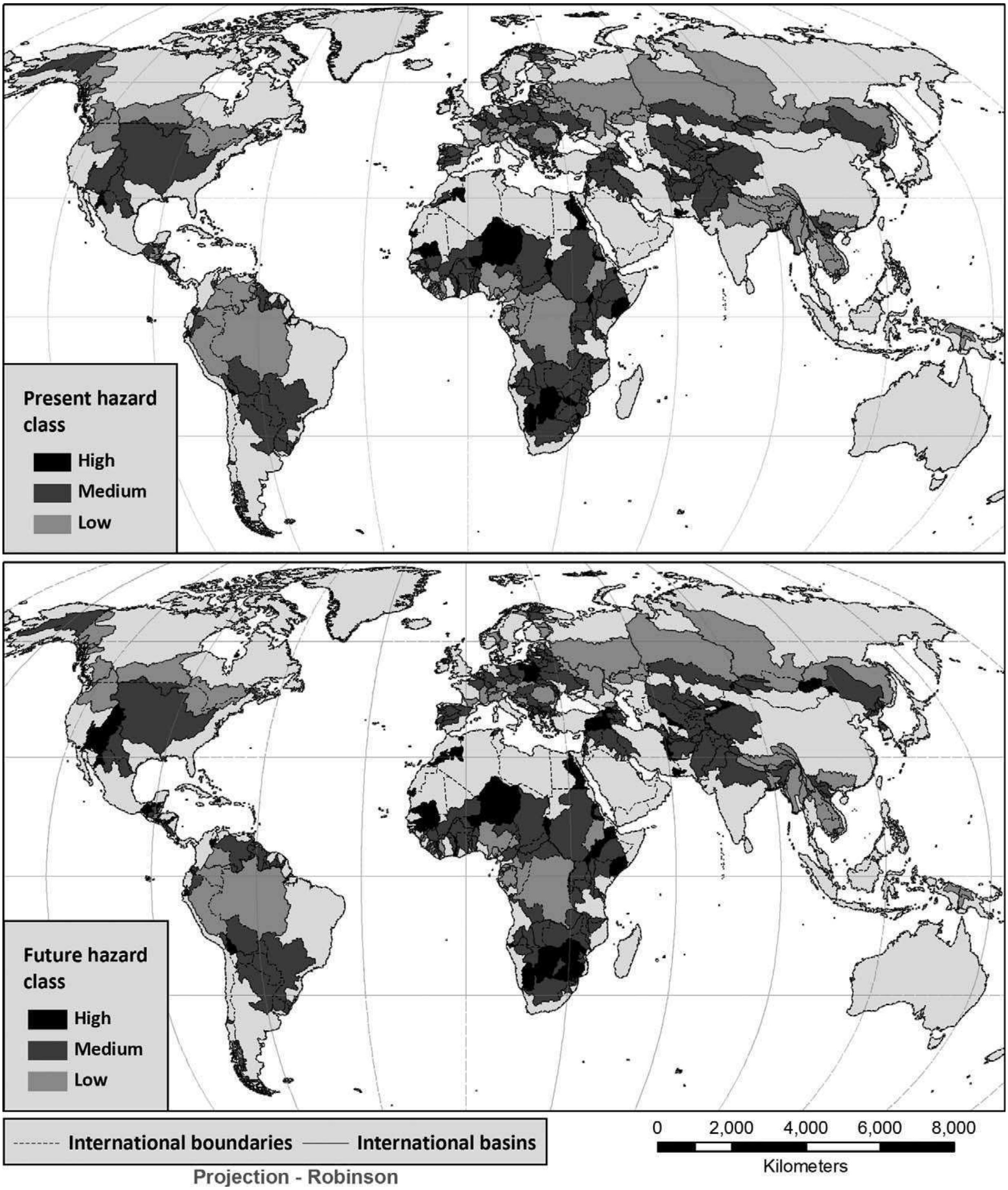

Figure 3. Global distribution of basin-country units in present and future hazard classes.

shared basins. Beyond their mere existence, the make-up and design of treaties, RBOs, and related provisions are anticipated to be particularly important in assuaging potential interstate conflict or country grievances, which may be caused by an increase in interannual water variability due to climate change.

The data analysis revealed marked differences between regions in the frequency of occurrence of certain mechanisms, particularly for allocation and variability mechanisms, and for the presence of RBOs. Gaps in the institutional coverage of population and area of transboundary basins should be further

Table III. Vulnerability of BCUs and population, present and future hazards

	Present hazard level			*Future hazard level*			
	High	*Medium*	*Low*	*High*	*Medium*	*Low*	*Total BCUs*
Vulnerability level (no. of BCUs)							
High	**41**	199	146	**94**	174	118	386
Medium	9	113	51	46	93	34	173
Low	15	111	50	35	93	48	176
Total BCUs	65	423	247	175	360	200	735
							Total population (in millions)
Vulnerability level (% of population)							
High	**0.27**	7.78	7.99	**2.05**	6.77	7.23	441
Medium	0.38	8.51	6.29	1.92	7.75	5.51	417
Low	2.37	31.55	34.86	4.25	47.07	17.46	1890
Total population (in millions)	83	1315	1350	226	1693	8309	2748

Bold entries are the highest risk categories.

analyzed as they could reveal a potential institutional weakness leading to hydropolitical stress in ill-equipped transboundary areas. A number of basins had large disparities among constituent BCUs in their treaty and RBO coverage, demonstrating the value of using a BCU approach and flagging basins where institutional imbalance in the relationships among riparian countries could seriously hamper dialogue and management at the river basin scale.

BCUs in the highest potential risk class under current variability conditions are clearly spatially concentrated in northern and sub-Saharan Africa, pointing to the need to focus on those two regions to assuage possible tensions related to variability. Interestingly, other basins where transboundary disputes are frequent (e.g. Indus, Ganges, Mekong) did not stand out in our analysis for present variability, suggesting that other causes can be behind water-related tensions. BCUs in the highest level of risk due to variability change by 2050 were more spatially dispersed than in the present.

Fourteen basins were identified as particularly interesting for further study based on their high level of potential risk and their relevance in terms of population, area, discharge, and intensity of water use. It is interesting to note that, with two exceptions, all the basins identified which merit further study due to present variability are in Africa, suggesting that improving the transboundary institutional resilience to water variability should be a priority for the involved countries and the international community. In contrast to the present situation, by 2050 only half of the basins identified are in Africa, the rest being distributed between Latin America and Eastern Europe/Western Asia. With all the caveats related to the precision of future runoff projections (see below), this distribution of basins suggests that some of the potentially large impacts of climate change are projected to occur away from those areas currently under scrutiny. Determining where institution-building should be focused using only historic regimes of variability could miss those areas with the greatest need for increased resilience in their institutional systems to absorb or adapt to change in the hydrologic system. Because of this range in our findings, it is critical for the water resources research and policy community to broaden its focus to include also basins traditionally outside the scope of concern to adequately address the human and institutional impacts of climate change. There are additional basins that no doubt would prove interesting and in need of further study, but our study provides a starting point for understanding what constitutes risk both now and in the future, and what might serve to ameliorate that risk.

In order to better understand the implications of our findings, we should mention some caveats based on the data used. The modeled runoff (derived from World Bank, 2009) represents natural conditions and does not take into account river flow as altered by human use and physical infrastructure such as dams. The chosen indicator, the runoff coefficient of variation, did not take into account seasonal variability or extreme events, which may also pose critical challenges to basin riparians. Moreover, BCUs were treated as unconnected units

Table IV. River basins at high risk meriting further study. Future hazard level and vulnerability are 'high' for all the listed BCUs

Basin	Riparian countries identified in filtering	Present hazard level	Treaty-RBO scores and disparity: Disparity	Treaty-RBO scores and disparity: (Min/max)	Basin population[a] (count)	Area (km^2)	Discharge[b] (km^3/yr)	Irrigated area[c] (km^2)	Additional riparians
Asi/Orontes	Turkey	Medium	2	(0/2)	5,607,300	37,900	8.14	10,000	Lebanon, Syria
Catatumbo	Colombia	Medium	0	(0/0)	1,255,700	30,900	23.97	2,000	–
	Venezuela	Medium							
Chira	Ecuador	High	0	(1/1)	747,400	15,600	0.96	1,300	–
	Peru	High							
Congo/Zaire	Uganda	High	4	(0/4)	81,395,000	3,674,800	1,262.74	103,900	Angola, Burundi, Central African Republic, Cameroon, Republic of the Congo, Gabon, Malawi, Rwanda, Sudan, Tanzania, Democratic Republic of Congo, Zambia
Gash	Ethiopia	High	2	(0/2)	3,687,500	39,900	1.09	2,800	Eritria, Sudan
Kura-Araks	Georgia	Medium	3	(0/3)	13,047,100	193,400	17.80	47,600	Armenia, Azerbaijan, Iran
	Turkey	Medium							
Lake Chad	Algeria	High	3	(0/3)	41,249,100	2,380,500	102.69	39,200	Central African Republic, Cameroon, Chad, Niger, Nigeria
	Libya	High							
	Sudan	High							
Lotagipi Swamp	Ethiopia	High	0	(0/0)	328,500	38,700	1.12	0	Kenya
	Sudan	High							
	Uganda	High							
Neman	Poland	Medium	1	(1/2)	4,722,200	90,700	20.62	100	Belarus, Latvia, Lithuania, Russia
Nestos	Greece	Medium	0	(0/0)	301,000	10,200	3.14	500	Bulgaria
Niger	Algeria	High	4	(0/4)	88,602,400	2,105,200	328.39	80,000	Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Guinea, Mali, Niger, Nigeria
Oued Bon Naima	Algeria	High	0	(0/0)	79,300	500	0.00	200	–
	Morocco	High							
Sarata	Moldova	Medium	0	(0/0)	98,300	1,800	0.06	60	–
	Ukraine	Medium							
Zapaleri	Argentina	High	0	(0/0)	200	2,600	0.04	0	Chile
	Bolivia	High							

[a] Data from Oak Ridge National Laboratory (2008); [b] data from Fekete, Vörösmarty & Grabs (2000); [c] data from Döll & Siebert (1999).

and, consequently, the extent to which high variability changes in one BCU may increase pressure on the water resources of other BCUs in that basin was not considered. In terms of institutional capacity, we argue that water variability may lead to tension and conflict between states and that institutional stipulations and RBOs can potentially assuage such potential tensions. Although we considered and investigated an important array of institutional stipulations, we recognize that other stipulations exist such as non-water linkages, which likewise deserve scrutiny. Additionally, the textual analysis of the treaties limited our analysis to a binary absence/presence of stipulations rather than considering their overall quality. Similarly, the level of treaty implementation and treaty equity need to be included in future research. We assumed that the treaty and river basin organization landscape would not change over time, which may not necessarily be the case. Nonetheless, this assumption allowed us to explore what the existing institutional arena today would look like projected into a future affected by climate change. While this analysis did not empirically and quantitatively estimate or measure how particular contextual factors may directly affect the relationship between treaty-RBO capacity and resilience to variability, it does provide motivation for such future work. Future large-N investigations can thus utilize the rich hydropolitics literature that has considered factors such as militarized interaction, power disparities, regime type, level of interdependence, and geography (Gleditsch et al., 2006; Lowi, 1993; Brochmann & Hensel, 2009; Toset, Gleditsch & Hegre, 2000). Further work can also be done on individual basins or regions (as has already been accomplished in varying capacities by Goulden, Conway & Persechino, 2009; Conway, 2005; Fischhendler, 2004).

In conclusion, this study highlights that the global distribution of treaties and river basin organizations is quite varied and reflects a long and complex history of development in response to specific demands on water systems and larger sociopolitical processes. Likewise, the variability in basin-wide hydrological regimes is unevenly distributed in space and intersects with human use and management in both intranational and international settings. Global climate change adds another layer to this already complex picture. Understanding when and where to target capacity-building for greater resilience to change is critical. This study represents a step toward facilitating these efforts with the goal of motivating further qualitative and quantitative research into the relationship between hydrological variability regimes and institutional capacity for accommodating variability.

Replication data

The dataset, codebook, and do-files for the empirical analysis in this article can be found at http://www.prio.no/jpr/datasets.

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Weathering climate change: Can institutions mitigate international water conflict?

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Abstract

Although the subject remains contested, some have speculated that climate change could jeopardize international security. Climate change is likely to alter the runoff of many rivers due to changes in precipitation patterns. At the same time, climate change will likely increase the demand for river water, due to more frequent droughts and greater stress being placed on other sources of water. The resulting strain on transboundary rivers could contribute to international tensions and increase the risk of military conflict. This study nevertheless notes that the propensity for conflicts over water to escalate depends on whether the river in question is governed by a formal agreement. More specifically, the article argues that the ability of river treaties to adapt to the increase in water stress resulting from climate change will depend on their institutional design. It focuses on four specific institutional features: provisions for joint monitoring, conflict resolution, treaty enforcement, and the delegation of authority to intergovernmental organizations. Treaties that contain more of these features are expected to better manage conflicts caused by water stress. This expectation is tested by analyzing historical data on water availability and the occurrence of militarized conflict between signatories of river treaties, 1950–2000. The empirical results reveal that water scarcity does increase the risk of military conflict, but that this risk is offset by institutionalized agreements. These results provide evidence, albeit indirect, that the presence of international institutions can be an important means of adapting to the security consequences of climate change by playing an intervening role between climate change and international conflict.

Keywords

climate change, environmental security, river treaties, water conflict, water cooperation

Despite consensus regarding the basic propositions that climate change is real and will have serious ecological consequences, there is much less certainty regarding its social and political implications. It has been suggested, particularly in policy circles, that the ecological effects of climate change will lead to political instability and exacerbate the risk of armed conflict (CNA, 2007). Speculation about how climate change may endanger national security encompasses a variety of possible mechanisms, including extreme weather events and rising sea-levels; see Busby (2008) for a comprehensive review. Nevertheless, statements from public officials regarding the connection between climate change and security have rarely been based on peer-reviewed research (Nordås & Gleditsch, 2007; Salehyan, 2008). Until recently, there were very few systematic studies of the security consequences of climate change for policymakers to draw on. This is beginning to change as scholars are starting to move beyond single-case methods to address the possible connections between climatic factors and intrastate conflict with large-sample empirical studies.

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In this article we aim to apply a similar systematic empirical approach to the possible connection between climate change and *militarized international conflict* ('conflict' for short), focusing specifically on shared sources of freshwater as a potential causal mechanism. Our intended contribution to this larger question is to investigate the impact that international institutions might have on the relationship between climate change and conflict. In particular, we consider the degree to which international institutions that govern transboundary rivers are able to manage the political effects of water stress. We expect that those treaties that are highly institutionalized – with provisions for monitoring, conflict resolution, enforcement, and delegation of authority to intergovernmental organizations – will be better equipped to deal with the international tensions that can arise over transboundary water sources. Our empirical analysis tests the link between institutional design and the occurrence of conflict in a sample of river treaties formed since 1950. The empirical results reveal that water scarcity does increase the risk of conflict, but that highly institutionalized river agreements are effective at steering riparian state interactions away from conflict.

These findings have several implications. First, international institutions can function as an intervening variable in the relationship between climate change and security. Salehyan (2008) advises researchers to consider the social processes and governance mechanisms that play an intermediating role in the connection between the environment and conflict; our findings suggest that international institutions should be considered as one class of governance mechanisms. Forecasts that do not account for the important conflict management potential of international institutions will produce overly pessimistic scenarios regarding the impact of climate change on international security. Likewise, empirical studies of the effects of climate change that use historical data on environmental conditions but do not control for the effect of institutions could fail to undercover important empirical patterns; for example, null findings regarding the connection between water scarcity, shared water sources, and conflict might reflect the positive role played by existing international institutions.

Second, if climate change does have consequences for security, then researchers should start investigating possible policy responses. The theoretical literature on international environmental cooperation has long held that the design of international environmental institutions will condition their ability to promote cooperation (Haas, Keohane & Levy, 1993). The emphasis on the importance of regime design is echoed by specific studies of international water management (Bernauer, 2002; Marty, 2001; Giordano, Giordano & Wolf, 2005; Zawahri, 2009 a,b). This article provides a novel extension of this research. By observing whether the design of river treaties conditions their ability to prevent conflict, we can gain insight, albeit indirect, into methods of managing the effects of climate change on security.

International institutions are a policy response that can be undertaken in the short to medium term. In the long run, mitigation will be necessary to address climate change, but even rapid emissions reductions will have a lag time before atmospheric conditions improve. The political barriers to emissions reductions also make their timely implementation unlikely. Consequently, many have concluded that some effects of climate change are unavoidable, particularly for many tropical and subtropical developing countries. Given the need to adapt to some consequences of climate change, we investigate whether international institutions might be one type of adaptive response to a specific consequence of climate change: international conflicts arising from water stress.

We start by discussing the possible connection between climate change, shared rivers, and international conflict. The next section examines the possible intervening role played by international agreements. We then discuss how four different institutional design features can influence the effectiveness of treaties, followed by a section summarizing our hypotheses. After the research design, we present the empirical results and finally conclude by discussing the implications of our findings.

Climate change, water stress, and transboundary water conflicts

Hypotheses about how climate change leads to conflict encompass a variety of possible mechanisms, including the effects of climate change on precipitation, agricultural output, extreme weather events, economic growth, and human migration. In considering the possible influence on international security, we focus on one anticipated effect of climate change: the expected increase in the scarcity of renewable freshwater. We emphasize water for three reasons. First, although many climate models differ regarding the likely ecological effects of climate change, increases in both seasonal and overall water stress in many geographic regions are projected in several models (Bates et al., 2008).[1] Second, when considering

[1] Given the uncertainty in climate model projections, our findings are applicable to the effects of climate change predicted by several different climate models, although not all.

the effect of climate change on *international* conflict, an increase in water scarcity due to climate change represents the most likely scenario in which conditions in one country can have adverse repercussions in another, due to the importance of transboundary rivers as sources of freshwater. In effect, transboundary rivers are an important source of ecological interdependence, under which water stress in one country can be transmitted to another. Third, analyzing the historical record of water scarcity allows us to gain some valuable, although admittedly indirect, insights into what the consequences of increasing water scarcity in the future might be. Below, we first discuss the projected effects of climate change on water scarcity, and then present three possible routes by which greater water scarcity may increase the risk of international conflict.

Based on studies using both observational records and projections from climate models, Working Group II of the Intergovernmental Panel on Climate Change (IPCC) offers a comprehensive overview of the projected impacts of climate change on freshwater (Bates et al., 2008). The projected effects of climate change discussed in this section are limited to those rated with high or very high confidence by the IPCC. First, the overall level of water available annually is expected to decrease in many dry regions of the world by the middle of this century.[2] Reduced precipitation, more frequent droughts, and reduced river runoff are expected to occur particularly in arid and semi-arid regions where water is already scarce (e.g. the Mediterranean Basin and Southern Africa). Although some regions will experience an increase in precipitation and available freshwater, this will occur mostly in high latitude regions where water is already plentiful and drought is not a major concern to begin with. The benefits of any increase in precipitation will also be offset by the fact that some of it will occur as heavy precipitation events, making the water more difficult to capture and utilize.[3] Moreover, the total area of land subject to increased water stress due to climate change is expected to be double the area in which water stress is expected to decline (Bates et al., 2008). Thus, the total costs of climate change related to the availability of freshwater are expected to outweigh the potential benefits.

Additionally, climate change is anticipated to impact the seasonal variability of precipitation and river runoff. For many regions, reduced precipitation is projected to occur during summer dry periods, increasing the frequency of summer droughts. And because river flow in many regions depends on glacial and snowpack melt during warm and dry periods, an increase in winter precipitation falling as rain rather than snow will reduce melt water contributions to runoff from glaciers and snowpack in the spring – decreasing river flows during dry summer periods. This is especially problematic in arid regions, which already experience little to no summer precipitation, making them more reliant on surface water. Research supporting this conclusion includes evidence from the European Alps, Scandinavia and the Baltic, Russia, the Himalayas, and North America (Bates et al., 2008). The above trends are thus expected to reduce the availability of water in many geographic locations.

The manner in which climate change-induced water scarcity is likely to jeopardize international security is by damaging the relations between states sharing a freshwater source. Transboundary rivers, lakes, and aquifers are often the subject of conflicting utilization, as is typical of common pool resources. The value that states place on these water sources can be expected to increase as climate change amplifies water stress. Climate change can thus magnify water-related international tensions, increasing the risk of armed conflict both directly and indirectly.

First, the increased economic and political value of water due to scarcity caused by climate change will heighten the likelihood of international disputes over transboundary water sources. In response to reduced precipitation, states will likely increase their reliance on other water sources, including transboundary rivers. As is the case for common pool resources, increased unilateral consumption of a transboundary river by one user decreases the amount available to others.[4] Furthermore, the political reaction to water diversion will be more severe under conditions of increased scarcity, because it will be occurring at a time when water will be more valuable for all other riparian states. These issues were highlighted during a recent visit by the UN Secretary-General

[2] This is based on the projections of multiple climate models using the mid-range A1B non-mitigation scenario from the IPCC Special Report on Emissions Scenarios.

[3] Abundant precipitation may negatively impact interstate relations, for example when upstream states release excess water, causing flooding downstream. This possibility is, however, beyond the scope of this article.

[4] Increased scarcity of surface water will also likely cause greater withdrawal of water from underground aquifers. We omit transboundary aquifers from this analysis because there are few existing agreements governing them.

Ban Ki-moon to the Aral Sea. The lake has shrunk by 90% due to water diversion, damming, and irrigation projects on rivers feeding it. In addition to the current ecological disaster, the competition for remaining water among Kazakhstan, Uzbekistan, and Turkmenistan 'could become increasingly heated as global warming and rising population further reduce the amount of water available per capita' (Heintz, 2010).

Even when scarcity does not prompt new river diversion projects, the increased demand for water can lead to disagreements by making states more likely to object to the current behavior of other riparians. Previously acceptable river diversion (for human consumption, industrial use, agriculture, etc.) could become politically problematic after the river flow has been reduced due to climate change. These problems will be compounded when the externalities of the common pool resource are asymmetric, as in the case of rivers for which there are clear upstream and downstream states.

Climate-induced water stress can also lead to a greater reliance on coercive diplomacy. Whereas competing uses of a water source might be manageable politically during normal times, conditions of scarcity can make states less likely to wait for diplomatic options to resolve conflicts. For example, the increased sensitivity to water issues can lead to a more combative response to the damming of a river. Downstream states may use threats or overt military force as a bargaining tactic to coerce upstream states into limiting water diversion. The heightened value of the water source to both sides will shrink the zone of agreement and increase the potential payoff of using coercive bargaining. Accordingly, Hensel, Mitchell & Sowers (2006) find that water scarcity increases the likelihood of militarized conflicts over competing river claims between riparian states. Political and military tensions are also observable between Syria and Turkey over Turkish dams on the Euphrates, while Egypt vehemently opposes diversion of Nile waters by upstream riparians.

