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WHAT IS THE EVIDENCE THAT SCARCITY AND SHOCKS IN FRESHWATER RESOURCES CAUSE CONFLICT INSTEAD OF PROMOTING COLLABORATION?

Systematic Review

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The views expressed in this document do not necessarily reflect the views of the Department for International Development.

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List of Abbreviations

BAR	*Basins At Risk*
BWR	*Basic Water Requirement*
CINC	*Composite Index of National Capabilities*
COMTRAD	*Commodity Trade Statistics Database*
DFID	*Department for International Development, UK*
DOTS	*Direction of Trade Statistics*
GCM	*Global Climate Model*
GDP	*Gross National Product*
GEMS	*Global Environmental Monitoring System*
GIS	*Geographic Information Systems*
GPCP	*Global Precipitation Climatology Project*
GNI	*Gross National Income*
IA	*Irrigation Association*
ICoW	*International Correlates of War project*
IGO	*Intergovernmental Organisation*
IPCC	*Intergovernmental Panel on Climate Change*
IMR	*Infant Mortality Rate*
IWRM	*Integrated Water Resource Management*
MENA	*Middle East / North Africa*
NRR	*Natural Renewable Resource*
PDSI	*Palmer Drought Severity Index*
PRIO	*International Peace Research Institute, Oslo*
SADC	*South African Development Community*
SCAD	*Social Conflict in Africa Database*
SSA	*Sub-Saharan Africa*
TFDD	*Transboundary Freshwater Dispute Database*
UNCTAD	*United Nations Conference on Trade and Development*
UNEP	*United Nations Environment Programme*
WEIS	*Water Event Intensity Scale*
WRI	*World Resources Institute*

Summary

1. Background
Anthropogenic activities such as the combustion of fossil fuels, land-use change and intensive agriculture are increasingly influencing the Earth's climate and exerting pressure on ecosystems. These changes have amplified the risk of scarcity and shocks (discrete and sudden events) in natural renewable resource (henceforth, NRR) scarcity across the spectrum of spatial scales.

The interplay between freshwater scarcity and conflict/collaboration is the most prominent and referenced of the environment-conflict issues in the Third and Fourth Assessment Reports of the IPCC. Discussions with the review user-group, confirmed that a systematic mapping of the literature in this particular field was a priority.

2. Objectives
To identify and systematically map all published and unpublished research to address the following primary question, '*What is the evidence that scarcity and shocks in freshwater resources cause conflict instead of promoting collaboration?*'

The secondary objectives are to:

- Provide an overview of research activity in the area for different users of research such as practitioners, academics, policymakers, students and the public;
- Inform decisions on what future research might usefully address by identifying gaps in the literature;
- Improve access to knowledge by supporting identification of high quality study design;
- Provide a resource for future systematic reviews in the field.

3. Methods
A search strategy was employed to identify both academic and grey literature using general purpose electronic databases (e.g. Web of Knowledge), web searches, hand searching of key academic journals and consultation with content experts. Our survey of previous reviews was used to test the efficacy of the search strategy.

To be considered for inclusion in this study, a primary study had to match key concepts in the review question.

Relevant subject(s): human populations in arid, semiarid and dry subhumid hydroclimates. nations outside these climatic zones will be excluded. Global studies were also included.

Types of exposure: Any study where a measure of sudden (shocks) or long-term scarcity of freshwater resources is used as the explanatory variable. Studies that only consider freshwater quality were excluded. Both physical and social scarcity of freshwater resources were considered.

Types of outcome: Studies where a measure of human conflict or collaboration as the dependent variable at the micro level (within communities), micro-micro level (between communities), micro-macro (between communities and private/state institutions), and macro-macro (between states).

Types of study: To be included, a study had to be empirical and quantitative in nature, such as an observational, quantitative study analysing freshwater scarcity as an independent variable.

Language: Studies should be published in English.

Date: Studies should be published after 1990.

All reports that meet the inclusion criteria that were available were then coded using EPPI Reviewer 4. The coding was based on generic, methodological and review specific keywords.

Studies were ranked using an assessment framework developed from discussions with experts in the field, and based on their suggestions of the ideal study design for addressing the research question.

4. Main results

From a set of 589 studies identified after the first round of screening, we identified just 47 relevant studies. Of the 47 studies, 19 explored interstate interactions. Just one examined interstate conflict in relation to freshwater scarcity, while the remaining 18 were specifically related to transboundary river basins. At the intrastate level, 15 studies examined the relationship at the national level, while the remaining 13 explored interactions at the sub-national level.