Finally, water stress can increase the risk of conflict indirectly, whereby transboundary water source disagreements damage the general relations between states. Because poorly managed interdependence contributes to overall tensions between states (Starr, 1997), disagreements over water may spill over into other issue areas. For example, the sluggish implementation of the Israel–Jordan peace agreement's water-related provisions damaged overall relations between the parties (Fischhendler, 2008a). More broadly, several empirical studies link shared river basins with an increased risk of dyadic conflict (Toset, Gleditsch & Hegre, 2000; Furlong, Gleditsch & Hegre, 2006; Gleditsch et al., 2006); because these studies use a general measure of international conflict – the Militarized Interstate Dispute data – their findings support the notion that water disputes can spill over to other areas of interstate relations.

For both the direct and indirect scenarios, climate change and attendant increases in water scarcity could heighten the risk of conflict. The most pessimistic version of this 'neo-malthusian' prediction is that water scarcity will lead to future full-scale 'water wars' (Gleick, 1993; Klare, 2001), a prediction criticized on both empirical and theoretical grounds (Lonergan, 1997; Gleditsch, 1998; Wolf, 1998). One important objection is that international cooperation over transboundary water sources has thus far been much more common than conflict (Yoffe, Wolf & Giordano, 2003). Additionally, international agreements can help manage transboundary rivers and thus discourage international conflict. The next section explores this in greater detail.

Transboundary river treaties and international conflict

While this study is motivated by the premise that water scarcity can contribute to militarized international conflict, we echo some of the skepticism regarding the 'water wars' scenario. As Salehyan (2008) observes, proponents of the deterministic view that environmental scarcity leads to armed conflict tend to overlook the role of human agency and the moderating effects of institutions. International institutions, in particular, are one important factor that helps explain why international conflicts over water are comparatively rare. Rather than simply being the opposite of conflict, formal international cooperation is one method for managing transboundary water sources and thereby preventing the emergence and escalation of international water disputes. We thus view international institutions as critical explanatory variables that have been largely overlooked in many discussions of international water conflict.[5]

International treaties have become an increasingly common means of managing transboundary rivers. International organizations, such as the United Nations and World Bank, often advocate the formation of river treaties. In the case of tensions in the Aral Sea basin, for example, the UN Secretary General has recommended a formal international accord to better manage the rivers feeding the Aral Sea (Heintz, 2010). This trend has been

[5] Important exceptions include Wolf, Yoffe & Giordano (2003), Hensel, Mitchell & Sowers (2006), and Brochmann & Hensel (2009).

reflected in recent academic research investigating the conditions leading to river treaty formation (e.g. Tir & Ackerman, 2009; Stinnett & Tir, 2009; Tir & Stinnett, 2011). River treaties can specify how the river will be shared, set water quality targets, determine acceptable water withdrawal rates, or balance navigation, water level, and water quality needs; this will, in turn, help minimize the stresses placed on the river and make use more effective in the long run. By helping to resolve the underlying problems that occur because of the competing use of rivers – and which are likely to be exacerbated by increased water scarcity – treaties can alleviate political tensions and reduce international conflict (Wolf, Yoffe & Giordano, 2003).

Nevertheless, river treaties will be effective conflict management tools only to the extent that the signatories actually comply. In this respect, they face several limitations. First, states might engage in intentional cheating. The same incentives that necessitate formalized cooperation in the first place can also tempt parties to cheat on the treaty obligations (e.g. drawing more water for irrigation and industrial purposes than permitted by the treaty). This incentive structure is typical of common pool resources, where the cheater can enjoy the collective benefits created by other parties' actions, while avoiding the private costs of compliance. Second, failure to comply can occur because the language of the agreement is imprecise and open to multiple interpretations in specific situations (Chayes & Chayes, 1995). For example, Fischhendler (2008b) observes that the water use provisions in the 1994 Israel–Jordan peace treaty were left intentionally vague to facilitate domestic acceptance of the agreement. While ambiguity may give a treaty some flexibility, it also allows multiple interpretations of an agreement. Combined with imprecise treaty language, unforeseen conditions can lead to disagreements over treaty compliance. This is uniquely problematic for river management treaties, given both annual and seasonal variability of river conditions. Third, failure to comply with a river treaty can result from a lack of the technical, regulatory, or economic capacity needed to implement it (Chayes & Chayes, 1995). For example, improvements in water infrastructure typically require long-term, capital-intensive investments (Dombrowsky, 2007).

Achieving compliance can be a difficult proposition even under the best circumstances, but climate change – and its consequences for the availability of freshwater – will greatly complicate both the willingness and the ability of the parties to adhere to a river treaty. By increasing the value of water, scarcity will raise the incentive to violate treaty provisions that prohibit unilateral infrastructure development or limit the consumption of river water.[6] It might also prompt small-scale diversion by non-state actors, resulting in unintended violations. Climate change will also exacerbate problems of treaty ambiguity by creating hydrological conditions that were not anticipated when an agreement was formed. When unexpected circumstances in river flow arise, ambiguity can create diverging interpretations of how to behave under these conditions and lead to agreement abrogation. Finally, the lack of capacity to deal with droughts may lead to treaty violations. In 1999, for example, drought reduced Israel's ability to deliver water to Jordan under the terms of the 1994 peace agreement (Kilgour & Dinar, 2001).

In short, the effects of climate change may exacerbate the causes of noncompliance and compromise the ability of river treaties to manage riparian disputes. Despite these limitations, we expect that some river treaties will be more effective than others in helping us adapt to climate change. Next, we focus on institutional provisions of agreements that can improve their ability to manage conflicts and adapt to new environmental conditions.

River treaty design and conflict management

Our central expectation is that river treaties that utilize formal institutions will be more likely to prevent riparian conflicts and alleviate the deleterious consequences of water scarcity for international security. This expectation is based on two related causal logics. First, international institutions help make treaties more effective at preventing conflicts by minimizing the various causes of noncompliance listed above, including those that are generated or exacerbated by the consequences of climate change. For instance, specific institutional provisions can help monitor behavior, facilitate enforcement, resolve disagreements over treaty obligations, and help boost the capacity of member countries. In the event of growing scarcity, better treaty compliance will help preserve available water provided by the corresponding river. This will lessen the stress placed on the river and minimize the temptation to engage in unilateral river diversion. Second, in the event that disputes emerge between signatories, institutions can prevent escalation by facilitating conflict resolution. If climate change, by placing countries in conditions of increasing water scarcity, generates new or intensifies existing conflicts between riparian states, highly institutionalized treaties will be better able

[6] Stress on surface water may also result in increasing conflict over groundwater.

to diffuse such situations than their less institutionalized counterparts.

We focus on four specific institutional features of river treaties. Among treaties signed between 1950 and 2000, taken from the International Freshwater Treaties Database (Hamner & Wolf, 1998), 72% contain at least one institutional provision. The remainder of this section discusses each institutional feature in detail, namely, monitoring provisions (found in 47% of the treaties), enforcement (7%), conflict management (35%), and delegation of authority to an intergovernmental organization (35%).

Monitoring

Formal treaty provisions mandating collection and sharing of river data, such as flows, can improve the functioning of river agreements. Given the complexities of transboundary river systems and the natural variability in river conditions, assessing treaty compliance often requires highly specialized and detailed data (Elhance, 2000; Dombrowsky, 2007). This uncertainty will be exacerbated by climate change; for example, reduced flow can be caused by drought rather than excessive diversion by the upper riparian. In addition, hydrological data can be difficult and costly to collect, especially for developing countries (Elhance, 2000).

Greater transparency and data sharing can reduce fears that the other parties are violating the treaty, though it is certainly no panacea (Feitelson & Chenoweth, 2002). This function of formal monitoring will be even more important if climate change reduces total annual river flow or flow during the critical dry-season. In such cases, better information will help the parties distinguish between the effects of climate change versus the actions of other riparians and provide the basis for addressing water-related consequences of climate change in a comprehensive manner. In other cases, a signatory may be deterred from temptation to cheat because the likelihood of being caught is greater. Finally, provisions for coordinated monitoring can help address capacity limitations by sharing these costs.

Conflict management

To cope with disagreements among signatories, some river treaties specify a variety of formal procedures for dispute management. The Permanent Indus Commission, for example, is responsible for resolving disputes between India and Pakistan over the implementation of the Indus Waters Treaty. Disputes are managed primarily through regular meetings of the officials that make up the two national sections of the Commission (Zawahri, 2009b). At the opposite end of the spectrum lie mandates for binding arbitration or adjudication by an existing international institution. For example, Hungary and Slovakia have resorted to the ICJ to resolve a dispute involving a 1977 treaty governing water infrastructure projects on the Danube (McCaffrey, 2003).

Dispute resolution provisions can address different sources of noncompliance, including those related to anticipated consequences of climate change. A formal process of resolving disputes can address overt cheating by raising the visibility of noncompliance (Abbott & Snidal, 2000). By increasing the costs of violations – some of which may appear particularly tempting due to the effects of climate change (e.g. unilaterally increase withdrawal rates to compensate for lack of water due to a number of dry years) – dispute settlement mechanisms can improve compliance.

Conflict management institutions can also address disputes over an agreement's exact obligations. If climate change causes changes to a river system that were not envisioned at the time of the treaty signing, such as lower flow or greater seasonal variation, then these conditions will make the treaty less effective and increase the risk of conflict. In these circumstances, provisions in a treaty for dealing with unforeseen conditions will become important for preventing conflict. The rulings of a third-party arbitration panel, court, or even informal mediation through a secretariat or intergovernmental body can clarify the terms of a treaty (Chayes & Chayes, 1995). This enhances compliance by limiting the occurrence of unintended violations that result from treaty ambiguities or changed circumstances.

Enforcement provisions

Formally specified procedures for enforcement can improve a treaty's ability to prevent and deal with disputes in multiple ways. First, the reduction in the transaction costs of punishing cheaters increases the costs of non-compliance and deters violations – and thus supports the decentralized self-enforcement of an agreement by its signatories (Keohane, 1984). Furthermore, sanctioning according to the rules laid out in an international agreement will be seen as more legitimate than direct, unilateral retaliation by an aggrieved state; punishments seen as legitimate will help prevent dispute escalation and relations from collapsing in a spiral of retaliatory and counter-retaliatory measures. Finally, even in the absence of strong punitive sanctions, institutionalized enforcement procedures can deter violations by increasing the reputational consequences of non-compliance by disseminating information.

If climate change introduces a host of unexpected shocks to the relationship between riparian states, then the frequency of both intentional and unintentional defection is likely to grow. Enforcement provisions can help force states to comply with the agreement while coping with the changes, punish cheaters to assure broader compliance, and manage disputes so that the mutually-retaliatory, escalating conflicts are avoided.

Intergovernmental organizations

Lastly, some river treaties delegate authority to new or existing intergovernmental bodies. These organizations vary widely in their structure and functions. An example of a complex organization is the Mekong River Committee, which consists of the Secretariat, a permanent executive; the Joint Committee, which makes technical decisions and oversees the Secretariat; and the Council, which is composed of representatives from each member state and has the authority to make policy decisions. Some organizations also include technical committees made up of engineers and other experts, responsible for daily operations. These bodies include the Permanent Indus Commission, the Israel–Jordan Joint Water Committee, and the International Joint Commission for rivers shared by Canada and the United States. Finally, simpler organizations are basically consultative committees that facilitate diplomacy.

Intergovernmental bodies can help manage disputes through several different means. In the event that treaty violations occur, intergovernmental bodies, as centralized venues for communication and diplomacy, will enhance the reputational consequences of noncompliance and thus help sustain cooperation over time (Keohane, 1984). By facilitating diplomacy between member states, intergovernmental bodies can also help clarify the understanding of an agreement's obligations and prevent the escalation of disputes. For technical committees, conflict management is enhanced by the fact that water experts, engineers, and regulators from member states will often address issues in a non-political manner. For example, the success of cooperation on the Komati River in southern Africa under the Komati Basin Water Authority has been attributed to the fact that most issues have been addressed by technical experts, rather than at a political level (Keevy, Malzbender & Petermann, 2009). Finally, intergovernmental organizations can address shortfalls in technical or economic capacity by coordinating national efforts through a centralized administrative structure and by pooling members' technical capacities (Abbott & Snidal, 1998).

All these functions will enhance treaty signatories' ability to weather the water-related effects of climate change while keeping their relationship from devolving toward violent confrontations. As climate change introduces new challenges and unanticipated scenarios, river treaties supported by intergovernmental organizations will be better able to enhance the signatories' technical capacity, promote treaty compliance, deter violations, and provide unbiased interpretation of signatories' obligations.

Water scarcity, institutional design, and militarized conflict

Conducting an empirical study of the security consequences of climate change presents a unique problem because it involves conditions that are expected to occur in the future. Therefore, social scientists have few data points with which to study its potential effects. As Salehyan (2008) observes, however, environmental conditions in the past can provide a basis for testing conjectures about the future. Several recent studies addressing the effects of climate change on violent conflict have taken a similar empirical approach; see, for example, Raleigh & Urdal (2007) and Hendrix & Glaser (2007).

Based on this logic, this study uses historical data on renewable freshwater to gain, admittedly indirect, insight into how climate change might impact international security through the mechanism of increased water scarcity. Specifically, we use annual data for a state's total renewable water per capita, where higher numbers indicate less scarcity. This gives us an empirical record with which we can analyze the effects of localized water scarcity on international conflict. We concentrate on overall water scarcity, rather than changes in annual precipitation or discrete weather events, for several reasons. First, the forecasts of climate models are most certain when they address overall levels of water availability for large regions. As the spatial scale of climate model projections decreases, the models become less consistent (Bates et al., 2008: 3). Second, the causal mechanisms connecting rainfall to international conflict are not entirely clear, whereas there is previous evidence connecting water scarcity and conflict. Finally, precipitation alone is not the whole story when it comes to a country's available freshwater. Data on overall renewable water sources will encompass both precipitation and other sources of freshwater, most notably rivers.

The amount of renewable freshwater a state has will affect its reliance on shared transboundary rivers to meet its water demands. When water becomes scarcer for a state, it will be more likely to come into conflict with its riparian neighbors. In particular, we expect that conflict behavior between a pair of countries will be influenced by the degree of water availability for the state with the lower amount of available freshwater. It will be the water poorer state that will be more likely to divert water going to downstream states, or more likely to become hostile to diversion by other riparians. In short, the water poorer state's reactions to scarcity are the most likely – and the earliest – sources of political conflict.

To assess the conflict management potential of river treaty institutions, we compare their effects on conflict along with the effect of water scarcity. Although we have discussed the various institutional features separately, our main interest is in understanding the overall, cumulative effect of the institutional design of river treaties. Accordingly, we measure institutions using an index comprised of all four institutional features. We refer to this measure as the degree or level of river treaty institutionalization. Our central hypothesis is that the more institutional features a treaty contains, the more effective it will be in preventing the occurrence of militarized conflicts between signatory states. In addition, we expect that water scarcity will have a lower impact on the occurrence of conflict for agreements containing more institutional provisions.

Research design

Our empirical sample covers the signatories of 315 river cooperation agreements signed between 1950 and 2002, identified by the International Freshwater Treaties Database. We conduct the empirical analysis at the level of the dyad, rather than at the level of the agreement or basin, because militarized international conflict is essentially a dyadic phenomenon; this approach has become standard in studies of international conflict. For each dyad the analysis begins the year after each agreement is signed. We analyze annual interactions between all treaty member pairs; the unit of analysis is therefore the dyad-year.[7] We utilize a large-N empirical analysis in order to control for many other factors that influence conflict and to avoid the problem of selecting only high-profile cases – which has been common in the case study freshwater literature.

[7] If multiple treaties are signed between the same states, we act on the assumption that the latest treaty is the most relevant to future relations.

The dependent variable

To identify militarized conflict between riparians, we use the Militarized Interstate Dispute (MID) project (Ghosn, Palmer & Bremer, 2004). Each dyad-year is coded 1 if it experiences the onset of a MID. A potential limitation of using the MID data is that the militarized interactions may not be water or river related; yet, we follow the logic that water conflicts can escalate by spilling over and damaging relations in other issue areas, as explained above. In addition, using these data has important precedents in the water conflict literature (Gleditsch et al., 2006). Although the MID data do not distinguish between river and non-river related events, they suggest that proper management of river-induced interdependence can temper general conflictual relations between riparian states.

Primary explanatory variables

Our first key explanatory variable is an additive *river treaty institutionalization index*. It is composed of the following institutional features potentially contained in each of the 315 agreements: monitoring, enforcement, conflict resolution, and international organization. The first three components are variables recorded in the International Freshwater Treaties Database. International organization was identified using the comments section of the database and was coded 1 if the agreement created a new international organization to oversee the agreement or delegated authority to an existing organization. Each component is scored 0 or 1, and then all four component variables are summed for each agreement. This produces a scale of institutionalization ranging from 0 to 4, with a mean of 1.25 and a median score of 1 in our sample. Although we weigh each component equally, we only make the weak assumption that the final index is ordered, rather than an interval scale. Second, we capture the political pressure related to water scarcity by measuring *water availability* for the water poorer dyad member (see the above rationale), using the renewable water per capita data found in the FAO Aquastat database (Engelman, 2000). As this variable increases, the state's degree of water scarcity declines.

Control variables

We control for several potential influences on conflict proneness between signatory countries. These are drawn from the water politics and international conflict literatures and can be divided roughly into riparian, liberal, and realist groupings. Starting with the former, Toset, Gleditsch & Hegre (2000) provide data for whether a shared river bisects a boundary, creating an *upstream/downstream relationship* between treaty signatories.[8] Such a relationship is thought to be particularly problematic, as it allows the upstream state to impose negative externalities on the downstream state (Mitchell & Keilbach, 2001; Stinnett & Tir, 2009). Furthermore, in order to make sure that the observed dyadic conflict patterns are indeed a function of the institutional quality of the river treaty – and not simply a function of the quantity of treaties signed – we control for the *number of treaties* in effect between the dyad members.

Turning to the liberal influences, much international relations scholarship reports that democracies have a special conflict-minimizing relationship with each other (Russett & Oneal, 2001). We therefore control for *joint democracy*, using the net regime score from the Polity IV data (Marshall & Jaggers, 2006), a dataset commonly used to measure regime characteristics. The level of *economic development* affects water affordability (Feitelson & Chenoweth, 2002) and is thought by some to affect relations between riparian states (Biswas, 2001); both systematic riparian (e.g. Gleditsch et al., 2006; Tir & Ackerman, 2009) and general international conflict (e.g. Russett & Oneal, 2001) researchers, however, tend to report insignificant findings. This variable is measured by the wealthier dyad member's gross domestic product per capita. Furthermore, economic interdependence provides a positive context in which states will be more amenable to resolving their disagreements peacefully (Elhance, 2000). More generally, established trade relationships can act as signals of countries' trustworthiness and create environments in which cooperation can flourish and costs of conflict are increased (Gartzke, Li & Boehmer, 2001). *Trade interdependence* is measured by the ratio of trade between the dyad members to the total trade they engage in with the world. The data for both economic variables come from Gleditsch (2002).

Finally, we include three control variables related to the realist theory. We control for the influence of *relative power* distribution, which is measured as the natural logarithm of the stronger to weaker state's capabilities, based on the Correlates of War Material Capabilities composite index (Singer, Bremer & Stuckey, 1972). Second, we control for whether the dyad members are *allies*, with data from Gibler & Sarkees (2004). Finally, using the ordinal COW contiguity data (Stinnett et al., 2002), we capture the effects of *distance*. Both the ability to fight and the interest in engaging other states is strongly conditioned by proximity.[9]

Method of analysis

Given the dichotomous nature of the dependent variable, we utilize logit regression. The Beck, Katz & Tucker (1998) binary time-series cross-section correction is added to account for the fact that the data are composed of several cross-sections (i.e. dyads) and to deal with potential duration dependence as these cross-sections are observed over time. To save space, the associated years of peace and natural cubic spline (with three interior knots) variables are omitted from the tables. Finally, robust standard errors are employed to account for the observations from the same dyad being related.

Empirical results and discussion

Model 1, Table I, is a baseline model composed of the control variables. Overall, these results are very similar to those typically found in the standard empirical model of international conflict and demonstrate that the sample of river treaty signatories is not skewed due to sample selection bias.[10] The only apparent exception is the joint democracy coefficient's insignificance. Yet, this is a function of multi-collinearity with the trade interdependence variable; dropping the latter makes the joint democracy coefficient negative and significant ($p = .01$). Furthermore, the conflict-reducing impact of trade-based interdependence is confirmed, as is the general lack of relationship between the level of economic development and interstate conflict. The findings for all three liberal variables are thus consistent with well-established findings (see Russett & Oneal, 2001). Likewise, the results concerning power distribution, alliance ties, and distance comport well with the literature (see Russett & Oneal, 2001).

Model 2 adds the river- and water-politics variables and, most importantly, provides two findings critical to

[8] Whether this variable reports upstream/downstream relationships for contiguous countries only (per Toset, Gleditsch & Hegre, 2000) or includes both contiguous and non-contiguous states (per Gleditsch et al., 2006) has no appreciable effect on the findings.

[9] Inclusion of additional controls for contiguity and dyad size, based on Hegre's (2008) gravity model of international conflict, had no appreciable effect on the findings: both river treaty institutionalization and water availability coefficients remained negative and significant.

[10] Additional empirical analyses demonstrate that the effect of river treaty institutionalization is not unduly influenced by the selection and endogeneity effects, that is, the processes by which (highly institutionalized) river treaties are formed.