The systematic map suggests research into the impact of freshwater scarcity and conflict/ collaboration is growing. This is true at all spatial scales examined, apart from state-state interactions that were not specifically related to transboundary river basins. However, there is little consensus on the impact of scarcity on social interactions at multiple spatial scales and this is true across the three scales examined (interstate, national-level, micro-level). This is because the research in this field is still at the formative stage, and is limited by data availability.

There is significant heterogeneity between studies. We find that divergent definitions of conflict/collaboration, scarcity, theoretical frameworks and additional explanatory variables are key reasons for variations between study outcomes. As such, we do not attempt to draw any conclusions regarding the direction of the relationship.

The systematic map identifies seven theoretical frameworks that define the literature. The neo-liberal, neo-Malthusian and common property management theoretical frameworks are most commonly used. But, it is only the neo-Malthusian theoretical framework has been adopted across all spatial scales. Neo-liberal and common property management are used at the interstate (transboundary river basins) and intracommunity levels respectively. Despite the popularity of the neo-Malthusian theoretical framework, the causal pathway posited by this theory not widely supported by the literature identified in this review.

At the intrastate level, no study considered the impact of scarcity on collaborative interactions. At the transboundary and micro-levels, however, the distribution between collaborative and conflictive interactions was much more balanced. However, studies at all spatial scales considered rarely examined multiple outcomes in the same analyses. Instead, binary variables such as treaty/no treaty or conflict/ no conflict are most commonly employed.

It is only at the micro-level (i.e. intercommunity, intracommunity interactions) that multiple dimensions of the collaboration-conflict spectrum are explored. Here, multiple indicators of collaboration are observed and analysed such as sharing, participation in local institutions or compliance with local institutional rules.

5. Conclusions

Implications for policy

There are a number of reasons why, despite the increase in studies in recent years, there is, as yet, no clear sign of consensus on the expected societal responses to freshwater scarcity. The heterogeneity of study design is one key reason. This review has shown that studies vary significantly in research question, theoretical frameworks employed, definitions of conflict or collaboration and scarcity, and spatial scale. Furthermore, freshwater scarcity is rarely considered to be the sole driver of conflictive or collaborative interactions between two or more parties. Instead it is regarded as one of many factors that influence social dynamics.

While the quantitative research included in this review may appear to be at odds with the dire predictions cited in early empirical case studies, we caution such conclusions from being drawn from the evidence presented here; particularly when policy makers and researchers seek to identify the implications of this review. The small number studies identified and the

heterogeneity between them means we are not in a position to confirm or refute this position. Furthermore, few studies identified were considered weighted as 'very high' (n=7) or 'high' (n=6) in our assessment of methodological approach and reporting.

Observed and predicted trends in global environmental change, and particularly climate change, means there is an urgent need to develop understanding of the multiple conditions of possibility under which conflict and cooperation emerge when societies are exposed to environmental stress. The huge economic and social costs of violent conflict, means a systematic and coordinated research programme in this field would be worth the investment.

Implications for research

Understanding how and why conflict or collaboration emerge under conditions of scarcity are a critical research questions. However, this review suggests that the field is still formative. This review has identified a number of gaps in the literature and future research priorities. These include:

- A coordinated research strategy of both small-N and large-N studies
- Theory building: the development of new or refined theories.
- Monitoring and datasets, dependent variables: The continuum from harmony to conflict is multidimensional, and therefore requires a broader monitoring and systematic reporting of different forms of social interactions
- Monitoring and datasets, independent variables: More widespread, comprehensive and geo-referenced data for control and interactive terms may make a significant contribution to the robustness of future studies.
- Consideration of groundwater aquifers: one study reported a growth in claims over groundwater aquifers; however, we did not identify any study that specifically addressed groundwater aquifers and conflict or collaboration. This highlights a significant gap in the research
- Continued research into the differentiation between progressive and acute scarcity.
- Additional exploratory variables: There is a need for more research into additional social, economic, political, geographical and historical explanatory variables.
- Continued focus on methodologies that use spatially disaggregated and geo-referenced data: The state-centric approach has the potential to overestimate the risk of conflict.
- An increase in micro-level research: research at this level offers the opportunity to examine the importance of the cultural and historical context.
- Geographical diversity: The review has demonstrated there is a strong geographical bias in the literature. The majority of studies identified at the national level or below were conducted in African states, and in particular SSA
- Interdisciplinary approaches: Future research could benefit from working closely with researchers from other disciplines.
- Future systematic reviews: Systematic reviews are evolving processes. As such we welcome continuation of this work that draw on non-English language studies. Building on this review, further mapping of studies that explore other NRRs is recommended.