Table I. Analyses of MID onset between river treaty signatories

	Model 1: Control variables only	*Model 2: River- and water-related variables added*	*Model 3: Interaction term added*
Level of river treaty institutionalization		–.173** (.066)	–.409 (.389)
Water availability		–.132** (.047)	–.168* (.076)
Institutionalization * water availability			.027 (.044)
Upstream/downstream relationship		.820** (.154)	.842** (.158)
Number of treaties		.012 (.023)	.010 (.023)
Joint democracy	–.357 (.219)	–.189 (.221)	–.165 (.225)
Level of economic development	.0000 (.0001)	.0000 (.0001)	.0000 (.0001)
Trade interdependence	–54.611** (19.726)	–56.864** (20.049)	–57.145** (20.049)
Relative power	–.090* (.049)	–.117* (.054)	–.116* (.054)
Alliance	–.582** (.137)	–.597** (.144)	–.592** (.144)
Distance	–.468** (.054)	–.385** (.066)	–.383** (.067)
Constant	–.397** (.150)	.326 (.470)	.632 (.682)
N	6,816	6,620	6,620
Chi-square (df)	489.82** (10)	546.29** (14)	546.66** (15)

Cell entries report logit coefficients and robust standard errors (in parentheses). Significance levels (one-tailed): * p < .05; ** p < .01. MID = Militarized Interstate Dispute. Statistics correcting for the binary time-series cross-sectional nature of the data (see Beck, Katz & Tucker, 1998) are omitted from the table to save space.

our study. First, the water availability coefficient is significant. Its negative direction indicates that as water becomes more plentiful, the likelihood of conflict decreases. Conversely, this means that water scarcity increases the chances for militarized conflict, which is consistent with the basic argument found in much of the water conflict literature. For states that share a source of water, militarized conflict is more likely under conditions of scarcity. In sum, water scarcity is highly problematic from the militarized conflict perspective and a problem that needs to be managed. Predictions that climate change will increase the strain on freshwater sources suggest that climate change, if not addressed, may increase the risk of international conflict in the future.

Second, Model 2 demonstrates the beneficial effects of river treaty institutionalization. The significant and negative coefficient indicates that the more institutionalized the river treaty, the lower the likelihood of militarized conflict between the river treaty signatory states. This result suggests that the institutional design of river treaties conditions their potential as tools of conflict management. Due to provisions for monitoring, conflict resolution, enforcement, and/or delegation of authority to intergovernmental organizations, institutionalized treaties are better equipped to prevent tensions over transboundary water issues from contributing to military conflicts. This provides hope that the security consequences of water stress stemming from climate change can be effectively managed.

As can be seen from Model 2, the liberal and realist variable findings remain similar to those reported in Model 1, with collinearity continuing to obscure the importance of joint democracy. The river-related variable findings follow our expectations. The upstream/downstream relationship significantly increases the proneness for militarized conflict. As discussed above, this relationship is thought to be highly problematic, as it allows the upstream state to impose negative externalities on the downstream state (Mitchell & Keilbach, 2001; Stinnett & Tir, 2009). This complicates the dyadic relationship considerably as it provides the downstream state with incentives to resort to militarized threats and actions in order to curtail the upstream state's behavior. Furthermore, the insignificance of the number of treaties coefficient is not surprising given that we suspect that the quality (i.e. institutionalization) of river treaties matters more than their quantity (i.e. how many have been signed).

Returning to the main findings for Model 2, we have established that both water scarcity and river treaty institutionalization have significant, yet opposing impacts on the likelihood of MID onset. Next, we investigate the extent to which institutionalization can actually mitigate the ill effects of water scarcity in two ways. First, we calculate marginal effects based on Model 2 and compare the effects of these two (and other significant) variables. The calculations – obtained while holding the explanatory variables at their mean or mode values and then varying the value of the variable of interest – reveal that some of the control variables have the most influence. Namely, upstream/downstream relationship and distance, at +91% and –90%, respectively, are the most

Table II. Marginal effects

Explanatory variable	*Change in the explanatory variable value*	*Impact on the probability of MID onset*
Level of river treaty institutionalization	0 → 1	–23%
	0 → 2	–42%
	0 → 3	–58%
	0 → 4	–71%
Water availability	1 standard deviation around the mean	–17%
	From the 90th to the 10th percentile	+40%
Upstream/downstream relationship	0 → 1	+91%
Trade interdependence	1 standard deviation around the mean	–43%
Relative power	1 standard deviation around the mean	–15%
Alliance	0 → 1	–30%
Distance	1 standard deviation around the mean	–90%

Marginal effects are calculated for Model 2 significant variables, by holding variable values at their mean or mode values and then varying the value of the variable of interest. MID = Militarized Interstate Dispute.

influential; see Table II. Yet, the calculations also further support our finding that river treaty institutionalization matters. Specifically, adding just one institutional dimension to an un-institutionalized treaty reduces the probability of MID onset by nearly one-quarter, while the addition of three institutional dimensions reduces that probability by over one-half. Most prominently, a fully institutionalized treaty reduces the probability of MID onset by 71% compared to a treaty with no institutional features.

Meanwhile, varying water availability by one standard deviation around the mean (as is typically done with continuous variables) reveals that increases in water availability reduce the likelihood of MID onset by only 17%. This would seem to indicate that even lower levels of treaty institutionalization are easily capable of negating the problematic effects of scarcity. Yet, the around-the-mean water availability values hardly capture the condition of water scarcity. To address this shortcoming, we perform an additional calculation by decreasing the water availability levels from the 90th (water abundance) percentile to the 10th (severe water scarcity). This produces a much more notable marginal effect, +40%. The good news is that in comparison to the impact of institutionalization, water scarcity is less influential. This is important as it suggests that even mid-levels of institutionalization can eliminate many of the ill effects of water scarcity. Our findings thus support the contention that institutionalized river treaties can be used to deal with the expected future increases in water scarcity, due in part to climate change.

Second, we consider the conditioning effect of institutionalization on scarcity. Model 3, Table I, therefore, introduces the related interaction term. Because with a multiplicative interaction term the empirical results cannot be directly interpreted from the lower-order coefficients (Brambor et al., 2006), we estimate the combined marginal effect of the interaction and component variables. If our argument is correct, higher levels of institutionalization should weaken the link between water availability/scarcity and MID onset. The marginal effect calculations are presented in Table III and show the impact of institutionalization under the conditions of severe water scarcity (10th percentile of water availability), notable water scarcity (30th percentile of water availability), modal level of water availability (50th percentile of water availability), and water abundance (90th percentile).

The marginal effects in Table III reveal that river treaty institutionalization has a uniformly mitigating effect on the link between water scarcity and MID onset across different levels of water availability. The conditioning effect of institutionalization is most apparent under the condition of severe water scarcity (10th percentile of water availability), where a fully institutionalized treaty cuts the likelihood of MID onset by over one-half, compared to an agreement without any institutional provisions; similar effects hold for the 30th and 50th percentiles of water availability. And as water scarcity turns into abundance (90th percentile), the impact of institutionalization is less, but still notable, at over one-third decrease in the likelihood of MID onset. Institutionalization therefore has a somewhat decreasing marginal benefit as we move away from the worst- to the best-case scenarios regarding water availability. But most importantly, its beneficial impact is the greatest precisely where it is needed the most. These calculations hence

Table III. Conditional marginal effects of the level of river treaty institutionalization on the likelihood of MID onset, given different water availability amounts

Water availability amount	*Change in the level of river treaty institutionalization*	*Impact on the probability of MID onset*
10th percentile (condition of severe water scarcity)	0 → 1	–18%
	0 → 2	–34%
	0 → 3	–46%
	0 → 4	–56%
30th percentile (condition of moderate water scarcity)	0 → 1	–17%
	0 → 2	–32%
	0 → 3	–44%
	0 → 4	–54%
50th percentile (modal amount of water availability)	0 → 1	–16%
	0 → 2	–29%
	0 → 3	–41%
	0 → 4	–50%
90th percentile (condition of water abundance)	0 → 1	–11%
	0 → 2	–21%
	0 → 3	–29%
	0 → 4	–37%

Marginal effects are calculated based on Model 3, by varying the values of treaty institutionalization and water availability while holding the other variable values at their means or modes. MID = Militarized Interstate Dispute.

suggest that river treaty institutionalization should be an effective policy for dealing with the expected, global climate-change related decreases in water availability and attendant interstate tensions.

The fact that states voluntarily select themselves into river treaties raises the possibility that the empirical results are influenced by endogeneity or sample selection bias. The logic is that dyads which are prone to conflict could also be less likely to form institutionalized agreements. Thus, the reasoning goes, the negative sign on the institutions coefficient is simply a product of a spurious correlation and not indicative of a causal relationship. Yet, there are several reasons to discount this possibility. First, other studies have shown that the previous conflict propensity of a dyad is not correlated with the formation of river treaties (Tir & Ackerman, 2009) or the tendency of river treaties to include more institutional provisions (Stinnett & Tir, 2009; Tir & Stinnett, 2011). Second, both received international relations theory and previous empirical studies suggest that the opposite should be true: agreements are actually *more* likely to contain institutional provisions in difficult circumstances. Institutionalist theory holds that states form international institutions when they are otherwise unable to cooperate (Keohane, 1984). It is precisely when states have a need for institutions that they will be willing to pay the costs necessary to create them. Empirical studies of river cooperation also bear this claim out. Previous empirical research shows that water scarcity prompts countries to form river treaties (Tir & Ackerman, 2009)[11] and include more institutional features (Stinnett & Tir, 2009). This suggests that, if anything, institutions are *more* prevalent in conflict prone situations, which would bias the institutions coefficient in a *positive* direction. Finally, follow-up analyses using different two-stage statistical techniques to model agreement formation and conflict simultaneously show that agreement design retains an independent effect on the initiation of conflict even after the process of formation is accounted for.

Conclusion

A literature survey compiled by Working Group II of the IPCC (Klein et al., 2007) concludes that some degree of adaptation to the effects of climate change is unavoidable, even if the most ambitious emissions reductions targets are to be met. With this in mind, this article

[11] This finding is also partially supported by Dinar (2006).

explores the ability of international institutions to help adapt to some of the potential security consequences of climate change. As localized water stress increases in many regions of the world, particularly those in which water is already scarce, states will have to rely more on sources of freshwater shared with other states, chief among them being transboundary rivers. This will bring states into conflict with one another over the use of the limited resource, which in turn can contribute to international tensions and increase the possibility of military conflict. Under these circumstances, international agreements can help manage the interdependent relationship by setting rules for the sustainable joint use of a river.

The results of this study show that agreements supported by more extensive institutions tend to be better equipped to prevent conflicts from escalating. Highly institutionalized river treaties can help regulate the use of the shared river, stipulate rights and obligations, and provide mechanisms for managing disputes before they escalate. We conclude that international institutions could be useful tools for addressing some of the predicted consequences of climate change, such as water scarcity and changes in the seasonal flow patterns of rivers. Given the uncertainty inherent in climate model forecasts, improving the governance institutions for international river basins is a no-regret strategy. In the event that the effects of climate change are less severe than predicted, either globally or in specific river basins, the establishment of institutionalized river treaties will have very few drawbacks.

Replication data

Replication files for analyses performed in this article can be found at http://www.prio.no/jpr/datasets and http://sobek.colorado.edu/~jati3108.

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Climate change and international water conflict in Central Asia

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Abstract

We engage in a critical assessment of the neo-malthusian claim that climatic changes can be an important source of international tensions, in the extreme even militarized interstate disputes. The most likely scenario is conflict over water allocation in international catchments shared by poorer, less democratic, and politically less stable countries, governed by weak international water management institutions, and exposed to severe climatic changes. The Syr Darya corresponds quite well to all these characteristics. If the neo-malthusian specter of conflict over water is empirically relevant, we should see signs of this in the Syr Darya. The riparian countries of the Aral Sea basin have experienced international disputes over water allocation ever since the USSR collapsed and, with it, existing water management institutions and funding. The worst such dispute concerns the Syr Darya, one of the two largest rivers in Central Asia. Based on hydrological data and other information we find that the only existing international water management institution in the Syr Darya has failed. Based on a coupled climate, land-ice and rainfall-runoff model for the Syr Darya, we then examine whether, in the absence of an effective international water allocation mechanism, climate change is likely to make existing international tensions over water allocation worse. We find that climate change-induced shifts in river runoff, to which the Uzbek part of the Syr Darya catchment is particularly vulnerable, and which could contribute to a deterioration of already strained Kyrgyz–Uzbek relations, are likely to set in only in the medium to long term. This leaves some time for the riparian countries to set up an effective international framework for water allocation and prevention of climate-induced geohazards. By implication, our findings suggest that a climate change-induced militarized interstate dispute over water resources in Central Asia is unlikely.

Keywords

Central Asia, climate change, conflict, international river, Syr Darya, water

Introduction

Existing research shows that one of the most important social and political risks associated with climate change pertains to water availability. It also shows, in this context, that the greatest risk of international disputes and perhaps even militarized interstate conflict is likely to materialize in international water systems located in poor and politically unstable parts of the world (Bernauer & Kalbhenn, 2010; Dinar & Dinar, 2003; Wolf, Yoffe & Giordano, 2003).

In this article we focus on one of the potentially most problematic cases in this respect, the Syr Darya river basin in Central Asia. As noted by Smith: 'Nowhere in

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the world is the potential for conflict over the use of natural resources as strong as in Central Asia' (Smith, 1995).[1] We engage in a critical assessment of this claim, both by studying, ex post, international water allocation problems in the Syr Darya, and by examining, ex ante, whether climatic changes are likely to make existing international tensions worse in future. The underlying logic is that, if the neo-malthusian claim of international water wars is empirically relevant, we should see signs of this in the Syr Darya.

Large-N statistical research on international river basins is very useful for identifying general patterns, for instance whether greater water scarcity is associated with more political or even armed conflict (Brochmann & Hensel, 2009; Dombrowsky, 2007; Gleditsch et al., 2006). Nonetheless, studies of individual international river systems, though weaker in terms of their ability to produce highly generalizable results, offer more detailed insights into dynamic processes that evolve between changing environmental conditions and human efforts to cope with those changes (Bernauer, 2002; Dinar & Dinar, 2003; Wolf, 1998) – hence our focus on a single and, arguably, critical case.

No existing event dataset on international river basin conflict and cooperation (Wolf et al. 2003; Bernauer & Kalbhenn, 2010) records an armed international conflict over water resources in Central Asia. In fact, the standard datasets on war, notably the UCDP/PRIO and Correlates of War datasets, do not record any international armed conflict, more broadly defined, in this region – though there have been several internal armed conflicts (not apparently water-related) in Central Asia over the past two decades.

We should, however, not jump too quickly from such conflict data to the conclusion that the neo-malthusian water wars claim is empirically irrelevant. The absence of international armed conflict among the Syr Darya countries could reflect successful institutionalized solutions to international water allocation problems. It could also reflect geophysical processes that have mitigated water scarcity and thus the potential for international water conflict. Moreover, data on conflict in the past may not tell us much about what the future holds, particularly in cases where climatic changes could have strong negative impacts on water availability. In-depth analysis of the neo-malthusian water conflict claim thus requires both an analysis of water allocation policy and institutions, and an analysis of hydro-climatological processes. This is the research agenda we pursue in this article.

Specifically, we are interested in studying two important propositions that are widely shared by observers of water problems in Central Asia (Swarup, 2009; Hodgson, 2010; Maplecroft, 2010; Perelet, 2007): first, that the water allocation problem in the Syr Darya basin is highly conflict-prone and attempts to solve the problem have thus far failed; second, that climate change will exacerbate the problem.

Our results show that the answer to the first question is: Yes. The answer to the second is, perhaps surprisingly: probably not as much as most observers think, at least in the short to medium term. The latter finding offers some room for optimism that policymakers of the riparian countries can set up an effective international water management system before the most severe climate change-related problems (primarily significant changes in the seasonality of runoff and geohazards) hit the region.

The next section describes the water allocation problem. We then examine the existing international water allocation system in the Syr Darya and assess its effectiveness. The following section looks at the implications of climate change.

Water–energy–food nexus and its history in Central Asia

The two major rivers of Central Asia, the Amu Darya and Syr Darya (Figure 1), were domestic rivers in the USSR until the latter broke down and disappeared in 1991. The two rivers thus turned from domestic into international water systems virtually over night.

The Syr Darya river, on which we focus in this article, originates as the Naryn river in the mountains of Kyrgyzstan. It then flows through Uzbekistan, Tajikistan and Kazakhstan where it drains into the Aral Sea. Its total length is around 2,800 km. Around 20 million people inhabit this river catchment, which covers an area of around 400,000 km^2. More than 75% of total runoff is generated in the upstream mountainous terrain on Kyrgyz territory, as the river is mainly fed by glacier- and snowmelt. The natural runoff pattern, with annual flows of 23.5–51 km^3 (around 40 km^3 in the past decade), is characterized by a spring/summer flood that usually starts in April and peaks in June or July. Around 90% of the Syr Darya's mean annual flow is regulated by reservoirs.

[1] Most studies of this kind use the word 'conflict' without defining it clearly. Most of them appear to refer to a large spectrum of conflictual interactions between states that may range from mutual accusations and diplomatic tensions all the way to what popular quantitative datasets define as militarized interstate disputes. We use words such as 'dispute', 'tension', and 'conflict' when referring to non-militarized conflicts between states, and the term 'militarized interstate dispute' or 'international armed conflict' when armed violence between state actors is involved.

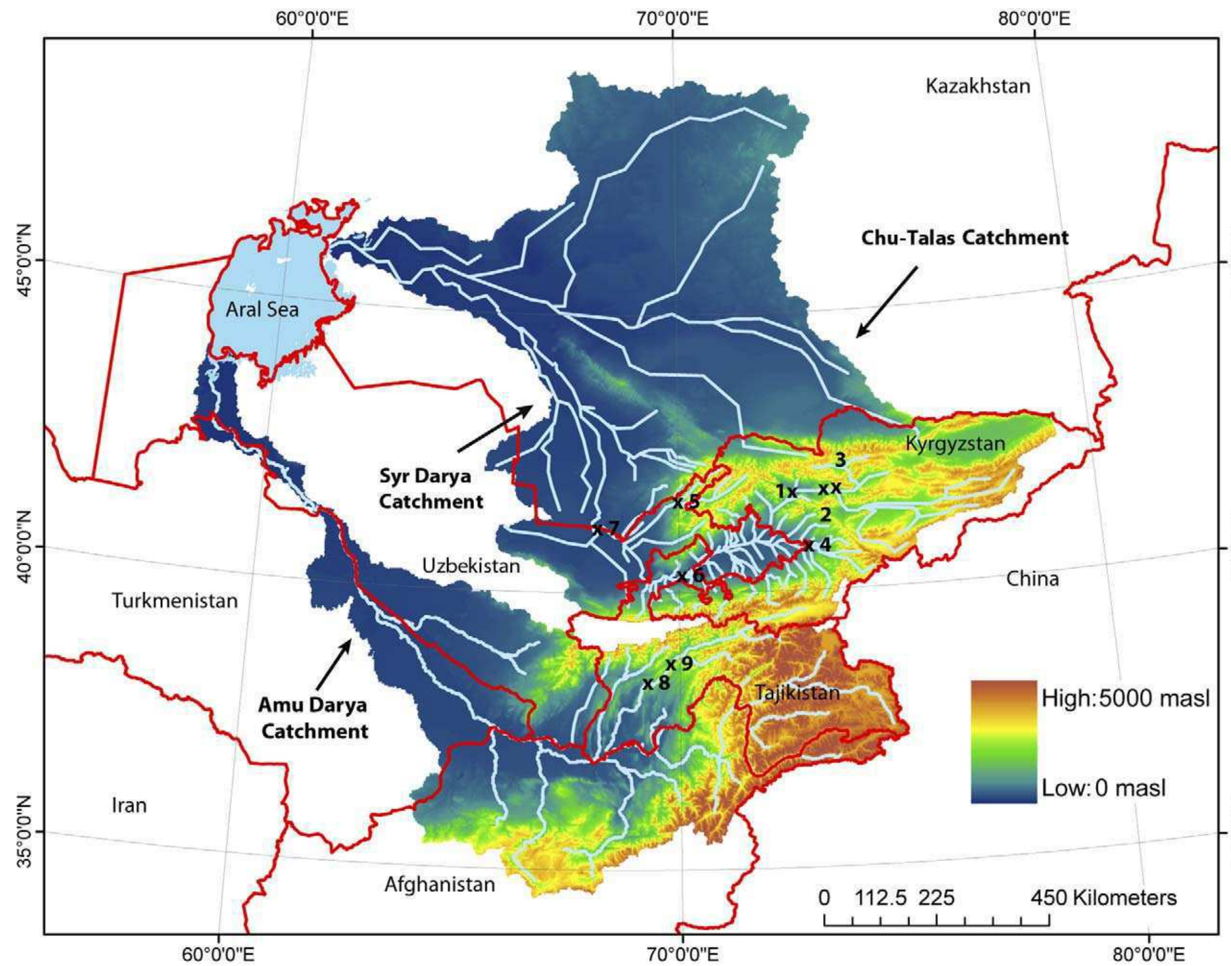

Figure 1. Map of Central Asia with major river catchments. Amu Darya, Syr Darya, and Chu-Talas are shown together with basin topographies

Locations of major dams are indicated with crosses. 1: Toktogul, 2: Kambarata II (construction completed), 3: Kambarata I (planned), 4: Andijan, 5: Charvak, 6: Kayrakum, 7: Chardara, 8: Nurek, 9: Rogun (planned). A color version of this Figure is shown in online Appendix Figure A.1, available at http://www.prio.no/jpr/datasets.

Decisionmakers in the USSR realized that the abundant water resources of Kyrgyzstan, together with a favorable topography, make the country exceptionally rich in water storage and hydropower potential. At the same time, the vast low-lying steppes in the midstream and downstream reaches of the Syr Darya (nowadays Uzbekistan and Kazakhstan) could be turned into centers of irrigated agricultural production (Dukhovny & Sokolov, 2003; Savoskul et al., 2003). Hence the USSR began to develop large-scale irrigated agriculture, particularly cotton and wheat production, in the Stalinist period and under Khrushchev in the mid-1950s. The major irrigated agricultural areas at present are the densely populated and ethno-politically unstable Fergana Valley in Uzbekistan and the Kyzylorda and South Kazakhstan oblasts in the Syr Darya catchment in Kazakhstan. The policy of turning Central Asia into a major irrigation economy ultimately led to the desiccation of the Aral Sea, with highly adverse social, economic and environmental consequences in the region (Micklin, 1988).[2]

[2] Both Uzbekistan and Kazakhstan are experiencing major problems with soil fertility due to negative effects of chronic salinization of heavily irrigated lands in places with insufficient and/or defunct drainage systems (personal communication: Yakovlev, Dronin, 5 January 2011. A list of all stakeholders interviewed for this article is shown in Appendix Table A.I, available at http://www.prio.no/jpr/datasets). The environmental disaster of the Aral Sea is imposing a heavy burden on Kazakhstan, notwithstanding concerted international and regional aid and the recent restoration of water levels in the north-eastern part of the Aral Sea basin after construction of the Kok-Aral dam (Burton, 2006; Micklin, 1988).

By 1960, the irrigated land area in the Syr Darya basin had reached around 2 million hectares (ha) and grew to about 3.3 million ha by 1990. With slightly more than 300 persons/km^2, Kazakhstan has a significantly lower labor intensity per permanently cropped area on its territory in the Syr Darya catchment, as compared to more than 600 persons/km^2 in Uzbekistan. From 1996 onwards, total agricultural output in the Kazakh part of the Syr Darya catchment increased to 2–3 million tons in 2009, whereas total agricultural production has been stagnating on the Uzbek side at around 8–9 million tons.[3]

Kazakhstan, like Uzbekistan, is a major hydrocarbon producer in the region. However, only a small fraction of Kazakhstan's GDP is generated in the agricultural sector, that is, 6% or USD 10.9 billion (2009 prices, PPP), as compared to 22% or USD 17.1 billion in Uzbekistan (CIA, 2011). In the Syr Darya catchment in the vicinity of the Fergana Valley, approximately 50% of the total Uzbek population live on 8.7% of the total national territory (39,000 km^2 out of 447,000 km^2). There, more than 40% of the total land area is irrigated. On the Kazakh side of the Syr Darya catchment, in the oblasts Kyzylorda and South Kazakhstan, 20% of the total Kazakh population live on 12.6% of its national territory (344,600 km^2 of 2,724,900 km^2) of which about 2% is irrigated.[4] Thus, unlike Uzbekistan, where the rural population is expected to increase by 60% from 1991 to 2020, Kazakhstan faces no population pressure in the agricultural sector as its agricultural population is expected to decline by approximately 16% over the next 10 years (FAO, 2011).

These differences between the two main downstream countries in the Syr Darya are crucial with respect to international water allocation: Uzbekistan is much more sensitive to changes in water availability than Kazakhstan. Not surprisingly then, the most severe international allocation disputes in the Syr Darya basin have materialized between Kyrgyzstan and Uzbekistan.

The management history of the Syr Darya is, at least in part, visible in the hydrological data (Siegfried & Bernauer, 2007). Runoff at the Uch Kurgan gauge station, which is located at the foot of the Naryn/Syr Darya cascade shortly after the river enters Uzbekistan from Kyrgyzstan, fluctuates strongly over time. It is characterized by four distinct periods, that is, natural runoff and Periods 1–3 as shown in Figure 2.

Until 1974, the runoff was largely natural, that is, determined by seasonal and climatic variability, with a high interannual variability in summer runoff and a mean flow of around 390 m^3/s. A major change in flow patterns set in with the commissioning of the Toktogul reservoir in 1974. This event marks the beginning of what one could label the first river management period (1974–90). This period was characterized by centralized management by the USSR of the Naryn/Syr Darya cascade and the river basin as a whole. The Toktogul dam is by far the largest water storage facility in the Aral Sea basin, with a total volume of ca. 19.5 km^3. It accounts for more than half of the total usable reservoir capacity in the entire Naryn/Syr Darya Basin. The reservoir area is around 280 km^2, its length around 65 km. The capacity of the Toktogul hydropower plant is 1,200 MW, that is, the second biggest in the Aral Sea basin (Antipova et al., 2002). After the commissioning of the dam, a general attenuation of peak downstream flows can be observed and an overall decline of monthly flow variability set in due to targeted releases (Figure 2).

From 1974 to 1990, the management system for the Syr Darya was primarily oriented towards water provision for irrigated agriculture (above all, cotton and wheat production) in Uzbekistan and Kazakhstan. Consequently, the timing of winter and summer flow releases did not change substantially compared to the natural runoff pattern, where peak flows also occur in the agricultural growing season. This water allocation pattern is visible in the hydrograph, where the in- and outflows to and from the Toktogul reservoir are in phase (Siegfried & Bernauer, 2007).

After a severe drought in the early 1980s, the USSR set up a river basin organization for the Naryn/Syr Darya, with headquarters in Tashkent, Uzbekistan. Its mandate was to operate and maintain all head water structures with a discharge of more than 10 m^3/s. This management system and its infrastructure were funded from the federal budget of the USSR. In consultation with the governments of the riparian Soviet republics and based on forecasts by the Central Asia Gidromet Service, the ministry of water resources (Minvodkhoz) in Moscow defined annually (based on a multi-year master plan) how much water was to be released for irrigation during the growing season (April to September). On top of that, overall annual water use from the Syr Darya was limited to 10 km^3 for Uzbekistan, 10 km^3 for

[3] Statistics for the Uzbek part of the Syr Darya catchment cover the oblasts Syrdarya, Tashkent, Namangan, Andijan, and Fergana. Population and agricultural data for Kazakhstan and Uzbekistan are taken from http://www.cawater-info.net/data_ca/.

[4] See footnote 3.

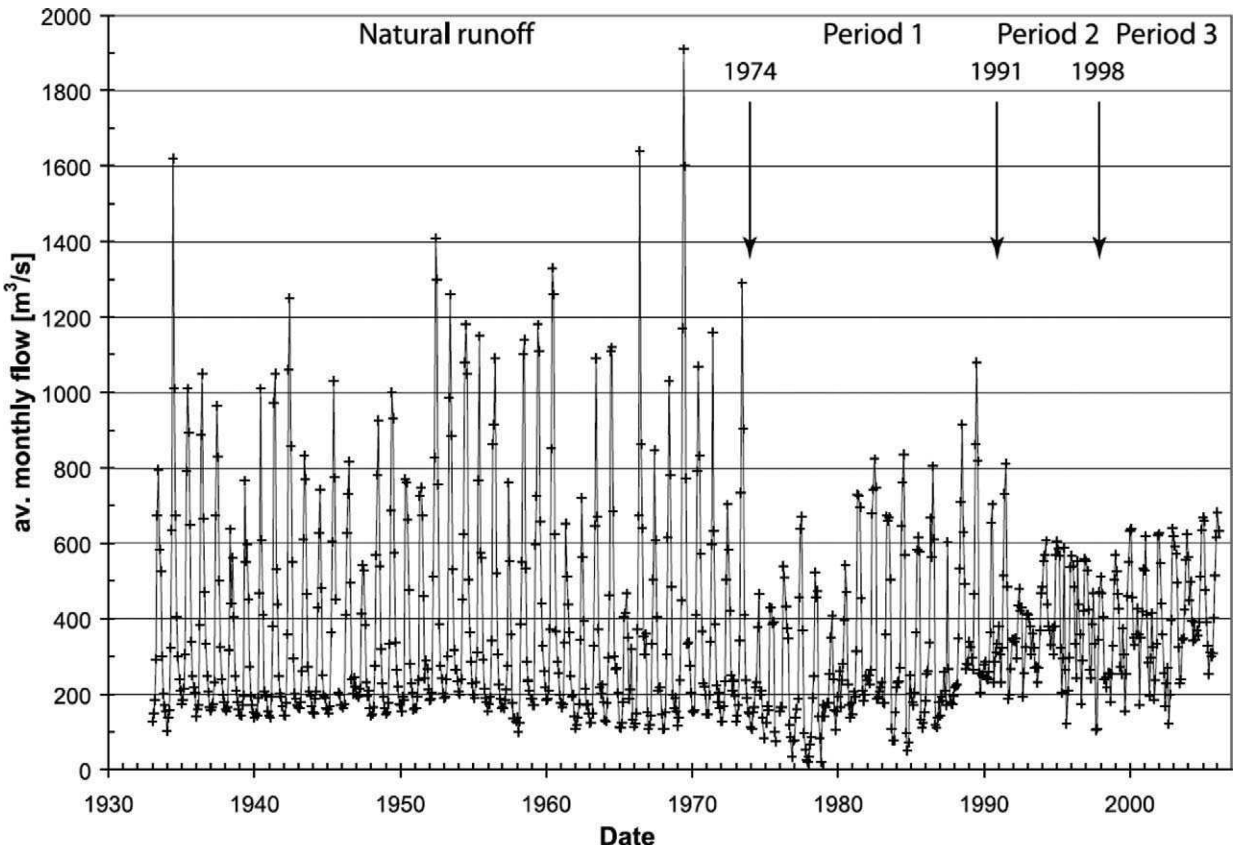

Figure 2. Mean monthly flow of the Naryn/Syr Darya river at the Uch Kurgan gauge
Period 1: USSR period. Period 2: Post-independence period. Period 3: Post-1998 agreement period. Data Sources: Uzbek Hydrometeorological Service (Gidromet) and Portal of Knowledge for Water and Environmental Issues in Central Asia (http://www.cawater-info.net/index_e.htm).

Kazakhstan, 0.4 km^3 for Kyrgyzstan, and 1.8 km^3 for Tajikistan, that is, 22 km^3 in total (Protocol no. 413, issued by the USSR in February 1984). The river basin organization also had the authority to increase or reduce allocations to each Soviet republic by up to 10%, depending on anticipated climatic conditions, reservoir levels, and other factors. The electricity produced at Toktogul during that period went into the Central Asian Energy Pool and was shared among the riparian republics. The neighboring republics supplied coal, oil, and gas to Kyrgyzstan in winter to cover increased Kyrgyz energy demand for heating during the colder months (Antipova et al., 2002; McKinney, 2004; McKinney & Kenshimov, 2000; Weinthal, 2002).

The collapse of the USSR led to a breakdown of this centralized water and energy resources management and sharing system. Coal, oil, gas, and electricity supplies from the downstream countries to Kyrgyzstan declined dramatically from 1991 onwards (Wegerich, 2004). As a consequence, thermal and electric power output of Kyrgyz thermal power plants,[5] which had hitherto operated largely with low-cost or even free fossil fuels imported from Uzbekistan and Kazakhstan, fell dramatically.[6] To compensate for the drastic loss in imported primary and secondary energy, Kyrgyzstan changed the operation of the Toktogul reservoir from an irrigation to an electric power production mode (see Period 2 in Figure 2). The hydropower share in the total energy

[5] The main thermal power plants in Kyrgyzstan are located in Bishkek and Osh. The capacities of the Bishkek plant and the Osh plant are around 660 MW and 50 MW, respectively, though both plants have been running well below that capacity in the past decade (personal communication: Nazarov, Aliev; see also Table A.I).

[6] The electricity output dropped from 4,108 GWh in 1988 to 1,631 and then to 982 GWh in 1998 and 1999, respectively. The thermal power output dropped from 5,145 thousand Gcal to 2,716 and then 2,054 Gcal in those years (Antipova et al., 2002).

supply of Kyrgyzstan grew to around 90%. This change, in turn, has led to severe upstream–downstream conflict.

Upstream interests deriving from seasonal water demands are diametrically opposed to downstream water demands and interests. Kyrgyzstan has, since 1991, sought to store water in spring to autumn and release this water in winter to spring for hydropower production when demand for electricity is highest. Conversely, downstream Uzbekistan and Kazakhstan, by far the largest consumers of irrigation water in the basin, are interested in obtaining sufficient amounts of water during the growing season from April to September. A second priority for them is to obtain minimal winter runoff due to the threat of catastrophic flooding caused by collapsing ice dams in the often frozen river and its tributaries (Savoskul et al., 2003).

The principal challenge in the Syr Darya therefore pertains to coordinating the management of the Naryn/Syr Darya cascade of reservoirs, which are located entirely in Kyrgyzstan, and in particular the handling of trade-offs between consumptive water use for downstream irrigation in summer and non-consumptive use for upstream energy production in Kyrgyzstan in winter.

The Syr Darya water–energy–food nexus is viewed by the riparian countries also in terms of an important national security issue (Gleick, 1993; Hodgson, 2010; Weinthal, 2002). From the Uzbek perspective, people and agriculture in the Fergana Valley are almost entirely dependent on the Syr Darya's water entering the country from Kyrgyzstan; and this water supply is not only controlled by natural variability, but also by a large Soviet-area hydraulic infrastructure whose operation is almost entirely in the hands of the upstream country. This hydro-political setting has been causing great anxiety, particularly among Uzbek policymakers, ever since the country became independent. These concerns have grown further since Kyrgyzstan revived Soviet-era plans to develop two additional reservoir and hydropower production sites, Kambarata I and II, a few kilometers upstream of the Naryn's inflow into the Toktogul reservoir.[7]

Kazakhstan too, being the most downstream country in the Syr Darya, faces several inter-related water challenges. Similarly to mid-stream Uzbekistan, it is primarily concerned with ensuring access to sufficient amounts of river water for irrigation in the summer, and with controlled low-flow in the winter months for effective flood control. Moreover, Kazakhstan is very concerned with river water quality since a large fraction of its population in the catchment uses the river water for household purposes. As the river accumulates total dissolved solids and pesticides and herbicides from irrigation drainage return flows (mainly from the cotton fields in Uzbekistan), and as its waters have become ever more allocated along the flow path, maintaining river water quality targets has become increasingly difficult for Kazakhstan in recent years (Shalpykova, 2002).

The Syr Darya setting is in fact quite unique in comparison to other prominent international water catchments that appear conflict prone. In the Nile, for instance, there is a rather strong downstream hegemony. The downstream country (Egypt) is the militarily and economically most powerful country in the system, and it also controls the main water storage capacity (Aswan dam) (Howell & Allan, 1994; Zeitoun & Warner, 2006). In the Euphrates-Tigris, the upstream country (Turkey) is also the most powerful country in the system and in control of the main reservoirs (Daoudy, 2009; Kibaroğlu, 2002). The Syr Darya setting is arguably less hegemonic and thus potentially more unstable politically; the dominant economic and military powers (Uzbekistan and Kazakhstan), which also face the most severe water security risks, are located downstream, whereas the upstream country is in almost total physical control of the catchment's runoff.[8]

At the most general level, many game theoretic and also empirical studies have shown that upstream–downstream conflicts such as the one in the Syr Darya are difficult to solve (Ambec & Ehlers, 2008; Ambec & Sprumont, 2002; Bernauer, 2002; Bernauer & Kalbhenn, 2010). The Syr Darya situation is particularly complex for the reasons outlined above. Such upstream–downstream conflicts can, in principle, be solved by installing adequate compensation mechanisms (Abbink, Moller & O'Hara, 2005; Bernauer, 1995; Dinar, 2006; Kilgour & Dinar, 1995; Moller, 2004). However, the transactions costs of reaching such deals can be very high. They usually increase

[7] Personal communication: Dukhovny, Maag; see also Figure 1 for the location of the new dams.

[8] The Composite Index of National Capability (CINC), a popular index in political science for measuring the material capabilities of countries for projecting power, has Kazakhstan as the most powerful country in the Syr Darya basin using 1991–2007 averages. If we set the value of this variable for Kazakhstan to 100%, the capabilities of Uzbekistan are 73%, and those of Kyrgyzstan and Tajikistan 11% each (Sarkees & Wayman, 2010). Moreover, Kyrgyzstan's water storage capacity (approximately 24.81 km^3 in total) is almost equivalent to the Syr Darya's total long-term average annual runoff measured at the inflow to the Aral Sea, not accounting for consumptive upstream allocation (approximately 30 km^3 per annum).

Table I. Water release schedule in the 1998 Agreement

Month	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
q [m^3/s]	495	490	300	230	270	500	650	600	190	185	395	460
q [km^3/month]	1.33	1.23	0.8	0.6	0.72	1.3	1.74	1.61	0.49	0.5	1.02	1.23

Sources: http://ocid.nacse.org/tfdd/treaties.php?BCODE=ARAL&GET=tfdd and information obtained from water management authorities in Uzbekistan and Kyrgyzstan (Zyrianov, Yakovlev, Chub, and Dukhovny).
Total water releases during the vegetation season amount to 6.32 km^3 (April–September) as compared to 6.03 km^3 during the non-vegetation season (October–December and January–March).

when general political relations between the riparian countries are poor. The main reasons are that poor relations are associated with low levels of trust, and low levels of trust normally lead to more acrimonious distributional bargaining and exacerbate time-inconsistency problems in implementing agreements. All these problems are clearly visible in the Syr Darya case.

Multilateral arrangements versus unilateral action

International negotiations on managing the Syr Darya began shortly after the demise of the USSR. In February 1992, the newly independent riparian countries of the Syr Darya basin set up the Inter-State Commission for Water Coordination (ICWC). They agreed to keep the water allocation principles of the former USSR in place until a new system could be established, albeit without the funding for the infrastructure that had formerly come from Moscow. The most important hydraulic structures, and in particular the biggest reservoirs in the basin (including Toktogul), were not put under the control of the ICWC. That is, they were de facto nationalized by the riparian countries.

From 1995 the riparian countries negotiated, annually, bilateral agreements on water releases and energy exchanges. In March 1998, under the aegis of the Executive Committee of the Central Asian Economic Community, Kazakhstan, Kyrgyzstan, and Uzbekistan signed a trilateral agreement. This agreement marks the beginning of Period 3, as defined in Figure 2. In 1999 Tajikistan joined this agreement. The 1998 agreement follows the approach of earlier bilateral agreements. It includes quantitative targets for monthly water releases from the Toktogul reservoir (Table I).

Moreover, the agreement holds that in the growing season (April–October), Kyrgyzstan will supply 2,200 million kWh of hydropower electricity to Kazakhstan and Uzbekistan (1,100 million kWh each). Kazakhstan and Uzbekistan, in exchange, agree to deliver specific amounts of electricity, gas, fuel oil, and coal to Kyrgyzstan in certain months under conditions set forth in earlier bilateral agreements. A framework agreement, also concluded in March 1998, holds that these exchanges will subsequently be specified each year through negotiations.

The reasoning behind this exchange is the following. Kyrgyzstan needs to release around 3.5 km^3 from Toktogul to meet its energy requirements in April to September, and around 8.5 km^3 in October to March. The downstream countries, in turn, need around 6 km^3 in April to September, but no water in winter. Natural constraints limit possible water releases from Toktogul to a total of around 12 km^3 per year. To meet downstream needs, a shift, compared to what Kyrgyzstan would prefer, of around 2.5 km^3 from the October to March period to the April to September period is required. Total releases of around 2.5 km^3 can generate electricity in the order of 2,200 million kWh. This implies that Kyrgyzstan can export around 2,200 million kWh in excess electricity in the form of cheap hydropower to the downstream countries in the growing season and get compensated for this amount in the winter season.[9]

The implementation of the 1998 agreement can be evaluated based on hydrological data, energy trade data, and expert interviews. Our analysis of this information strongly suggests that the 1998 agreement has, thus far, failed to solve the problem of effective water and energy resources sharing.

Table A.II in the online Appendix presents seasonal outflows of the Toktogul reservoir as well as deviations from the 1998 agreement. The summer releases have closely followed the levels agreed prior to 2008. In this year though, there was a strong negative precipitation anomaly, most probably related to the strong warm phase of the El Niño-Southern Oscillation (ENSO) at that time (Cane, 2010).[10] After that, compliance has remained very low as seasonal releases became more and more skewed towards the winter in favor of hydroelectric

[9] Personal communication: Zyrianov, Yakovlev, Chub, Dukhovny.
[10] ENSO is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales.

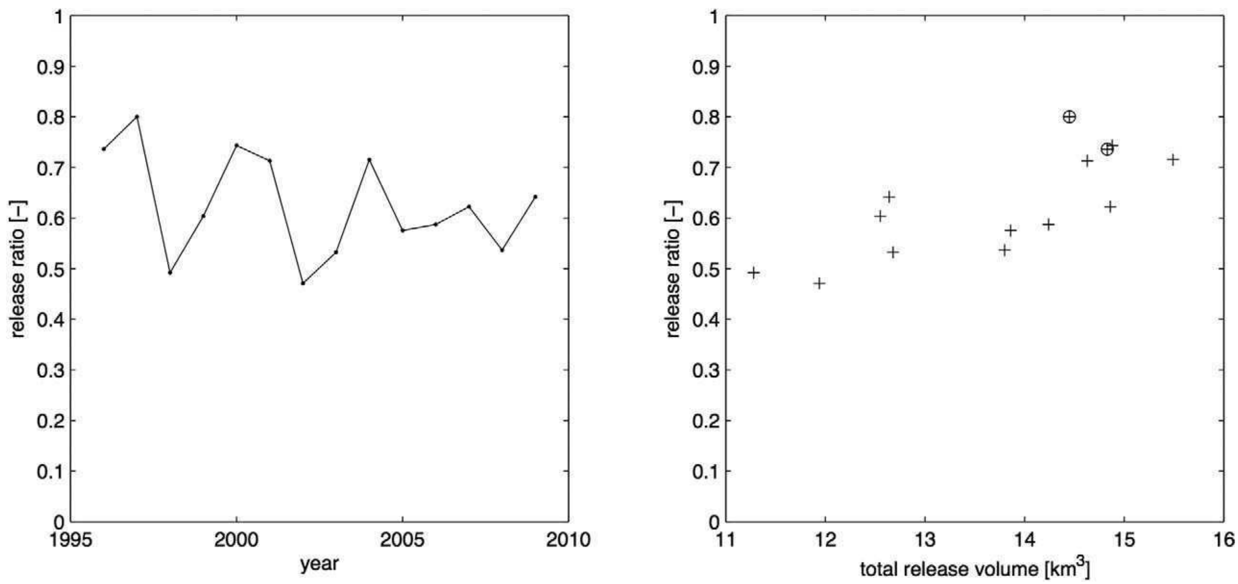

Figure 3. Left panel: release ratios of summer releases versus prior season winter releases in 1996–2009. Right panel: scatterplot of total annual release volumes versus release ratios as shown in the left panel (circles indicate 1996 and 1997 data)

production for Kyrgyzstan.[11] As shown in Figure 3, the high interannual variability of releases points to the fact that the multi-year storage at Toktogul is ineffectively managed. In addition, Figure 3 shows that there is a strong positive correlation between summer releases as a fraction of previous season non-vegetation period releases and total release volume. Hence, when unfavorable hydrological conditions force a reduction in annual release volumes, the downstream suffers disproportionally. This effect is certainly among the reasons why downstream stakeholders have in recent years become increasingly worried about the overall system's management.[12]

Data on electricity exports from Kyrgyzstan to Uzbekistan point in the same direction. Table II shows that these exports dropped to 523 million kWh in 2002 and to zero in 2004–06. After a short recovery in 2007 they again dropped to zero and have not picked up again since.[13]

[11] Elsewhere, we have developed a methodology for assessing the performance of international institutions and have applied this methodology to the Syr Darya (Siegfried & Bernauer, 2007). The results of this assessment show that the 1998 agreement has been ineffective in dealing with the water allocation conflict.

[12] Based on interviews with the persons listed in online Appendix Table A.I.

[13] Whether these data are accurate is, like in the case of any energy trade data from Central Asian countries, not entirely clear. For instance, there are rumors that considerable amounts of energy trade occur outside the official accounts. In fact, one recent initiative of the new Kyrgyz government seeks to establish more transparency and accountability in the energy sector (http://www.eurasianet.org/node/61653).