- **Main Text**

1. Background

This chapter introduces the aims and rationale for the review that addresses the following question: ***'what is the evidence that scarcity and shocks in freshwater resources cause conflict instead of promoting collaboration?'*** It also explains why the review is being undertaken at this time and the interests of the user group (UK Department for International Development) of the review.

The following Chapter introduces the aims and rationale of the review and presents the conceptual framework for this review. Chapter 2 presents the objectives of the review. In Chapter 3, the systematic review protocol is presented, while Chapter 4 describes results from the search and inclusion strategy and presents the systematic map. Chapter 5 discusses the review and its limitations, and Chapter 6 concludes the report.

1.1 Aims and rationale for the review

The environmental security literature that examines the interplay between direct or indirect impacts of climate change and/or natural renewable resources (NRR) scarcity and shocks and human conflict/collaboration is substantial and growing (Mason et al., 2008; UNEP, 2004). This field has captured the attention of researchers, policy makers, opinion formers and practitioners for at least the past 20 years (Gleditsch, 2001; Gleick, 1993; Renner, 2002; Rogers, 1997; Scheffran and Battaglini, 2011; Yoffe *et al*., 2003). There are three key reasons for this growing attention:

- Anthropogenic activities such as the combustion of fossil fuels, land-use change, intensive agriculture and growth in material consumption is increasingly influencing the Earth's climate and exerting pressure on ecosystems (Rockström *et al*., 2009; Solomon *et al*., 2007). These pressures have amplified the risk of scarcity and shocks across the spectrum of spatial scales in NRR on which humans depend (MEA, 2005; Parry *et al*., 2007). The continuation and potential worsening of these trends is likely to continue over time;
- The high direct and indirect human, social and economic costs at the individual, community or national level associated with violent conflict (Wolf, 2007). For example, conflict can lead to a fall in income levels, a rise in mortality, the spread of disease and the collapse of the education system, as household compositions change, assets are lost, institutions collapse and the economy stalls or shrinks (Bannon and Collier, 2003);
- While often absent from popular and political narratives, there is a need to develop a clear understanding of where, and under what circumstances cooperation or tensions (non-violent and violent) arise in response to shocks or scarcity (Postel and Wolf, 2001). Here, scarcity or distributional disparities may lead individuals, communities or states to seek alliances in order to escape resource imbalances. For example, Deudney (1991) argues that resource scarcity tends to encourage joint efforts while contributing to a network of common interests.

These three factors imply a growing need to develop capacity to monitor, predict, pre-empt or resolve conflicts. Developing an understanding and quantifying a robust relationship between NRR scarcity and human interactions is central developing this capacity. This, in turn is necessary to promoting human and environmental sustainability in a changing global environment.

Despite the attention this field has received, many researchers acknowledge the disconnection between policy rhetoric and empirical evidence in this field (Bernauer *et al*., 2010; Barnett, 2009; Hartmann, 1998; 2010; Katz, 2011; Leach and Mears, 1996; Nordås and Gleditsch, 2009; Theisen, 2010; Toset *et al*., 2000). For example Theisen (2010) writes,

> '*Politicians and NGOs have repeatedly claimed a strong link between climate change and violent conflict…but this is rarely done with reference to existing scholarly work.*' (Theisen, 2010: 6)

According to Hartmann (2010: 233), this disconnect could potentially misdirect policy. For example she argues,

> '*…the portrayal of climate change as a security threat could 'militarise' the provision of development assistance and distort climate policy.*'

In a limited[1] systematic search of the academic literature to explore biases in water research, Gupta and van der Zaag (2009) found that there is a significant focus on the relationship between water scarcity and conflict. The authors conclude,

> '*…water wars hypothesis still very much alive and much research effort focuses on conflict. However, this focus is at the expense of understanding the role of water in fostering cooperation between users, communities and nations. Nearly three times more scientific articles are published on the topic of water conflict than on water cooperation, and articles on conflict are cited five times more frequently.*' (Gupta and van der Zaag, 2009: 15).

Reviews of the literature consistently argue there is little consensus on the direct correlation between climate change, scarcity or shocks in NRR and conflict (Bernauer *et al*., 2010; Buhaug *et al*., 2008; Carius, 2006; Dabelko *et al*, 2000; Gleditsch, 1998; Parry *et al*., 2007; Khagram and Ali, 2006; Mason *et al.*, 2008; Nordås and Gleditsch, 2007; Salehyan, 2008; Wolf, 2007). This is also true for cooperative interactions and the conditions under which they arise. For example in the context of transboundary rivers Kalbhenn (2009) argues that,

> *'…there is still little systematic empirical research on the circumstantialities of cooperative behaviour over shared rivers.'*

The lack of consensus is primarily due to the complex interaction of different variables that lead to the outbreak of human conflict or collaborative outcomes. For example, Bohorquez *et al*., (2009: 911) argue that,

> '*Possible political, ideological, cultural, historical and geographical influences make conflict arguably one of the 'messiest' of all human activities to analyse.*'

Additionally, empirical analyses examining the NRR/security nexus are diverse, varying in terms of method, definition and goal (Dabelko *et al*., 2000; Mason *et al*., 2008). Researchers have also argued there may be no clear relationship because of theoretical (*viz.* understanding of causal pathways) and methodological limitations (*viz.* diverse indicators of climate change and natural resource scarcity, data quality and coverage, different sample sizes, time periods and challenges of attribution) (Bernauer *et al*., 2010). The quality of the literature is also varied. For example, Nordås and Gleditsch (2009: 23) note that much of the climate-conflict literature,

> '*...tends to move from sophisticated climate models to flimsy evidence and (at best) case studies of unknown representativity.*'

Reviews examining the connection between NRR shocks/scarcity and climate change and conflict/cooperation are emerging (Buhaug *et al*., 2008; Carius, 2006; Dabelko *et al*., 2000; Gleditsch, 1998; Parry *et al*., 2007; Khagram and Ali, 2006; McCarthy *et al*. (2001); Mason *et al*., 2008; Nordås and Gleditsch, 2007; Salehyan, 2008). These reviews are limited, however, as they are not systematic.

[1] The authors did not look at grey literature, and only used two academic databases covering the period 1998-2007.

1.1.1 Focus on freshwater scarcity

Following an initial knowledge map to evaluate the scope of the environmental security literature, discussions with the user-group, and given time constraints, the focus of this review specifically considers the empirical relationship between shocks, longer-term scarcity of freshwater resources and conflict/collaboration. This reflects the research priorities of the user-group. We also note that the interplay between freshwater scarcity and conflict/collaboration has also received considerable attention within the environmental security literature. For example, it is the most prominent and referenced environment-conflict issues in the Third and Fourth Assessment Reports of the IPCC (Nordås and Gleditsch, 2009).

Research in this field is applied across the spectrum of scales from the individual to the international levels. Given this, **we consider all spatial scales that include: micro level (intra community), micro-micro level (intercommunity), micro-macro (intrastate), and macro-macro (interstate)**. A brief description scales is presented in Table 1. All four scales will be considered in this review.

Table 1: Description of spatial scale of analysis

Spatial Scale	Description
Interstate	State-state interactions
Intrastate	Interactions reported at the aggregate national level (e.g. civil war).
Intercommunity	Interactions where all or most of the individuals within each community may present a united front in their interactions with a neighbouring community
Intracommunity	Interactions over a very small area between members of the same community.

This review does not consider climate change stress specifically as the explanatory variable (independent variable). Despite the recent burgeoning of literature in this field, there are specific challenges of directly attributing discrete events and long-term changes to NRR to climate change (Stott et al., 2010). This is further compounded by the challenges of attributing conflict to any particular independent variable. However, the policy implications of climate change are discussed in the concluding chapter of this report.

1.2 Conceptual framework

The following section presents the conceptual framework that informs this review. Here we define scarcity and shocks in freshwater resources, conflict and collaboration.

1.2.1 Defining scarcity and shocks in freshwater resources

Within the literature there are multiple definitions of water scarcity which can be broadly defined as physical or social. Physical scarcity relates to absolute scarcity of water caused by natural and anthropogenic processes, while social scarcity is a measure of relative scarcity such as access. As such, physical scarcity relates to a 'volumetric imbalance' between supply and demand, while social scarcity is a distributional imbalance driven by social, political, technological and economic factors (Lankford, 2010). Given this, physical scarcity is not a pre-requisite for social scarcity. Falkenmark *et al*. (1989) describe three types of water scarcity:

Natural scarcity (*insufficient supply*): occurs in arid climates or is due to intermittent drought. Over 25 per cent of the world's population live in water-stressed areas (per capita freshwater availability) (Oki and Kanae, 2006).