Fossil fuel trade data between the riparian states is harder to track than electricity trade. Table A.III in the Appendix shows Kyrgyz energy imports and exports from/to Uzbekistan and Kazakhstan from 1991 to 1999. This information suggests that compliance with bilateral targets before the 1998 agreement and during the starting phase of this agreement has been incomplete at best. No systematic information exists for the period after 1999. Our interviews with decisionmakers in Bishkek and Tashkent in June 2009 strongly suggest, however, that in most years since 1999, negotiations did not take place, failed to produce specific targets, or set targets that were not met.

These hydrocarbon trade data are important because the 1998 agreement has been conceptualized primarily as an energy-for-energy, rather than a water-for-energy exchange. The reason is that, despite repeated requests by Kyrgyzstan that Uzbekistan pay for upstream water releases, Uzbekistan insists that it is, according to international conventions dealing with transboundary freshwater catchments,[14] entitled to receive a fair share of the Syr Darya's waters. Hence it refuses to pay for water per se.

Kazakhstan has followed a more conciliatory policy with respect to water–energy exchanges with Kyrgyzstan. The principal reason, as noted further above, is that Kazakhstan's economy and population are less sensitive to Kyrgyzstan's dam operations than Uzbekistan's.

[14] See, for example, the 1966 Helsinki Rules: http://www.internationalwaterlaw.org/documents/intldocs/helsinki_rules.html.

Table II. Electricity exports from Kyrgyzstan to Uzbekistan

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Exports(million kWh)	1,926	1,038	523	258	0	0	0	2,380	543	864

Sources: Ministry of Industry, Energy and Fuel Resources, Bishkek and interviews with authorities in Kyrgyzstan and Uzbekistan (see Table A.I) and presentation by A. Kalmambetov, Deputy Minister, Kyrgyzstan (available at: http://www.carecinstitute.org/uploads/events/2010/ESCC-Sep/Day1-KGZ-Energy-Sector.pdf). These data may also include some electricity exports outside the 1998 agreement, so higher amounts do not necessarily mean that the exchange is more effective. Conversely, however, no exports means that no electricity exports have taken place under the 1998 agreement and that, therefore, this agreement is non-operational.

Kazakhstan has usually paid Kyrgyzstan in cash and with hydrocarbon equivalents for summer irrigation water. However, on occasion, Uzbek and Kazakh decision-makers have clashed over Kazakh accusations that Uzbekistan does not route agreed-upon water volumes through its territory but uses some of the Kazakh quota for covering its own irrigation water demand.[15]

The 1998 agreement is, furthermore, suffering from a major design flaw that pertains to energy exchange prices. The energy-for-energy exchange was originally defined in terms of a kWh-for-kWh exchange. In the year 2000, a pricing mechanism was added. While Kyrgyzstan received around 2–3 cents per kWh from the downstream countries for its electricity deliveries, compensation deliveries by the downstream countries were priced in the order of USD 20–22 per ton of coal and USD 45–65 per 1,000 m^3 of gas. This exchange unraveled when energy prices of electricity and fossil fuels diverged. Whereas hydropower prices have remained at 2–3 cents per kWh, the downstream countries have, with increasing world market prices for fossil fuels, raised coal prices to around USD 40/ton and gas prices to more than USD 200/m^3.[16]

The implications are quite obvious: diverging prices have made it impossible for Kyrgyzstan to turn the additional water release of 2.5 km^3 in the months from April–September into income from hydropower exports that could buy the equivalent (in terms of energy value) amount of energy from the downstream countries in the winter period. As shown in Table II, this has virtually stopped Kyrgyz electricity exports to the downstream countries.

In summary, the institutional arrangements for water allocation in the Syr Darya have, thus far, failed to solve the problem. The reasons are multifaceted and at least in part due to the flawed design of the 1998 agreement, which clearly lacks robustness against hydrological variability and commodity price volatility. As climatic changes in Central Asia become more pronounced and, as a consequence, also greater hydrological uncertainty, it is widely feared that the current, dysfunctional approach to water- and energy-sharing will unravel completely and international disputes over water will escalate (Swarup, 2009; Hodgson, 2010; Maplecroft, 2010; Perelet, 2007). In the next section we thus examine how climate change could affect water availability in the Syr Darya.

Climate change impacts

We assess the implications of climate change for the Syr Darya catchment until 2050 using an integrated systems model approach that couples climate and land surface hydrology including snow- and ice-storage (details of the coupled climate, land ice, and hydrological model can be found in Pereira Cardenal et al., 2011; Siegfried et al., 2011). A baseline scenario (BL) with the current climate trend assumed to continue into the future is contrasted with the IPCC SRES A2 scenario that assumes a 2.9°C warming until the mid-21st century in the region.[17] Uncertainty is accounted for in an ensemble Monte Carlo approach.

Three important modeling results emerge. First, the most important impacts of climate change in the Syr Darya basin result from significant changes in the seasonality of runoff. Weekly runoff contributions from unregulated catchments that dewater directly into the Fergana valley are shown in the upper left plate of Figure 4. Historic contributions from 2000–09 are compared with the runoff regime for 2040–49 under the A2 scenario. The other plates in Figure 4 show weekly runoff contributions into the major surface reservoirs in the Syr Darya catchment under the assumption of unregulated flow and zero consumptive upstream use, that is, no human interference with the natural runoff regime.[18] In all instances, the runoff peak under the A2 scenario is shifted in time from the current spring/

[15] Based on interviews, cf. Table A.I.

[16] Based on interviews, cf. Table A.I.

[17] The temperature trend is a model ensemble average over 18 GCM models under the IPCC SRES A2 run (see Siegfried et al., 2011 for a detailed list of the utilized GCMs).

[18] See Figure 1 for the locations of the surface reservoirs.

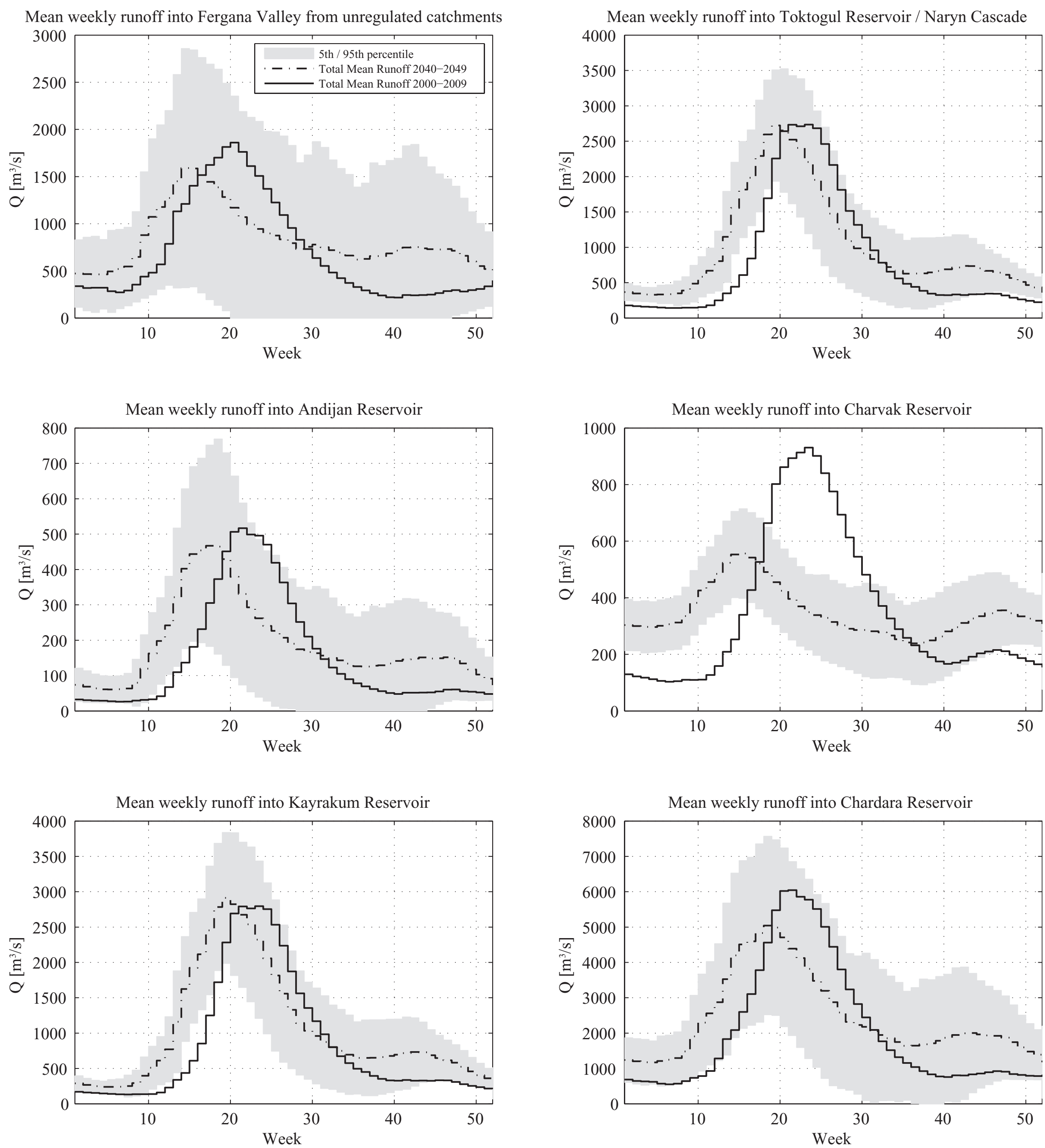

Figure 4. Seasonality of runoff (mean weekly runoff in m3/s) for selected locations in the Syr Darya catchment
Figures for the first decade of the 21st century and for 2040-49 are shown for the A2 scenario (see also Siegfried et al., 2011). The upper left plate shows total unregulated flows into the Fergana Valley, i.e. runoff from catchments that have no or only insignificant man-made surface water storage. The other plates show mean weekly runoffs into the major reservoirs in the basin (see Figure 1 for the location of these dams). Mean runoff for 2000–09 is the solid black line, expected mean runoff in 2040–49 is the dotted black line, with corresponding uncertainty bands (2 standard deviations).

early summer regime towards a late winter/early spring runoff regime. This change has important repercussions for reservoir management since a pronounced deficit of summer runoff as compared to the present regime starts to emerge. It translates into less direct water availability during the vegetation period when more than 90% of total average annual consumptive water use for irrigation purposes occurs (see also Figures A.2 and A.3 and the discussion in the following section).

Second, depending on the emissions scenario, glacier melt will continue to contribute to runoff during the first half of the 21st century. Even under the rather extreme emissions scenario IPCC SRES A2, only approximately one-third of present total land ice volume (approximately 200 km^3) will melt over this period. With an average expected mean annual runoff of 50 m^3/s under the A2 scenario, annual runoff contributions from 2010 to 2050 will stay roughly constant over the assessment period and are approximately double the contribution under the BL scenario. Expressed as a fraction of total natural basin runoff, this corresponds to around 2.7% or approximately one-third of present average inflow into the Aral Sea for the A2 runs, after all upstream consumptive use has been accounted for. Basin-wide glacier melt contributions to river flow are thus small compared to the natural runoff regime.

The third observation is that glacier lengths will experience a significant decline across all size categories as land ice continues to melt. As these glaciers retreat they leave behind unstable terminal moraines behind which significant volumes of meltwater can get trapped. If these moraines collapse, glacier lake outbursts can occur that can potentially cause catastrophic flooding in the downstream (see also Nayar, 2009 for a related discussion on the Himalayas). The Fergana Valley region will be particularly exposed to these geohazards because glaciers surround the valley floor in the south, the east, and the north.

In summary, climate change will impact the Central Asia region mainly through temperature effects on the snow and ice cover in the Tien Shan mountains. Whereas the frequently voiced concern about aridization of Central Asia over the near term (Malone, 2010; Swarup, 2009) is not supported by our model results, the distribution of water within the year could change quite dramatically. This development will have important implications for the management of surface water storage in the region, and also for the design of international water sharing mechanisms.

Conclusions

In this article we have engaged in a critical assessment of the neo-malthusian claim that climatic changes can be an important source of international tensions, in the extreme even militarized interstate disputes. The most likely scenarios are international disputes over transboundary waters. Existing event datasets on international river basin conflict and cooperation indicate that international disputes over water issues are quite common. But none of these disputes has thus far escalated into a militarized interstate dispute in a form that would, according to common definitions, qualify as a war. Nonetheless, many observers expect that the outbreak of future militarized interstate disputes remains a strong possibility.

The strongest 'candidates' in this respect are international catchments shared by poorer, less democratic, and politically less stable countries, governed by weak international water management institutions and exposed to severe climatic changes. Since the Syr Darya corresponds quite well to these characteristics, it is a critical test case. If the neo-malthusian specter of militarized interstate disputes over water is empirically relevant, we should see signs of it in the Syr Darya. Hence we have studied, ex post, international water allocation problems and institutions in the Syr Darya and, ex ante, whether climatic changes are likely to make existing international tensions worse in future.

Based on hydrological data and other information, we have found that the currently existing international water management institution in the Syr Darya has failed. Using a coupled climate, land-ice, and rainfall-runoff model for the Syr Darya, we have then examined whether, in the absence of an effective water allocation mechanism in this international catchment, climate change is likely to make existing international tensions worse. The biggest concern in this respect is Kyrgyz–Uzbek relations, which could deteriorate further because the Uzbek population and agriculture in the Syr Darya catchment are particularly vulnerable to climate change-induced shifts in runoff. We conclude, however, that such shifts are likely to occur only in the medium to long term. This leaves some time for the riparian countries to set up an effective international framework for water allocation and prevention of climate change-induced geohazards. By implication, our findings suggest that a climate change-induced militarized interstate dispute over water resources in Central Asia is unlikely.

Acknowledgments

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Climate change and security in the Israeli–Palestinian context

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Abstract

The Middle East is among the least stable and most fragile regions. It is not surprising, therefore, that concerns have been raised regarding the potential implications of climate change. This article critically examines the potential interactions between climate change and conflict in the Israeli–Palestinian case. Based on a review of the possible effects of climate change, water is identified as the main issue which may be affected, and it also has transboundary implications. We illustrate the potential implications of reduced freshwater availability by assessing the ability to supply normative domestic water needs under rapid population growth scenarios, including return of refugees. In addition, the ability to supply environmental needs and the needs of peripheral farmers under extremely reduced availability scenarios is examined. The normative domestic demand in Israel and the West Bank can be supplied on the basis of natural resources, though re-allocation of water from Israel to the Palestinians is necessary. The Gaza Strip cannot supply the normative domestic needs under any scenario and hence requires immediate augmentation, regardless of climate change. Desalination can supply Gaza's needs and augment water resources in Israel and the West Bank, thereby partially decoupling domestic and agricultural use from climate. Thus, it is unlikely that climate change will directly affect the conflict. However, framing water as a security issue, along with the potential for furthering such securitization with reference to climate change, may adversely affect the readiness of the parties to take adaptive measures and lead them to rigidify their negotiating positions. Possible effects of climate change on other regional players, particularly Egypt and Jordan, may have indirect effects on the Israeli–Palestinian scene. But this hypothesis requires further study.

Keywords

climate change, Israel, Middle East, Palestine, water

Introduction

As fears of the destabilizing effects mount, climate change is increasingly being referred to as a security issue. In 2009 the UN General Assembly adopted a non-binding resolution on climate change as an international security problem (A/Res/63/281 11 June). However, how climate change affects security has not been made clear. Barnett & Adger (2007) suggest that such effects may be an outcome of reduced access to natural resources that sustain livelihoods or of undermining states' capacity to provide opportunities and services.

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But they also note that the extent to which these factors may actually lead to violence requires empirical research.

The Middle East is among the least stable and most fragile regions. The Israeli–Arab conflict has assumed international dimensions and receives widespread attention, well beyond the realm of the parties which are at the core of the conflict – Israelis and Palestinians. It is not surprising, therefore, that concerns have been raised about the potential deleterious effects of climate change in the Middle East (Brown & Crawford, 2009; Trondalen, 2009).

The purpose of this article is to critically examine the extent to which climate change may aggravate the Israeli–Palestinian conflict. To this end we take a four-stage approach. First we review the possible effects of climate change on the Israeli–Palestian area. Then we search for those issues that are acute enough to lead a party to take action that it would not take otherwise and which may also impact the other party – notably water. To assess the extent to which climate change may reduce access to water, we conduct a scenario analysis. We examine whether water resources can supply the needs of the population under extreme climate change and population growth scenarios. These include a partial return of Palestinian refugees to the area west of the Jordan. We assess the extent to which the populations' welfare or livelihoods are vulnerable to disruptions due to the effects of climate change on water availability.

In the fourth stage, we discuss three possible second-order aspects that go beyond the scope of Barnett & Adger's study (2007) – how greater climate uncertainty may affect the negotiating positions of the parties, the possible constraints of security considerations on the ability to implement adaptive policies, and the possible implications of regional climate-change effects.

Implications of climate change

Figure 1 depicts the approach used to identify the effects of climate change on the Israeli–Palestinian region. The regional effects of climate change were first outlined on the basis of IPCC (2007). A wide-ranging literature survey was conducted to identify the main local effects, and an attempt was made to assess the degree of consensus regarding the direction and magnitude of these effects. Table I shows that there is little agreement.

The key variables identified in Figure 1 for assessing the local implications of global climate change are sea-level rise and regional climate changes, mainly in precipitation patterns. While a warming trend has been observed in the last few decades (Saaroni, Ziv & Alpert, 2003; Zhang et al., 2005), the trends in precipitation are ambiguous due to the difficulties inherent in downscaling global circulation models (Alpert et al., 2008; Golan-Engelko & Bar Or, 2008). But the regional climatic models have largely underestimated precipitation in Israel and Jordan (Black, 2009). The scenario analyses that have been prepared for the Israeli–Palestinian region using such models have suggested that precipitation levels may decrease and that extreme events may rise (Alpert et al., 2008; Black, 2009; Sowers, Vengosh & Weinthal, 2011). These effects vary, however, by scenario. Thus, while the IPCC A2 scenario leads to significant reduction in average precipitation, the effects of the B2 scenario on average rainfall is unclear (Alpert et al., 2008).[1]

However, the most important variable in this region from a water-management perspective is groundwater recharge. Groundwater constitutes the main interannual storage, which is crucial for addressing the multi-year droughts to which semi-arid and arid regions are prone (Amiran, 1995). Groundwater recharge and surface flows are influenced by the intensity, duration, frequency, and timing of precipitation events (USEPA, 1990). These can vary significantly and are non-linear with respect to average levels of precipitation. Moreover, recharge rates and stormwater runoff are affected by soil types and local variations (Yair, 1994; Yair & Kossovsky, 2002). As a result, climate change impacts on groundwater are not well understood worldwide (Kundzewicz et al., 2007). In a review of climate change effects on Israel, Golan-Engelko & Bar Or (2008) conclude that the currently available climate-related models are not detailed enough to allow for assessments of the impacts of climate change on rate of groundwater recharge.

The only effect which is fairly certain is that sea-level rise will lead to further intrusion of seawater into the already over-utilized coastal aquifer thereby causing a potential movement of the base of the aquifer basin (Golan-Engelko & Bar Or, 2008; Sowers, Vengosh & Weinthal, 2011). Melloul & Collins (2006) estimate that the storage capacity of this aquifer will diminish by 16.3 million cubic meters (MCM) per 1 km of coast for a 50 cm rise in sea level. While surface runoff may increase and enhance the flows into the sea of Galillee, higher temperatures may increase evaporation from the lake and reduce spring flows. This will lead to algae blooms that will adversely affect the water quality in

[1] Both scenarios suggest a greater frequency of droughts but differ in the extent to which these will be offset by rainy years.

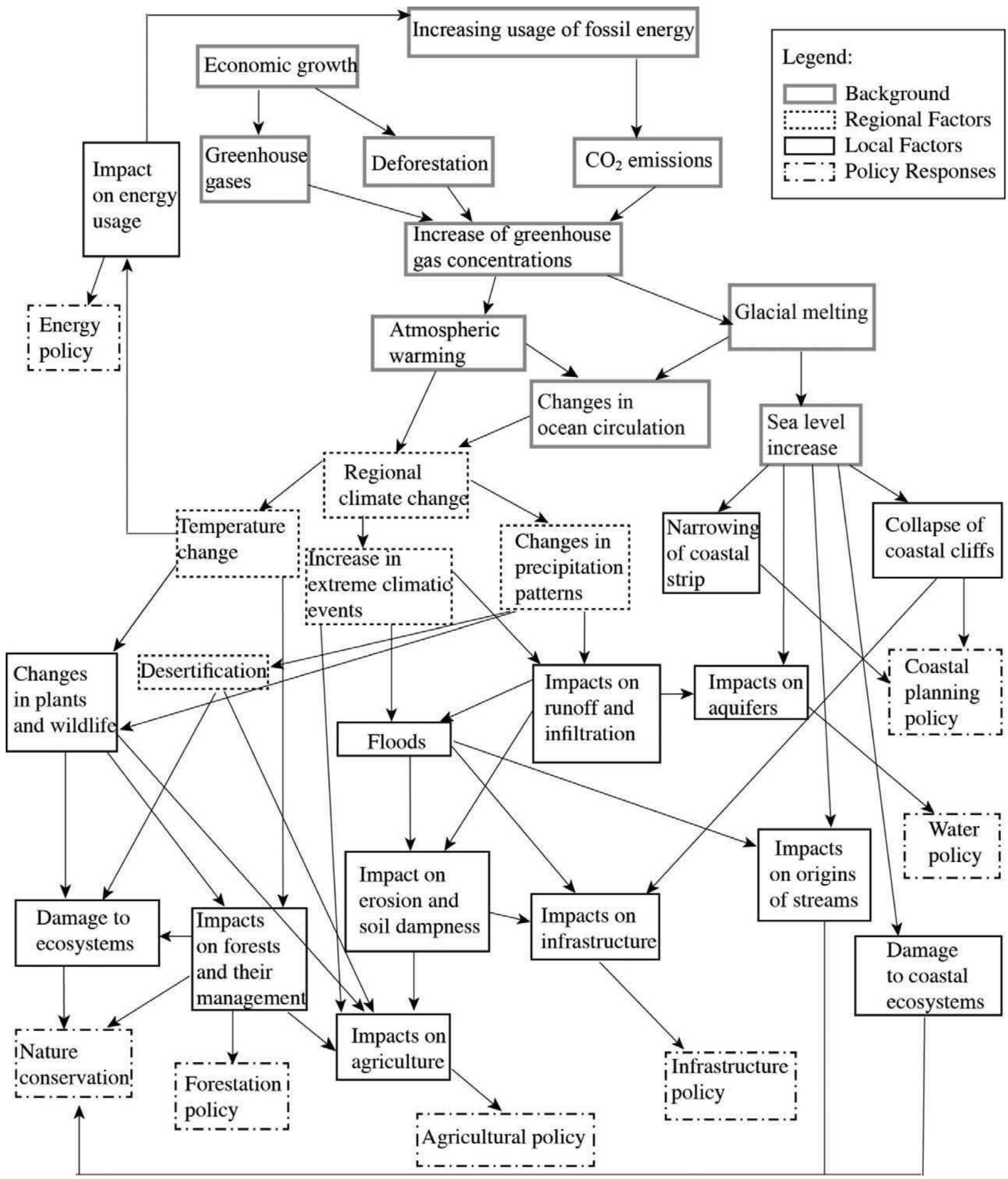

Figure 1. The methodology for identifying the climate change impacts in Israel
Source: Feitelson (2007). For a color version of this figure, see the replication file at www.prio.no/jpr/datasets.

the lake and decrease its potential for storage (Sowers, Vengosh & Weinthal, 2011). However, these are highly uncertain. Thus, with the exception of the loss of storage capacity in the coastal aquifer, the magnitude of effects on the major water resources is uncertain at present.