Anthropogenic scarcity: occurs through desiccation of the landscape driven by land degradation, population growth and/or economic development. In other words, a volumetric imbalance occurs due to anthropogenic environmental change, and demand pressures. By 2050 Rockström *et al*. (2005) predict that the demand for water for food production will double in order to cope with the needs of the growing human population.

At the same time, increased climate variability and change is expected to modify global hydrological cycles, increasing drought and flood risk (Hirabayashi *et al*., 2008). In the longer-term, climate change is also predicted to amplify hydroclimates over the course of the 21st century, where drier areas will desiccate further, and wetter areas will become wetter (Fung *et al*., 2011). Examples of regions experiencing recurrent water stress include the Sahel, South Africa, the central U.S., Australia, India, Pakistan and North East China (Hanasaki *et al*., 2008).

Regions with large aquifer systems often use groundwater as an additional water resource, particularly if surface water is scarce. If the rate of groundwater extraction exceeds the rate of recharge, depletion can occur. Whilst potentially exacerbating social impacts of freshwater scarcity, the impact of lowering groundwater levels can also have negative impacts on natural stream flow, groundwater fed wetlands, and related ecosystems. Additionally, in deltaic areas, groundwater depletion may lead to land subsidence and salt water intrusion (Wada *et al*., 2010).

Wada *et al*., (2010) estimate that groundwater extraction and depletion has more than doubled since the 1960s. Areas currently experiencing groundwater depletion include: North-East Pakistan, North-West India, North-East China, the Ogallala Aquifer in the central U.S, the San-Joaquin aquifer in the Central Valley of California, Iran, Yemen and the South East of Spain (Ibid.).

Social scarcity: (*unequal distribution*) relates to access, and is a function of political power, government policies, infrastructure/ technology and/or socio-economic relations (Ohlsson and Turton, 1999). Physical scarcity is not a pre-requisite for social scarcity.

While definitions of water scarcity are central to understanding the relationship and dynamics between water, conflict or collaboration, there is little agreement about how best to measure the concept (e.g. Hensel *et al*., 2006). Given this, **the review will consider all three types of scarcity, natural, anthropogenic and social**.

1.2.2 Shocks versus long-term scarcity

The distinction between acute (shocks) and progressive (long-term) scarcity, this is an important distinction for this review.

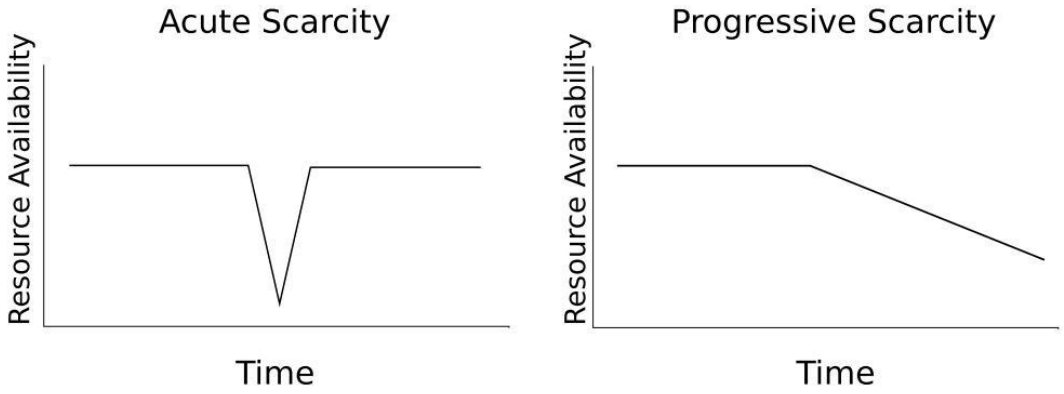
Figure 1 illustrates the difference between the two phenomena.

Shocks are expected to last for a finite time period, after which the resource level should recover to its expected average of availability. Conversely, progressive or long-term scarcity refers to the long-term decline in the availability of a resource. As such, shocks and longer-term scarcity may lead to different social, political and economic outcomes (Bogale and Korf, 2007; Hamner, 2009; Levy *et al*., 2005). For example Bogale and Korf (2007: 247) write,

> '*Scarcity has a dynamic dimension...We need to distinguish gradual deteriorating trends and sudden shocks, mostly drought-induced disaster. Such shocks often accelerate the gradual declining trend, but these two types need to be distinguished, because the resource users develop different coping and adaptive strategies to respond to these different types of environmentally induced challenges to their livelihoods*.'