A rise in the Mediterranean sea-level will lead to loss of beach areas and accelerate cliff erosion. The extent of these effects will be a function of the extent of sea-level rise (Klein, Lichter & Tzviely, 2004). Other potential climate-related effects, on public health, agriculture, and bio-diversity, have received only scant attention so far. However, the studies that were conducted in these fields found no agreed-upon effects (Golan-Engelko & Bar Or, 2008). The public health effects are very small, if any, while the effects on agriculture are largely limited to the effects of the uncertain changes in precipitation patterns on rain-fed agriculture. Irrigated agriculture is likely to be less affected, at least within Israel, as agriculture is increasingly shifting to recycled wastewater, which is insensitive to climate change (Feitelson & Rosenthal, 2011). The impacts on the Palestinians, however, may be more substantial due to the greater reliance on rain-fed agriculture in the West Bank (Mason, Mimi & Zeitoun, 2010).

Clearly, changes in precipitation patterns and temperatures may affect ecosystems. The Israeli–Palestine area is a biodiversity hotspot due to the exceptional diversity of its landscape and climate over short distances. Hence, there is a wide discrepancy in scale between climate models and ecosystem dynamics in Israel, thereby making any analysis of the impacts of climate change on ecosystems highly uncertain. Historical studies of the effects of past climate change suggest that ecosystems adapt by moving northward or southward. However, given the unprecedented extent of human habitation at present, it is unclear to what extent such adaptation options are still viable. Thus, local losses of ecosystems can be expected, as well as invasion by species migrating northward (Hatzophe & Yom Tov, 2002).

In the last part of the preliminary analysis we identify the policy implications for Israel. To this end the possible adaptive policies were enumerated, and the extent to which they deviate from policies that are taken in any case assessed. This analysis, summarized in Table II, shows that with the exception of policies geared to address sea-level rise, these policies do not deviate substantially from those undertaken in any case.

The main response to reduced water availability is a combination of wider conservation and desalination. Israel has already embarked on a wide-ranging desalination program (Feitelson & Rosenthal, 2011). Water rates in the urban sector (with more than 50% of freshwater use) have been raised substantially, to encourage urban water conservation, and saving devices have been distributed to households free of charge.

To mitigate the greater danger of flooding, floodplains have to be protected. Such protection has largely been regulated in district plans that designate most of the vulnerable area for recreation (Feitelson, 1999). Similarly, buffers around nature reserves and corridors that may allow ecosystems to migrate, have increasingly been incorporated in Israeli national and regional master plans, regardless of climate change (Feitelson, 1999). The only issues that arise from the climate-change scenarios and have not been addressed are those that pertain to sea-level rise and infrastructure. These will require shoreline protection measures in built-up areas, and possibly a change in infrastructure standards. Feitelson (2007) concludes that climate change is not a top priority policy issue for Israel. Nor are these issues likely to have a major effect on people's welfare or livelihood or serve as a source of internal discontent.

The implication of this analysis is that Israel has the capacity to address the potential implications of climate change internally and, hence, is unlikely to take action on the regional level solely or mainly on the basis of climate change or due to it. The same cannot be said with any certainty for the Palestinians, as the effects on livelihoods may be greater (Mizyed, 2009). Due to the greater reliance on rain-fed agriculture in the West Bank, the lesser amounts of water available to Palestinians overall, the dire water situation in Gaza and particularly Gaza's dependence on a highly over-utilized coastal aquifer, the Palestinians are much more vulnerable to climate change (Mason, Mimi & Zeitoun, 2010). Among the Palestinians the most vulnerable are likely to be the marginal semi-nomadic farmers in the Jordan Valley. In order to identify whether any of these effects may have potential ramifications for Israeli–Palestinian relations, the effects noted in Table I were scrutinized to discover whether they may have transboundary implications.[2] These are summarized in the right-hand column in Table I.

The only transboundary issue that seems to have potentially significant transboundary effects is water. This is also the issue which may increase Palestinians' vulnerability (e.g. Mason, Mimi & Zeitoun, 2010), and this issue received most of the attention in the environmental field in previous agreements (Feitelson & Levy, 2006). Hence, the potential effects of a reduction of renewable water in the Israeli–Palestinian context are analyzed further here.

Effects of reduced water availability

In semi-arid regions, the most important water management issue is the extent to which water can be stored from the rainy season to the dry season. Hence, the main concerns are the storage capacity of the aquifers and lakes, and the extent that replenishment rates might be affected. As noted, it is uncertain what the effects of

[2] This assessment was based on the extent to which there are natural transboundary flows between the two parties and the extent to which actions by one party may affect the other.

Table I. Possible local effects of climate change in Israel/Palestine

Issue	*Main effect*	*Unanimity*	*Transboundary*
Water resources	Increasing variability of precipitation may affect groundwater replenishment and surface runoff, loss of storage in coastal aquifer	no	Yes – shared resources (Mountain aquifers and Jordan River)
Mediterranean coast	Loss of few sq km of beach area, accelerated cliff erosion	high	Limited – sand flows along Mediterranean coast
Public health	Heat effects	no	No – mainly local
Agriculture	Less water for rain-fed crops	no	No – local
Biodiversity	Northward migration of ecological systems, loss of sensitive ecosystems	no	Limited – mainly limits on corridor continuity

Source: Feitelson (2007), partially based on Golan-Engelko & Bar Or (2008).

Table II. Possible policy responses to climate change in Israel

Issue	*Climate-change effect*	*Policy responses*	*Already discussed or undertaken?*
Water	Loss of coastal aquifer storage	Desalination;	Yes
	Lesser recharge to aquifers	Conservation in urban sector and agriculture;	Yes
	More flooding due to extreme events	Protection of flood plains and water-sensitive urban development	Yes
Infrastructure	Coastal erosion	Protection of cliffs, mainly in built-up areas;	Partially
	Peak floods	Changes in design standards;	No
	Sea-level rise	Adaptation of moorings	No
Ecosystems	Shift in ecosystems	Buffers around nature reserves;	Partially
		Wildlife corridors;	Yes
	Sea-level rise	Protection of open seashore and stream mouths	Yes
Agriculture	Less precipitation affects rain fed crops	Widen irrigation based on recycled wastewater	Yes

Source: Feitelson (2007).

climate change on replenishment rates will be. Yet, it is quite certain that sea-level rise will reduce the storage capacity of the coastal aquifer, which is central to Israel's water management system and the only source of water for Gaza (Melloul & Collins, 2006).

In order to assess whether climate change will necessarily have an adverse effect on welfare and livelihood under worst-case scenarios, several population and water-availability scenarios, described in the next subsection, were assessed. In essence, these scenarios are used to test what will be the effects of an extreme-case reduction in water availability on the potential ability to supply the normative freshwater needs in Israel, the West Bank, and Gaza under very high population growth scenarios. As desalination is coming on-line in Israel gradually, thereby potentially mitigating the effects of climate change in the long run, the target year chosen for all scenarios was 2030 (though an interim period of 2020 was assessed too). In other words, we strive to examine the ability to supply the normative needs, as defined by Feitelson (2012) and presented below, under the most extreme circumstances we could identify.

The scenarios

Four basic scenarios were compiled, as part of a cooperative Israeli–Palestinian study on water needs (Feitelson et al., 2011). The scenarios are comprised of two elements – population growth and water availability. We used the official medium population growth forecasts of the Israeli and Palestinian Central Bureaux of Statistics. The Israeli growth rate used is 1.58% until 2015 and 1.34% from 2015 until 2030, while the Palestinian agency uses a fixed rate of 2.3% in the West Bank and 3.3% in Gaza.[3] The base year from which all scenarios were

[3] Such a fixed rate is unlikely to persist in practice. But as the Palestinian agencies do not allow for lower fertility rates these were adopted. This means that the Palestinian population forecasts are probably upward biased.

Table III. The population and water needs scenarios (population in thousands, needs in MCM)

	Base scenario				Economic development scenario			
Year entity	*Pop.*	*Domestic need*	*Envi. need*	*Peripheral farming*	*Pop.*	*Domestic need*	*Envi. need*	*Peripheral farming*
2010								
Israel	7,464	448	65	120	7,464	448	65	120
WB	2,487	149	12	209	2,487	149	12	157
Gaza	1,562	94	5	129	1,562	94	5	98
Total	11,513	691	82	458	11,513	691	82	376
2020								
Israel	8,628	518	65	120	8,628	518	65	120
WB	2,958	177	12	209	2,958	177	12	157
Gaza	1,929	116	5	129	1,929	115	5	98
Total	13,516	811	82	458	13,516	811	82	376
2030								
Israel	9,857	591	65	120	9,857	591	65	120
WB	3,430	206	12	209	3,430	205	12	157
Gaza	2,323	139	5	129	2,323	139	5	98
Total	15,610	937	82	458	15,610	937	82	376
	Stepwise refugee return scenario				*Late large refugee return scenario*			
Year entity	*Pop.*	*Domestic need*	*Envi. need*	*Peripheral farming*	*Pop.*	*Domestic need*	*Envi. need*	*Peripheral farming*
2010								
Israel	7,464	448	65	120	7,464	448	65	120
WB	2,487	149	12	209	2,487	149	12	209
Gaza	1,562	94	5	129	1,562	94	5	129
Total	11,513	691	82	458	11,513	691	82	458
2020								
Israel	8,628	518	65	120	8,628	518	65	120
WB	3,338	200	12	209	2,958	177	12	209
Gaza	1,929	116	5	129	1,929	116	5	129
Total	13,896	834	82	458	13,516	811	82	458
2030								
Israel	9,857	591	65	120	9,857	591	65	120
WB	4,342	261	12	209	4,878	293	12	209
Gaza	2,323	139	5	129	2,323	139	5	129
Total	16,522	991	82	458	17,058	1023	82	458

Source: Feitelson et al. (2011).
Pop. = population in thousands
Domestic need = water used for domestic needs in MCM (60*Pop.)
Envi. Need = minimal water needed for viable ecosystems in MCM
Peripheral farming = water needed to maintain peripheral farming communities in MCM

calculated is 2007, in which there were 7.12 million Israelis and 3.76 million Palestinians. As this is a high estimate of the total Palestinian population,[4] these scenarios can be considered an extreme case, which is consistent with the purpose of this article.

We first consider a 'business-as-usual scenario', based on the above assumptions, but allowing all normative needs to be supplied. The second scenario assumes rapid economic development in Palestine, thereby increasing economic demand in the urban sector (above the normative demand) and widening the integration of the rural population in the urban economy. Then two scenarios of return of refugees were added. One scenario suggests a return by 10% of all Palestinian refugees to the West Bank by 2020 and another 10% by 2030, while the second scenario suggested a 30%

[4] For a critique of Palestinian population figures, arguing that they do not take into account emigration and hence are upward biased, see Faitelson (2009).

return by 2030. All scenarios were run for three time periods: 2010, 2020, and 2030 (Feitelson et al., 2011). The population and water use implications of each scenario are presented in Table III. The calculation of the water use implications are detailed in the subsection.

We focus on the implications of climate change, hence the four scenarios presented in Table III were run for three different freshwater availability scenarios. The first used current multi-year replenishment rates, as detailed in Appendix 1.[5] The second reduced the available freshwater (without desalination) by 20%, which is slightly less than the maximal reduction predicted by Ragab & Prudhomme (2002), Milly, Dunne & Vecchia (2005), and by Heming et al. (2020) for the 2020–50 period, and by other analysts (e.g. Alpert et al., 2008; Evans, 2009) for the end of the century (2070–2100). Finally, as some of the analyses of climate change suggest more drastic reduction in precipitation either toward the end of the century, or further east (in Jordan) by mid-century (Mason, Mimi & Zeitoun ,2010; Sowers, Vengosh & Weinthal, 2011), the third scenario assumed a 40% reduction in precipitation over the Israeli–Palestinian area. These are very large effects, and hence the total stress analyzed in these scenarios, combining high population growth and rapid decline in precipitation, must be considered extreme cases.

The sufficiency of water was first calculated for each climate-related scenario for the total population of Israelis and Palestinians, regardless of the division of water between them. This allows us to analyze whether it is possible to address the needs of both peoples based on the shared freshwater resources. The water in the shared Mountain aquifers was arbitrarily divided equally between the two parties (50% for each). This implies that the Palestinians in the West Bank were allotted 350 MCM, which is considerably more than the 142 MCM allocated under the Oslo B agreement, and also more than the current amounts used by Palestinians.[6] This allotment is an arbitrary assumption, as while it is more than the Palestinians use at present, it is less than the amount the Palestinians demand and does not relate to the Jordan River (Phillips et al., 2007).[7] Thus, the 50/50 allocation used in this article is merely a measuring rod to assess the extent to which each party may suffer from lack of water, focusing mainly on the Palestinians in the West Bank. In the case of the Gaza Strip, it is assumed that the freshwater resources are the natural replenishment of the local aquifer. While Abu Sway et al. (1994) suggest that the replenishment amounts to 55–70 MCM, we use a lower figure (45 MCM) due to the dire situation of this aquifer, which does not allow for the full replenishment to be stored within it without being polluted.

The analysis

Water use is divided into normative needs and economic demand (Feitelson, 2012). There are several normative needs. The highest priority is the water that is necessary to allow for a dignified level of living (Feitelson, 2012). The quantities used beyond the normative needs are viewed as an economic demand, whose supply is a function of the users' willingness to pay. On the basis of Chenoweth (2008), Feitelson et al. (2011) defined normative domestic needs as 60 m^3/capita/year.[8] To these domestic needs several second-tier normative needs can be added. These include spiritual water needs, environmental needs, and the needs of peripheral agricultural communities (Feitelson, 2012). Peripheral agriculture was defined by us as the irrigated agriculture in areas where no alternative employment exists within a reasonable commute-shed (Feitelson et al., 2011). The water needs of peripheral agriculture are thus the minimal quantity needed for irrigation to maintain peripheral agriculture-based communities.

The domestic normative needs presented in Table III were calculated by multiplying the four population scenarios by 60 m^3/capita/year. The environmental needs were assessed on the basis of expert judgments, as there is insufficient detailed work to quantify them.

[5] These replenishment rates exceed the current estimates of the Israel Water Authority (IWA, 2010). However, as IWA figures are based on a short (17-year) series while ours is based on a longer (30-year) series, we chose the higher figure. But as the sensitivity tests we conduct include a 40% reduction in replenishment rate, the figures we test exceed the average expected effect of climate change, even if we were to take the IWA figures.

[6] According to the IWA (2009), Palestinian water consumption in 2006 amounted to 180 MCM and was expected to rise to 200 MCM in 2007.

[7] The Jordan River is already fully utilized and hence is considered a 'closed basin' (Venot, Molle & Courcier, 2008). It has five riparian parties, all of which have claims to the river's water. Hence, any change in use of the river's water is likely to require multilateral agreements. Thus, it is difficult to foresee how much water the Palestinians may ultimately use from this source, and when this will come about. For this reason the Jordan River was not included in our scenario analysis.

[8] This is a quantity of water that allows for a viable advanced non-agricultural economy that allows households to maintain a high level of living, while implementing substantial conservation measures in domestic and municipal consumption.

Table IV. Water balances: Freshwater vis-à-vis normative domestic needs, 2030 (in MCM)

Scenario		*Average recharge*	*Recharge –20%*	*Recharge –40%*
Base	WB	74	18	–38
	Gaza	–94	–103	–122
	Israel	775	502	228
	Israel + WB	849	520	190
With 20% refugee return	WB	19	–36	–92
	Gaza	–94	–103	–112
	Israel	775	502	228
	Israel + WB	794	466	136
With 30% refugee return	WB	–13	–69	–125
	Gaza	–94	–103	–122
	Israel	775	502	228
	Israel + WB	762	433	103

Based on: Feitelson et al. (2011), Table 12.

These needs do not vary by scenario. Given the very limited quantities of water needed to supply the spiritual needs in Judaism and Islam, spiritual needs were not quantified.

Peripheral farming was defined to apply to those farmers for whom there is no alternative source of income within a reasonable commute. In Israel, Feitelson et al. (2011) defined these farmers to include the communities in the Arava area, a remote area with no nearby urban centers, and part of those located in the north Jordan rift valley. As the Arava Valley farmers rely on local sources, which are not shared with the Palestinians, their needs are of minor importance for our purpose. On the Palestinian side, Feitelson et al. (2011) regarded most of the farmers in the West Bank as peripheral farmers, despite most of them being within commuting distance of urban centers, due to the travel impediments in the West Bank at the time the study was conducted. Similarly, the farmers in Gaza were also included under this rubric, despite their access to urban centers in the Gaza Strip, due to the lack of alternative employment opportunities. By accepting these assumptions, we greatly increase the peripheral agriculture needs on the Palestinian side, relative to what is warranted from the more narrow interpretation put forward by Feitelson (2012) for these needs (termed 'community needs'). Hence, the quantity of water noted in Table III under the peripheral agriculture column can be seen as an upper bound to this need.

Food supply is not included as a need in this article, as most of the Middle East, including both Israel and Palestine, is supplied through the international market. Hence, the water needed to supply this region is mostly 'virtual water' (Allan, 2001), that is, water embedded in food. Thus, the effects of climate change on local water sources is not expected to have direct implications for food supply, though it may affect regional food prices, a point picked up later.

Table IV presents the ability to supply the normative domestic needs under three population scenarios (with no refugee return, a 20% refugee return, and a 30% refugee return) with adverse climate-change effects for the year 2030.[9] It can be seen that with the exception of the Gaza Strip, where shortages are imminent, freshwater resources will suffice to supply the total domestic needs of Israel and the West Bank under all scenarios. The total supply of Israel and the West Bank is presented separately from the Gaza Strip's, as the shared water resources (the Mountain aquifers[10]) underlie Israel and the West Bank, while Gaza's coastal aquifer is largely unaffected by Israel and does not affect Israel's supply.[11] Thus, while Gaza requires immediate augmentation, Israel and the West Bank can conceivably supply the

[9] The economic development scenario does not differ in this balance from the base scenario, as it affects economic demand and peripheral agriculture needs, both of which are not part of this balance. Hence, this scenario is not included in Table IV.

[10] The shared groundwater resources between Israel and the West Bank are comprised of three aquifers, shown in Figure 2, collectively named the Mountain aquifers.

[11] The Gaza aquifer is vulnerable to various sources of salinity, including sea-water intrusion for the west, intrusion of saline water from the east, and pollution from surface activities (Vengosh et al., 2005). Due to the saline water bodies to the east of the Gaza Strip, pumping in Israel actually reduces the rate of salinization of the Gaza aquifer. Thus while there are subterranean inter-effects they are not the expected upper–lower riparian zero-sum competition (Weinthal et al., 2005).

Table V. Water balances: Fresh+brackish water vs. normative domestic+environmental+peripheral agriculture needs, 2030 (in MCM)

Scenario		*Average recharge*	*recharge –20%*	*Recharge –40%*
Base	WB	–87	–142	–199
	Gaza	–223	–232	–241
	Israel	748	475	202
	Israel + WB	661	333	3
With Palestinian economic development	WB	–35	–91	–147
	Gaza	–192	–202	–211
	Israel	748	475	202
	Israel + WB	713	384	55
With 30% refugee return	WB	–173	–230	–286
	Gaza	–223	–232	–241
	Israel	748	475	202
	Israel + WB	575	245	–84

Based on: Feitelson et al. (2011), Table 13.

normative domestic needs. However, if the Palestinian supply is reduced due to the decline in recharge resulting from climate change in proportion to their 50% share, the water at their disposal will not be sufficient to meet their domestic needs with either a refugee return or a 40% decline in recharge. But if the initial Palestinian allocation of 50% of the Mountain aquifer is seen as fixed, thereby requiring Israel to shoulder the full burden of the reduced recharge, this quantity of water, 350 MCM, will suffice to supply the Palestinian domestic needs under all of the scenarios.

Normative domestic needs are supplied by freshwater. The environmental, and particularly the peripheral agriculture needs can be supplied by brackish water. Therefore, the balances for the year 2030 that include such needs on the demand side include both fresh and brackish water on the supply side. These balances are presented in Table V for all scenarios. Due to the travel restrictions on Palestinians in the West Bank and the economic situation in Gaza, most of the Palestinian farmers were included in the 'peripheral farming' category.[12] However, if the economic situation improves, commuting options and employment opportunities will probably widen. Hence the economic development in Palestine scenario was added in Table III to partially account for this eventuality, in which the number of villages included in the peripheral farming category was reduced on the basis of expert judgment.

As can be seen in Table V, the water resources available for the Palestinians under a 50% arbitrary allocation will be insufficient to supply the peripheral agriculture. Hence the livelihoods of peripheral farmers may be adversely affected. This is particularly likely to occur in the Jordan Valley where farmers largely depend on local sources, and for which there is keen competition from the Kingdom of Jordan (whose agriculture is largely concentrated in the Jordan Valley and is likely to suffer acute scarcity – a point picked up later in this article). Furthermore, reduced productivity in the Jordan Valley may have deleterious effects on the Palestinian economy, due to its current reliance on agriculture. Also particularly vulnerable are the semi-nomads in the southern part of the West Bank, who rely on rain-fed agriculture and on livestock for their livelihood. However, if the climate-change effects are borne by Israel rather than jointly, leaving the 350 MCM allocations for the Palestinians unaltered, this allocation (plus local brackish water in the West Bank) can suffice for all the Palestinian needs, except for the very extreme situation of a massive return of refugees, with a 40% drop in water availability within 20 years and no economic development. This combination is unlikely as such a return is contingent upon a comprehensive agreement, which arguably will bring new capital flows to Palestine. Moreover, agriculture can utilize recycled wastewater, which was not included in these scenarios. The availability of recycled wastewater is likely to increase as total domestic use rises, but is contingent on adequate treatment. Thus, some of the needs for peripheral agriculture, and probably all of

[12] The extent of villages which should be regarded as peripheral was determined by Palestinian experts well familiar with the situation on the ground in the West Bank. As the quantity of water used in these villages is very limited, it was assumed that it constitutes the minimal quantity needed.

them in the case of Gaza, can conceivably be supplied from recycled wastewater. This is also partially true for the Jordan Valley, which can conceivably receive some recycled wastewater from Jerusalem and Nablus.[13]

Implications

Climate change may worsen the water situation in Israel/Palestine, and particularly in the West Bank and Gaza (Mason, Mimi & Zeitoun, 2010). However, desalination can address gaps between availability and normative needs. The Gaza strip requires augmentation regardless of climate change. The amount needed to supply the current gap between the normative domestic demand and the potable water supply, supposing desalination replaces all of the over-utilized highly polluted Gaza aquifer, is about 100 MCM (to supply 60 m^3/person/year and assuming the population is slightly more than 1.5 million). This is less than the quantity currently being desalinated in Israel's nearby desalination plant in Ashkelon (see Figure 2). As the cost of water supplied from such a plant is not more than 60 cents per m^3, including capital costs,[14] such a plant is seen as technically and financially viable. As desalination largely decouples water supply from climate change, and the recyclable wastewater is also insensitive to climate change,[15] any solution to Gaza's current water crisis will essentially make the Gaza Strip much less vulnerable to climate change.

Israel has embarked on a widespread desalination program (see Figure 2). At present over 250 MCM are online, including the recently built 127 MCM plant near Hadera. The total quantity to be desalinated according to the latest government decision is 800 MCM which is more than 50% of Israel's current freshwater consumption. The Israeli water master plan currently being prepared suggests that this amount may increase substantially by 2050 (IWA, 2010).

Desalination reduces the sensitivity to weather and climate change, while contributing to global greenhouse gas emissions. Potentially, desalination can supply the Palestinians on the West Bank, too. At present Israel retains a site near Hadera for this purpose (Figure 2). There is a basic understanding within both parties that desalination will be needed some time in the future (Gvirtzman, 2010; Phillips et al., 2007). However, the question of whether desalinated seawater is an alternative to freshwater resources in transboundary contexts remains contentious (Feitelson & Rosenthal, 2011). The Palestinian position is that desalination is an alternative source, and hence Israel should desalinate while the Palestinians use most of the water from the Mountain aquifer (Phillips et al., 2007). The Israeli position is that only the shared resources are subject to negotiations, while desalinated seawater is an augmentation that each party should finance for itself (Gvirtzman, 2010). If this question is not resolved and the Palestinians get no more than 50% of the Mountain aquifers' total average annual water, thereby sharing also the burden of climate change, then households in the West Bank may suffer a welfare loss if recharge is reduced by 40% within 20 years, or there is a massive return of refugees. Both are unlikely. Moreover, even if the limited reallocation implied in the 350 MCM figure for Palestinian use is seen as a one-time reallocation and hence as a priority right (thereby implying that Israel shoulders the burden of climate change due to its greater adaptive capacity), it will suffice to address the West Bank's normative needs even under the most extreme scenarios.

In contrast to Israel and the West Bank, the fresh and brackish water will not suffice to meet Gaza's needs under any scenario. Regardless of climate change, there is a need to augment the water sources in Gaza. Climate change may make this need only more acute due to the intrusion of rising seawater into the aquifer. The only feasible source for additional water for Gaza is desalination (Al Yaqubi, Aliewi & Mimi, 2007). The quantities needed to supply the normative domestic needs are not greater than those supplied by a single large-scale desalination plant, of the type that is now built in Israel. If such a plant is built, the vulnerability of Gaza to climate change will be greatly reduced. But the ability to build such a plant is contingent upon the degree to which some level of accommodation can be reached between the Hamas leadership in Gaza, Israel, and the Palestinian Authority – issues that are beyond the scope of this article.

Climate change may, however, affect the livelihood of 'peripheral' farmers – those who are based on rain-fed agriculture or irrigated agriculture, and who do not have alternative employment options within a 'reasonable' commute from their current location. Given the short distances in the West Bank and within Gaza it could be argued that there would be very few farmers in this state. The numbers used in the scenarios were high, due

[13] On the options and impediments for such re-use from Jerusalem, under the current geo-political circumstances, see Dombrowsky et al. (2010).

[14] This cost estimate is based on the Israeli experience, assuming the plant uses reverse osmosis and is based on the off-shore natural gas fields.

[15] Feitelson & Rosenthal (2011) make the point that as desalinated seawater is geared toward the domestic sector, desalination results in greater quantities of recyclable wastewater, and of higher quality.

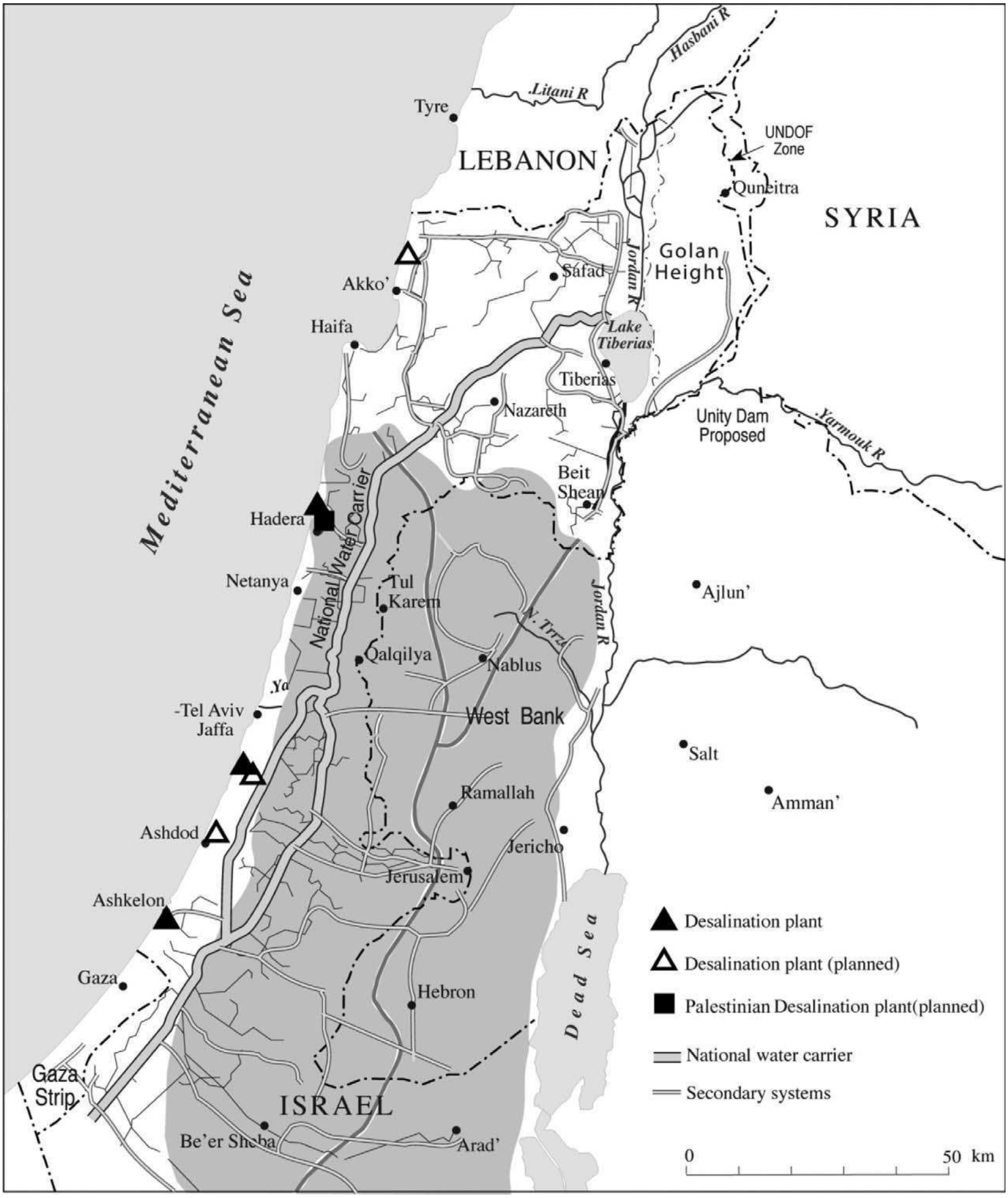

Figure 2. Desalination plants in Israel
The gray area depicts the shared Mountain aquifers.

to the current mobility restrictions and the shaky economic situation in Palestine. However, if any agreement is reached, and implemented, this situation is likely to be altered. Hence, as the scenarios used here are extreme, the actual impact of climate change on the livelihood options of Palestinians is likely to be less than implied in the results presented in Table V, thereby suggesting that the immediate human security concerns identified by Barnett & Adger (2007) as critical variables in analyses of the climate-change induced risks are not likely to materialize in the Israeli–Palestinian case, despite the increasing likelihood of droughts.

Indirect implications of climate change

Discussions of adaptation to climate change usually focus on the country level. However, the options may be affected by transboundary relationships. In the Israeli–Palestinian case, transboundary relations are typified by concurrent cooperation and conflict (Zeitoun, 2007). Yet, these relations are highly unstable. How might climate change affect these relations, particularly the positions of the parties in future negotiations? How are the prospects for implementing transboundary adaptive measures affected by security perceptions? At what scale should the security implications of climate change be discussed? Can the relations between Israel and the Palestinians be disassociated from the wider Israeli–Arab setting?

Effects on parties' negotiating positions

The main potential transboundary effect of climate change in the Israeli–Palestinian context is an increasing likelihood of multi-year droughts, which adversely affect freshwater availability to both parties. The actions and statements of the two parties during the series of droughts that afflicted the area in the past decade allow us to assess the potential implications of series of drought years on their negotiating positions.

The Palestinian position is that the joint institutions established under the Oslo accord are inequitable, and hence they strive to obtain property rights ('water rights') over the shared aquifers and reduce their dependence on Israel for water supply. Climate change is likely to become an additional argument for greater Palestinian control over the Mountain aquifers (Lautze & Kirshen, 2009). Due to their greater vulnerability and Israel's greater adaptive capacity (mainly due to desalination), the Palestinians argue that they should obtain control over most of the Mountain aquifers.

Israel has increased the amount of water supplied to the West Bank, beyond the amounts stipulated under the Oslo accords, but argues that desalination is the real answer to the increasing threats of droughts (Gvirtzman, 2010). However, desalination does not substitute for storage capacity. Desalinated water is increasingly viewed in Israel as a base flow, whereas the aquifers serve as storages to be used to address fluctuations in precipitation patterns and replenishment rates.[16] Thus, in previous negotiations the Israelis insisted on retaining the operational flexibility of the water-supply system, and particularly the ability to adjust abstractions from the Western Mountain aquifer to shifts in precipitation and replenishment patters (Feitelson, 2006). As the storage capacity of the coastal aquifer may be reduced due to sea-level rise, the importance of the storage capacity of the Western Mountain aquifer from an Israeli water-management perspective is likely to rise. Hence, Israel is less likely to forgo its control over abstractions from the Western Mountain aquifer due to climate-change scenarios. This is reflected in the Israeli official argumentation, where the use of a lower average annual recharge is related to climate change (IWA, 2009: 20).

Security limitations on adaptation

In recent years there has been increasing emphasis on the importance of adaptive capacity to climate change, particularly as the prospects for mitigation seem low (Pielke et al., 2007). But there are limitations on the ability to adapt (Adger et al., 2009). These limitations can be exogenous (i.e. a function of ecological or technological limits) or endogenous (e.g. social and cultural factors) to society. Yet, the extent to which the framing of climate change as a security issue (securitization) constrains adaptability has not been discussed.

There are two adaptive policies that are of central importance in the Israeli–Palestinian case: desalination and cooperation. Desalination provides the potential to address the gaps between natural replenishment and domestic needs, as well as domestic economic demand, and subsequently to increase the quantity and improve the quality of wastewater. Thereby desalination widens the scope for wastewater recycling for agriculture. Desalination thus effectively decouples both domestic supply and irrigation from climate change. Yet, desalination affects power relationships, as the seashore party, which is usually the lower riparian on freshwater flows, becomes the upper riparian on the desalination flows (Feitelson & Rosenthal, 2011). Due to these power implications the Palestinians and the Jordanians try to avoid any reliance on desalination plants located along the Mediterranean seashore, as such desalination will place Israel in the

[16] The desalination plants are built through Build Operate Transfer tenders. In order to keep the average cost down, the government needs to provide purchase assurances (Feitelson & Rosenthal, 2011). For the official Israeli position on this point, see IWA (2009: 22–23).

position of an upper riparian on the flow of desalinated water. Perhaps for the same reason Israel insists on a Palestinian desalination plant at Hadera as the 'best' solution to the northern West Bank's water stress. Thus, the securitization of desalination seems to limit its ability to serve as an adaptive approach to climate change.

Several scholars have argued that cooperation is essential for meeting the water challenges facing Israelis and Palestinians (Feitelson & Haddad, 1998; Haddad et al., 2001; Brooks & Trottier, 2010). This is particularly true when adjustments have to be made, such as is the case when precipitation patterns change. But the growing mistrust between the parties and the securitization of perceptions, manifest in the framing of discussions of cooperation within a power perspective, have discredited cooperative proposals, mainly by the Palestinians. Thus, the prospects for cooperation on climate change, when they are set within a security and power nexus, are arguably lower, thereby impeding the coordination of adaptation strategies.

Regional effects

The potential for conflict between Israel and the Palestinians, both over water and in other fields, is strongly affected by other parties in the Middle East. The four Arab countries neighboring Israel (the 'first circle' of Arab countries) are of particular importance. Two of these four countries (Egypt and Jordan) have signed peace agreements with Israel and have been heavily criticized in the Arab world. Thus, if climate change affects the political stability of these countries, the chances for peace between Israel and its neighbors, as well as with the Palestinians, may be compromised.

The most likely effect of climate change to materialize in the Eastern Mediterranean is sea-level rise. In the Israeli–Palestinian context this may affect low-lying areas in southern Israel and along the Gaza Strip. Given the shoreline characteristics, sea-level rise is likely to have smaller effects the further north we move along the eastern Mediterranean. Areas to the north of Israel are not likely to be greatly affected. However, in Egypt, sea-level rise may have severe implications for the Nile delta and Alexandria region (El Raey, 1997; Dasgupta et al., 2007). If the effects on these areas contribute to further instability, they may adversely affect Egypt's position in the region. Egypt may also be particularly sensitive to shifts in world food prices, particularly the price of staples that Egypt imports. In this context, the extent to which food prices had a role in the fall of the Mubarak regime would be worth investigating.

The second country to sign a peace accord with Israel is Jordan. Jordan has thrived on its image as a stable state in a highly unstable Middle East, thereby attracting investments in finances and tourism. But if the water situation in Jordan turns to the worst, as it may well (Abu-Taleb, 2000), given the dire state of water in Jordan and its limited options (Venot, Molle & Courcier, 2008), water may become a destabilizing issue. However, the study of these admittedly somewhat speculative hypotheses is beyond the scope of this article.

Conclusions

Climate change has been portrayed as a potential security threat in the Middle East, mainly due to its potential effect on water availability (Brown & Crawford, 2009; Trondalen, 2009). Water is indeed found to be the main issue also in the more limited Israeli–Palestinian context analyzed here. However, based on analysis of extreme scenarios we find that the likely direct effects of climate change per se are limited. While climate change may affect the livelihood of Palestinian farmers and semi-nomads, particularly in remote areas, it is unlikely to affect the welfare of the urban population substantially if some water re-allocation occurs, even under extreme scenarios. The exception to this finding is the situation in Gaza, which requires additional water regardless of climate change. Within Israel it is highly unlikely that citizens will feel the direct effects of climate change, as Israel has embarked already on an extensive desalination program, which largely decouples urban supply from climate change, though some ecosystems and rain-fed agriculture may be affected. Thus, the likelihood that climate change will lead to a conflagration and violence beyond what might occur without climate change is low.

Water is scarce in Israel and Palestine. Hence, water issues need to be addressed regardless of climate change. Desalination is increasingly seen as an essential and central element in this response. In the case of Gaza, it is virtually impossible to supply even normative domestic needs without desalination (Al Yaqubi et al., 2007). But the ability to desalinate in Gaza is currently curtailed by the 'high politics' of the Israeli–Palestinian conflict. Once built, desalination and the increasing potential for wastewater recycling resulting from it, partially decouples water supply for both the domestic and the agricultural sector from climate-change effects. Hence, following the logic outlined by Barnett & Adger (2007), climate-change effects on water resources are unlikely to have a discernible effect on Israeli–Palestinian relations, which will continue to be dominated by 'high politics' (Lowi, 1993).

However, climate change may be used by the parties to justify their bargaining positions. Perceptions of climate change and the possible reduction in storage capacity may lead to the hardening of negotiating positions. Thus, climate change may hinder the ability to reach agreements regarding water. Yet, such agreements are crucial for implementing the type of measures that may mitigate the effects of climate change. Without such agreements it is unlikely that desalination plants will be built in Gaza in the near future or in the West Bank later, or that abstractions from the shared aquifer (particularly the Western Mountain aquifer) will be regulated. A major obstacle is the securitization of the water discourse and perceptions. If water is viewed as a security issue, the steps that can be taken to mitigate the effects of climate change may not be taken due to the view that such cooperative mechanisms impinge on sovereignty (Fischhendler, 2004).

In conclusion, climate change does not seem to pose a major direct security risk in the Israeli–Palestinian context. However, the framing of water issues and of climate change as security issues, and the subsequent subservience of water and environmental issues to the 'high politics' of the conflict may hinder the ability to undertake the adaptive measures that may mitigate the effects of climate change.

In a wider regional perspective, the potential effects of climate change cannot be completely discounted. If climate change adversely affects the stability of key countries vulnerable to sea-level rise (e.g. Egypt) or facing greater losses of water and where the reliability of water supply is tenuous (e.g. Jordan), this may have an indirect effect on the Israeli–Palestinian conflict.

Replication data

The replication data for this article can be found at http://www.prio.no/jpr/datasets.

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Appendix

Table AI. The water resources of Israel and Palestine

*Basin**	*Annual replenishment**(in MCM)*	*Riparian parties*
Sea of Galilee	520***	Israel, Lebanon, Syria
Mountain aquifers:		
Western	350–360	Israel, Palestinians
North-eastern	140–150	Israel, Palestinians
Eastern: upper	40	Mainly Palestinians
lower	170	Palestinians, Israel
Coastal aquifer	250	Israel
Gaza aquifer	45–70	Palestinians
Western Galilee aquifer	140	Israel
Carmel aquifer	35	Israel

Sources: IWA (2009); Golan-Engelko & Bar-Or (2008);
Al Yaqubi, Aliewi & Mimi (2007), for the Gaza aquifer.
* There are additional smaller basins in Israel. The lower Jordan River, currently shared by Israel, Jordan, and the West Bank, is not included. Most of the river's replenishment below the Sea of Galilee originates in Syria and Jordan.
** Multi-year average.
*** The annual replenishment is presented after deducting evaporation from the lake.

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Arquilla, John (2011) *Insurgents, Raiders, and Bandits: How Masters of Irregular Warfare Have Shaped Our World*. Chicago, IL: Ivan R Dee. xviii + 310 pp. ISBN 9781566638326.

The talents of great generals leading 'big battalions', from Hannibal and Caesar to Guderian and Patton, are examined from every possible angle in thousands of volumes, but the captains of insurgencies are usually treated as supporting and often rogue characters. Yet the wars of nowadays are fought and won not by pitched battles but by ambushes and raids, so Arquilla is right to insist that the exploits of his 18 heroes 'carry important lessons for military practitioners in this new era of irregular warfare' (p. 269). His selection of cases from Robert Rogers to Aslan Maskhadov will leave every reader wanting to add a personal favorite (my choice would be Nestor Makhno, while Ahmad Shah Massoud would probably come out as a top contender), but the arresting vividness of analytic portraits makes the book very hard to put down. Where Arquilla is rather dry and imprecise is in defining 'irregular warfare' by three key features: engagement of small units, prevalence of guerilla tactics, and resort to terrorism (pp. 4–6). This definition may be no worse than the Pentagon's vague description of 'unconventional' war, but it doesn't quite answer the purpose of the book. No bona fide terrorists are presented, despite occasional references to Al Qaeda and Osama bin Laden. The problem area of urban guerillas should have been covered but isn't, while banditry belongs to a different analysis, so Phoolan Devi is an odd woman out. Another disappointment is Arquilla's abbreviated effort at drawing lessons, where the question most relevant to this narrative – how important for sustaining and winning irregular war is personal leadership? – is not raised. Nevertheless, the book is excellent.

Pavel Baev

Brabazon, James (2010) *My Friend the Mercenary*. Edinburgh: Canongate. 352 pp. ISBN 9781847674401.

Liberia's relapse into violence following its devastating civil war (1989–96) is frequently overlooked. Between 2000 and 2003, the Liberians United for Reconciliation and Democracy (LURD) attempted – ultimately successfully – to forcefully remove President Charles Taylor from power. James Brabazon, then a fledgling television producer, employed gun-for-hire Nick Du Toit for protection and filmed LURD as it advanced towards the capital Monrovia. Written as a memoir, the publication focuses on the journalist's relationship with Du Toit, who became notorious for his leading role in a failed 2004 coup in Equatorial Guinea. While the latter third of the book describes the coup (and its organization and outcome), the section on Liberia is particularly revealing. Brabazon's travels with LURD form the book's major backdrop, and there are fascinating anecdotes and insights into the rebel group. Despite the book's popular style and wide intended readership, it would be a mistake to disregard the writing as that of a carefree, ill-informed journalist, as academics are, on occasion, prone to do. The publication provides an important, often graphic, account of a dynamic often missing from the literature on Liberia. The author was one of the few foreigners able to access the rebels, interview both foot soldiers and leaders, and develop a rapport with the group. Such was the intensity of Brabazon's interaction with the rebels and Du Toit that one even wonders whether his independence was severely compromised. Many may argue that his conflicted views on the integrity of LURD, the 2004 coup, private security and the propriety of war reporting bear witness to this. The book has its faults, but it certainly provides an important reminder of LURD's role within Liberia and, more broadly, the shocking brutality of armed conflict.

Mark Naftalin

Chenoweth, Erica & Maria J Stephan (2011) *Why Civil Resistance Works: The Strategic Logic of Nonviolent Conflict.* New York: Columbia University Press. 320 pp. ISBN 9780231156820.

In this theoretically informative and empirically rich volume, Erica Chenoweth and Maria Stephan present strong evidence indicating the advantages of nonviolent forms of resistance when challenging authority. Drawing on a new dataset of 323 violent and nonviolent resistance campaigns (an enormous feat in itself), the authors rely on quantitative analysis to marshal support for the advantages of civil resistance. They find that nonviolent campaigns enable greater participation from larger sectors of society than violent insurgencies, which makes them more likely to produce loyalty shifts that tear at the regime's economic, social, and political base. Nonviolent campaigns also permit greater tactical diversity and innovation, are more resilient in the face of adversity, and draw more sympathy in the wake of brutal repression. The theory and quantitative chapters are followed by studies of four cases – Iran, Palestine, the Philippines, and Burma – to illustrate the links between nonviolence and success. The case studies enable within-case comparisons between violent and nonviolent resistance, and also between successful (Iran, Palestine, Philippines) and unsuccessful (Burma) cases of civil resistance. The authors systematically map the reasons why civil resistance works and, just as important, why alternative explanations fall short. Although the book is not entirely convincing when addressing endogeneity problems or the potential interactive or additive effects of violent and nonviolent forms of resistance within cases (Philippines or Iran), readers will still appreciate the authors' attempt to instill methodological rigor into their work. Published in the wake of the Arab Spring, the authors only briefly touch on events in Egypt and Tunisia. It will be fascinating to see how their argument extends across the rest of the region.

Andrew Yeo

Chivers, Chris (2010) *The Gun*. New York: Simon & Schuster. 481 pp. ISBN 9780743270762.

Chris Chivers has written a fascinating and comprehensive history of the development of automatic firearms. The book is divided into three parts. The first covers the initial inventions of the Gatling and Maxim machine guns and culminates in the 'industrial slaughter' of the trenches of the First World War. It focuses upon the people behind the inventions – including Richard Gatling and Hiram Maxim – and the conservative military establishments that for a long time ignored and overlooked the new inventions. The middle section focuses upon the development of the Kalashnikov assault rifle. Chivers covers the invention of the gun and its initial production in the Soviet Union. The last section covers the global production and proliferation of the Kalashnikov and the development of its US rival, the M16 rifle. Chivers has a refreshingly critical view of the mythology of the Kalashnikov and its eponymous inventor. He points out that Mikhail Kalashnikov is an unreliable witness, perhaps due to spending most of a lifetime adapting his life story to the whims of the party. The original AK-47 was difficult to manufacture and inaccurate. Its eventual ubiquity and form was a consequence of the Red Army's requirement for a rugged assault rifle and the Soviet system's penchant for mass production, rather than the genius of its inventor. It became the symbol of revolution across the developing world because it was produced in such vast numbers and then given away to friends and allies. Chivers also notes how the development of ammunition played as important a role as that of the firearms. Above all, Chivers paints in meticulous detail how the technology of killing explains much of both the deadliness and the outcome of armed conflicts.

Nicholas Marsh

Cunningham, David (2011) *Barriers to Peace in Civil War*. Cambridge: Cambridge University Press. 282 pp. ISBN 9781107007598.

Negotiated settlements to civil wars are notoriously unstable. David Cunningham contributes to this important topic with a study revealing that an increase in veto players makes for longer civil wars. In other words, the more armed actors involved in a war that are viable veto players, the harder it is to reach settlement and hence the longer the war. The veto player theory is rich and the author does a strong job measuring aspects of veto players. The focus on veto players is a natural theoretical progression from Doyle and Sambanis's work, which demonstrated that the number of factions involved affected the prospects of civil war peacebuilding success. One part of Cunningham's analysis is quantitative, where the main dependent variable is duration of civil war and the method is hazard analysis. His use of time-varying covariates and dyadic analysis is commendable. Controlling for many different factors, he finds that the number of veto players has a positive impact on war duration. The statistical analysis is supplemented with case studies. There is no doubt the book makes an important contribution, though the following points need to be made: It would have been nice to see some mention of third-party mediation, though this would raise endogeneity issues. Mediators are drawn to the most intractable conflicts such as those with many actors. Another interesting possibility would have been the use of competing risk hazard analysis, since civil wars can end in various ways. Cunningham writes clearly and makes his points strongly. Examples are worked in to the text nicely, and the rigorous statistical analysis is convincing. The book concludes with an interesting look at the policy implications of the research. I recommend this book to civil war scholars.

Karl DeRouen Jr

Grodsky, Brian K (2010) *The Costs of Justice: How New Leaders Respond to Previous Rights Abuses.* Notre Dame, IN: University of Notre Dame Press. x + 355 pp. ISBN 9780268029777.

The main task of this book is to discuss why new elites in postcommunist states pursue the transitional justice (TJ) processes they do. Grodsky argues that previous theories explaining TJ decisions focus too much on relative power between new and old elites and too little on public goods provision. New leaders, he claims, will be sensitive to their constituents' demands and ultimately will not pursue TJ policies if this reduces their chances of staying in power. Therefore, when deciding on TJ measures, new leaders will ensure that such policies do not have a negative impact on public goods provision. Even if there are pressures for addressing former wrongdoings through TJ, both from domestic actors and internationally, new leaders also have to address public demands related to employment, economic growth, health care, etc. Grodsky introduces a justice spectrum with seven types of TJ: (1) cessation and codification of human rights violations, (2) rebuke of the former regime, (3) rehabilitation and compensation of victims, (4) truth commissions, (5) purging human rights abusers from public offices, (6) criminal prosecution of 'executors', and (7) criminal prosecution of commanders. He uses this spectrum to analyze TJ policies undertaken in four postcommunist states: Poland, Croatia, Serbia and Uzbekistan. Based on media analyses and interviews, Grodsky concludes not only that new leaders make TJ decisions based on the relative power of former elites, but also that they are sensitive to the delivery of other political goods. Grodsky's book is an important contribution to the growing TJ literature; in particular, his theoretical framework provides a new and fruitful explanation of why new elites pursue the TJ policies they do.

Helga Malmin Binningsbø

Human Security Report Project (2009/2010) *Human Security Report 2009/2010: The Causes of Peace and the Shrinking Costs of War.* Oxford: Oxford University Press. 128 pp. ISBN 9780199860814.

The 2009/2010 Human Security Report provides a detailed account and thorough explanation of the significant recent decline in the number of conflicts worldwide. The report is divided into three parts. Part I examines the forces and political developments behind the decrease in international conflicts. It highlights the reduction in casualties caused by interstate war since the end of the Second World War, and by civil war since the beginning of the 1990s. In Part II, the report analyzes the challenges inherent in measuring mortality rates and exploring death rates in conflicts. The final part of the report examines the recent conflict trends around the world with particular emphasis on Afghanistan, Iraq, Pakistan, and Somalia – places with a high level of violence. It also analyzes the notion of Islamist extremism as a source of conflict and scrutinizes the claim that wars have become more intractable. Finally, it discusses the potential for the global economic crisis to underpin political violence in fragile developing countries. The report argues that the primary explanation for the current positive global trend is the growth of international initiatives serving to settle and prevent conflicts. The report makes a nuanced prediction that while the future is uncertain, and most likely will include fluctuation in terms of global security, the recent trend gives reason to be carefully optimistic. The importance of the report cannot be overestimated. Few academic initiatives have been able to attain such high influence as the Human Security Report. It will continue to provide essential analysis for policymakers, practitioners, and academics on the state of affairs in international conflict around the globe.

Jonas Gräns

Jackson, Paul & Peter Albrecht (2011) *Reconstructing Security after Conflict: Security Sector Reform in Sierra Leone*. London: Palgrave Macmillan. 236 pp. ISBN 9780230239005.

Sierra Leone today is a stable state, an electoral democracy, free from international tutelage and peacekeeping assistance. Most important, there is a perceived sense of 'security' among its civilian population, a major shift from the civil war years marked by widespread rebel abuse, terror and looting. How did this change happen? Jackson and Albrecht adopt a process tracing methodology to understand the mechanisms (actors and actions) that aided reconstruction of Sierra Leone's security sector between 1997 and 2007. In this historical narrative, the authors suggest that improved personal security was not simply a product of Britain's lead nation intervention and UN mission presence. The key to success lay in positive political will and local ownership. Sierra Leone's security sector reform success was far from a linear process. Synergies from local participation, initiative and field-level decisions, rather than brilliant and timely external political inputs, helped the process forward. Despite the overall peace consolidation, poverty and low human development persist. This socio-economic weakness makes the positive strides in security, justice and governance reform important yet incomplete. Jackson and Albrecht add in-depth case information to a literature dominated by policy and lessons-learnt manuals, but their book fails to raise novel questions and does not point the reader in any new directions. It would help if the authors had developed quantitative comparisons of outcomes across the spectrum of recent security sector reform cases or a qualitative typology to highlight the nuances of the Sierra Leone case. This volume adds to a long list of 'post-mortem' analyses on Sierra Leone's recovery process. However, its contribution is limited at best.

Sukanya Podder

Kalinovsky, Artemy M (2011) *A Long Goodbye: The Soviet Withdrawal from Afghanistan*. Cambridge, MA: Harvard University Press. ii + 304 pp. ISBN 9780674058668.

This book presents an excellently researched historical case, but it is destined to be read primarily by experts in security policy who struggle with the impossible task of bringing the US and NATO intervention in Afghanistan to an acceptable conclusion. Kalinovsky goes as little as necessary into the calamities of the protracted war, dismissing along the way such popular myths as the crucial role of the portable surface-to-air Stinger missiles (p. 43), and focuses primarily on decisionmaking in the Kremlin, particularly in Gorbachev's Politburo. The main value of his research is in analyzing a mass of new primary sources obtained primarily from the Gorbachev foundation, which prove that the top brass had strikingly little influence, while crucial deliberations involved an extremely narrow group of people (p. 219). The views of Vladimir Kriuchkov, the head of the KGB, are certain to remain shrouded in mystery, but the role of the particular personal friendship between Najibullah and Eduard Shevardnadze, the Minister of Foreign Affairs, comes out as an issue open to further investigation (p. 139). The author argues that Gorbachev gained confidence to overrule the 'hawks' in the permanently reshuffled and increasingly stressed leadership in the course of advancing the dialogue with the USA, which underpinned his New Political Thinking (p. 144). The author's criticism of Gorbachev for the failure to take effective control of the Afghan problem might invite many a reader to put a question mark on the margin of p. 234 as it goes clearly against the thrust of the central argument that pins on Gorbachev responsibility for wasting too much time with the bad choice. Today, again, no good choices are available and procrastination makes them worse.

Pavel Baev

Moodie, Ellen (2010) *El Salvador in the Aftermath of Peace: Crime, Uncertainty, and the Transition to Democracy*. Philadelphia, PA: University of Pennsylvania Press. 294 pp. ISBN 9780812242287.

This insightful book tells a stark, simple story with great analytical depth: after El Salvador's 12-year civil war ended in 1992, rising levels of violent crime led to repeated claims among ordinary Salvadoreans that the situation had become 'worse than the war'. This paradox is not just a striking point of departure for the book, but an analytical reference point throughout. The study is based on more than four years of fieldwork in the San Salvador metropolitan area between 1994 and 2008, purposefully cross-cutting the socio-economic strata of the city. Moodie shows how exposure to violence was transformed from a communal and purposeful experience during the war to a privatized and unpredictable experience in the postwar period. Much of the analysis revolves around 'crime stories', narratives that serve to give a shared dimension to the individualized victimization. The analyses of these stories also illustrate how the social impact of violence is determined not so much by the actual events as by how they are given meaning. Moodie's style of writing is praised as 'beautiful' on the back cover but may, at times, be perceived by some readers as pretentious and opaque (this is especially true of Chapter 6, parts of which have been published in the journal *Social Text*). Her mastery of the genres of anthropology and cultural theory comes at the cost of possibly shutting out a broader readership. That is a pity, since her work could make important contributions to the study of violence across disciplines. Beyond the specific experiences of El Salvador, Moodie's book fundamentally challenges the meaning of peace and sheds new light on the societal dynamics of violence.

Jørgen Carling

Nepstad, Sharon Erickson (2011) *Nonviolent Revolutions: Civil Resistance in the Late 20th Century.* Oxford: Oxford University Press. 200 pp. ISBN 9780199778218.

This book is ambitious. Sharon Erickson Nepstad – fascinated by the power of nonviolent action – provides a comparative study of the factors affecting the success or failure of nonviolent revolutions. The aim is not to develop a general explanation of revolutionary outcomes, but to advance and inspire further research on this topic. Her research focuses on structural conditions and political circumstances, and on strategic factors such as the unity of protest movements and the counter-strategies of the rulers. Therewith, the author goes beyond the focus on individual factors in previous studies. Moreover, she chooses a comparative approach in which successful and failed nonviolent revolutions of the 1980s are contrasted and assigned to certain regime types: socialist regimes (East Germany and China), military regimes (Chile and Panama) and personal dictators (Philippines and Kenya). For that purpose she uses only Anglophone secondary literature, which limits the scope of the findings. The central result is that the strategies of actors to unite the protest movement and stick to nonviolence increase the chance of nonviolent revolution. Above all, the author emphasizes the disposition of domestic security forces to defect as a crucial factor for nonviolence to succeed. Furthermore, she finds an ambivalent influence of international actors, who under certain circumstances even undermine the prospects of nonviolent revolution. Although generating fascinating insights, the macro-perspective of the book has to be criticized in order to encourage in-depth case studies. In general, the author overestimates the impact of strategic decisions by resisters and undervalues the self-dynamics of revolutionary events. This book is provoking in its briefness, but inspiring in its culminations. It comes at the right time.

Christian Fröhlich & Alexander Leistner

O'Gorman, Eleanor (2011) *Conflict and Development: Development Matters.* London: Zed. 179 pp. ISBN 9781848135758.

The interconnections between armed conflict, poverty, and economic development have greatly preoccupied academics, Western governments and international aid organizations in the last decade or so. Eleanor O'Gorman provides a short, 'critical' introductory text to this increasingly complex field, seeking to cover developments within both the research and policy spheres since the end of the Cold War. Defining the topic broadly, she gives most attention to the debates of 'new' versus 'old' wars, the liberal peace paradigm and its impact on peacebuilding policy, and how to define peace and security. The book is quite loosely structured. It includes chapters on 'conflict' and its relationship with poverty and development; the role of 'conflict analysis frameworks' in development project planning; changes in focus and organization within the international aid architecture; the role of gender in armed conflict and development work; and the recent focus on fragile states and liberal statebuilding in Western development policy. Most useful is probably the book's overview of the shifts in focus as well as in organization within Western development policy circles. The chapter on our knowledge of 'conflict' and its relationship with poverty and development is somewhat disappointing, as it is more of an introduction to analytical perspectives on peace and conflict than an overview of what we know about the links between development-related factors and various forms of armed conflict. Moreover, it is hard to see that the gender dimensions of armed conflict are the most relevant to cover in this short book. That being said, the book works as a brief introduction, perhaps particularly to recent development policy debates, for people new to the topic.

Helge Holtermann

Reno, William (2011) *Warfare in Independent Africa.* Cambridge: Cambridge University Press. xxii + 271 pp. ISBN 9780521615525.

Willam Reno's analysis of warfare in independent Africa has three main ingredients: African elites' strategies for gaining power and staying alive; the commercial and political systems within which they operate; and how they utilize limitations and opportunities offered by an international system in flux. Armed with a typology of five categories of rebellion, Reno provides a loosely chronological presentation of the evolution of warfare in Africa since the 1960s. He breaks new ground for the study of rebellions in the 1960s when demonstrating how actors and institutions within the international system played a crucial, although not always prudent, role in their support for liberation movements of various calibers. Reno's chief interest is, however, developments since the end of the Cold War: to explain the rationale of currently predominant warlord rebellions and the less ambitious parochial rebellions. An international setting less prone to indulge African rebels, crumbling state control and increased insecurity have changed African elites' fields of leverage – a key concept in the book – and forced them to refashion their strategies for recruitment and justification of their struggles. This book is not a bombshell. The purpose of *Warfare in Independent Africa* is not to prove any high-concept, mono-causal theory about war in Africa or the world as such. It stands in a tradition of down-to-earth empirical studies of politics and conflict in Africa where the main goal is to understand the cases under scrutiny. Reno makes results from a growing field of research accessible in an elegant and rich analysis and takes our understanding of these murky phenomena one step further.

Øystein H Rolandsen

Slater, Dan (2010) *Ordering Power: Contentious Politics and Authoritarian Leviathans in Southeast Asia.* Cambridge: Cambridge University Press. xviii + 324 pp. ISBN 9780521165457.

This groundbreaking study will set the stage for many books to come. Slater asks why some authoritarian states are more stable than others and finds the answer in 'protection pacts' between governments and social elites. What decides the terms of such protection pacts is the level of fear among elites of social revolution, separatism or external aggression. The greater their fear, the more power they yield to the state, and the more they let themselves be taxed. Southeast Asia, with its mix of strong and fragile authoritarianisms as well as democratic elements, forms a fruitful testing ground for comparative political science. It is refreshing to see Slater round off his analysis by showing that theory derived from Southeast Asia may be applicable to other parts of the world, not least Europe. Elite threat perceptions are the 'causal motor' of ordered power. This explains why the Singaporean and Malaysian 'authoritarian Leviathans' are strong and durable whereas the states of the Philippines and Thailand are fragile. The key factor is the relative strength of leftist movements in the aftermath of WWII. Burma and Indonesia's long-term military rule has a different explanation: threat from separatist movements. Slater's treatment of the former South Vietnam is not quite as convincing. However, he ends his book with an interesting remark about a kind of authoritarianism he otherwise leaves out of his analysis – the states born in successful leftist revolutions: China, Laos, North Korea and Vietnam. Drawing from the Mexican experience, he sees such states as prone to internal fragmentation and factionalism. Some of them have existed for a long time, but duration is not the same as durability, he says.

Stein Tønnesson

Stone, Randall W (2011) *Controlling Institutions: International Organizations and the Global Economy.* Cambridge: Cambridge University Press. 256 pp. ISBN 9781107005402.

At a time when the world is tumbling from one financial crisis to the next, some look with hope, others with anger and fear to the International Monetary Fund (IMF). According to the anti-globalization movement and a strange bedfellow – realist international relations scholars – the IMF is simply a tool in the service of US interests. Randall Stone advances a more sophisticated model of informal governance and US influence over the IMF and international organizations. Stone suggests that Washington is ready to accept comparatively low levels of formal decisionmaking power in international institutions, knowing that US policymakers can use informal mechanisms to control these institutions when vital US interests are at stake. The USA's informal influence is built upon organizational advantages such as superior access to information and the power to persuade key officials. These informal resources allow Washington to shape key IMF decisions despite holding only 17% of votes. Stone's analysis is rigorous, including case studies on the World Trade Organization and the EU. Yet, Stone's model may overstate leading powers' ability to take control of an organization. It implies that the USA can overcome bureaucratic resistance alongside secondary powers' opposition whenever necessary. In our increasingly multi-polar world, secondary powers are becoming more willing to unite to block leading states' efforts at manipulation of institutions. For example, even at the height of US hegemony, Germany and France prevented NATO from endorsing the 2003 US invasion of Iraq. Nonetheless, *Controlling Institutions* makes an important contribution to the contemporary debate on the scope and nature of global governance. Stone's book is essential reading for all scholars and practitioners who are interested in learning how international institutions really operate.

Michael F Harsch

Toft, Monica Duffy; Daniel Philpott & Timothy Samuel Shah (2011) *God's Century: Resurgent Religion and Global Politics*. New York: WW Norton. 276 pp. ISBN 9780393069266.

Delivering another blow to secularization theory, *God's Century* argues that religious individuals and institutions are and will continue to be important political actors. But whether they are actors for violence or peace, for totalitarianism or democracy – indeed, whether they are effective or ineffective actors – depends on two variables, according to the authors. The first is the relationship between religion and government in each particular state: is religion independent of or integrated with political institutions, and is the relationship consensual or conflictual? The second is the specific 'political theology' of the religion: does it possess a theology of peace or of violence? While the latter explanation sounds (and to some extent is) tautological, the authors' point is that religious beliefs matter; religion is not a mere epiphenomenon of more 'real' forces like class or ethnicity. With the aid of many historical and contemporary examples, and supported by tables and charts, the book explores the rise of politically assertive religion (partly as a consequence of liberalization and democratization, together with modern media) and the contribution of political religion to global democracy and to global violence and terrorism. The book acknowledges that religions can be agents for peace and justice but that 'religious civil wars' can be even more virulent than secular struggles. The final chapter presents 'ten rules for surviving God's century', on the (probably correct) premises that religion will not be fading anytime soon and that its effects – for good or bad – will remain significant. The book is written in a popular and accessible style but offers some information and insights for scholars too.

Jack David Eller

Van Dam, Nikolaos (2011) *The Struggle for Power in Syria: Politics and Society under Asad and the Ba'th Party*, 4th edition. New York: IB Tauris. xiv + 255 pp. ISBN 9781848857605.

Good books on modern Syria are few and hard to come by. Nikolaos Van Dam's work on the rise of the Ba'th regime in Syria, however, stands out as one. It is a short historical account of the rise to power of the current Ba'th regime, following Syrian history only from the last half of the 20th century. Unlike most works on Syria, however, Van Dam's focus is entirely Syrian. This allows for a more concentrated version of events than that which is provided in most accounts of Syrian history, which tend to factor in the regional and international aspects of Syrian politics. This broader picture is obviously necessary, but the insider view that Van Dam provides is a rarer account to come by. It is therefore easier to supplement Van Dam's work than it is to understand Syria without it. The greatest strength of Van Dam's book is that he allows both the Syrian regime itself and its internal opponents, such as the Muslim Brotherhood, to have a voice. Extensive quotations from these actors are used throughout the main text, as well as in three appendixes and in a separate bibliographic chapter titled 'Syrian Ba'thist memoirs'. The book also contains extensive demographic breakdowns of the country, which provide the reader with a deeper understanding of exactly how the minority-based regime functions. If there is anything for which the book can be criticized, it is insufficient updating since the 1996 third edition. Some updates have been made, but they relate mainly to the death of Hafiz al-Asad in 2000.

Jørgen Jensehaugen

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