Additionally, the driver of scarcity could be both absolute (drought, changing rainfall patterns, reduction of melt water, falling water table) and social (increasing demand, poor maintenance of infrastructure, price shocks). **We differentiate between acute and progressive scarcity in the coding of included studies**.

Figure 1: Acute versus progressive scarcity (from Hamner, 2009)



1.2.3 Defining conflict and collaboration

Our initial scoping of the literature revealed that there are no generally accepted definitions for either conflict or collaboration, which in turn leads to wide variations in use of indicators and conceptual models.[2] In the earlier literature (*viz.* pre-2000), conflict is defined in very narrow terms. For example, Ellis and ter Haar (2004) define conflict as,

> *'…forms of interaction that include violence or the threat of violence'.*

More recently the literature has begun to take a more nuanced view. For example, Hammill *et al.* (2009: 2) define conflict as,

> *'…the result of two or more parties (individuals or groups) having or perceiving to have incompatible goals and interests and acting upon these differences.'*

In this broader definition, conflict can be viewed as a multidimensional concept that incorporates contention over both tangible resources (e.g. water, land), and intangible resources (e.g. claims to power or status). As such, the absence of more visible forms of violence does not necessarily mean the absence of conflict. Additionally, Turner (2004) cautions that the absence of conflict is also misleading, as political repression may mask underlying tensions.

Conflictive interactions should not always be viewed as negative. For example, Ruelas-Monjardin *et al.* (2009: 767) argues,

> *'…conflicts have become highly functional to humanity, because they bring forward the opportunity to examine fears and different visions about shared problems'*

As such, they can often be necessary for societies to survive, evolve and develop, and a route to cooperation in the longer-term (Delli Priscoli, 1998; Moore, 2005; Ruelas-Monjardin *et al*. 2009; Turner, 2004).

[2] While our research question specifically refers to collaboration, we find there is little distinction between cooperation and collaboration within the literature and the two terms are often used interchangeably. Cooperation is the most commonly used term within the transboundary river basin literature; however collaboration is more commonly associated with smaller-scale interactions, particularly in the disciplines of community-based natural resource management/ common property management.

Low-level non-violent conflict such as mass demonstrations and strikes, however, can undermine government authority and disrupt the economy (Hendrix and Salehyan, 2010). Furthermore, conflict may also lead to further environmental degradation, especially if it prevents effective management of a resource (Rwabizambuga, 2007).

Cooperation is often viewed as the absence of conflict (e.g. Brochmann and Gleditsch, 2006a, 2006b). For example, in the context of transboundary river basins, Bernauer and Siegfried (2008) argue that,

> *'Cooperation, when defined as a dependent variable in causal explanations of international water management, is usually measured in binary terms - that is, with a yes/no answer to the question whether an agreement, treaty, or international institution is in place.'*

While, others focus on the institutionalised cooperation over rivers such as river treaties (e.g. Conca *et al.*, 2006; Hamner, 2009; Gerlak and Grant, 2009; Tir and Ackerman, 2009; Stinnett and Tir, 2009). For example, Kalbhann (2009: 4) defines cooperation as,

> *'…including both formal agreements (such as river treaties) and non-institutionalised forms of cooperation, such as meetings between environmental ministers to initiate or foster joint management of shared basins.'*

Given this, several researchers have argued that cooperation is a complex concept that needs to be viewed within the wider political economy (Bernauer and Siegfried, 2008; Zeitoun, 2007). This view stems from Keohane's (1984) *Cooperation and International Regimes*. Here, harmony is defined as the absence of conflict, where two (or more) parties can achieve their own goals without the need for communication. Cooperation, however, implies some behavioural adjustment to other's interests, and there may be differences in power or cost of the cooperative arrangement to the parties involved.

If evidence for conflict/collaboration is to be explored, there needs to be a clear disaggregation of the different degrees of conflict and cooperation. While developed for transboundary water relations, and therefore mostly addresses interactions at the macro-macro level, Figure 2 illustrates one such approach developed to define the spectrum of interactions spanning harmony, different collaborative interactions and forms of conflict. The Water Event Intensity Scale (Basins at Risk, henceforth BAR) is described in more detail in

Table **2**. The scale is based on the International Cooperation and Conflict Scale (Azar, 1980); however, the BAR Scale incorporates water specific consideration and terminology (Yoffe and Larson, 2002). This review has taken the broadest view, that conflict and cooperation are less of a dichotomy, but rather a continuum of social interactions spanning from harmony to war.

Figure 2: Conflict Framework: Dynamics, Forms and Relations (Zeitoun, 2007: 106)

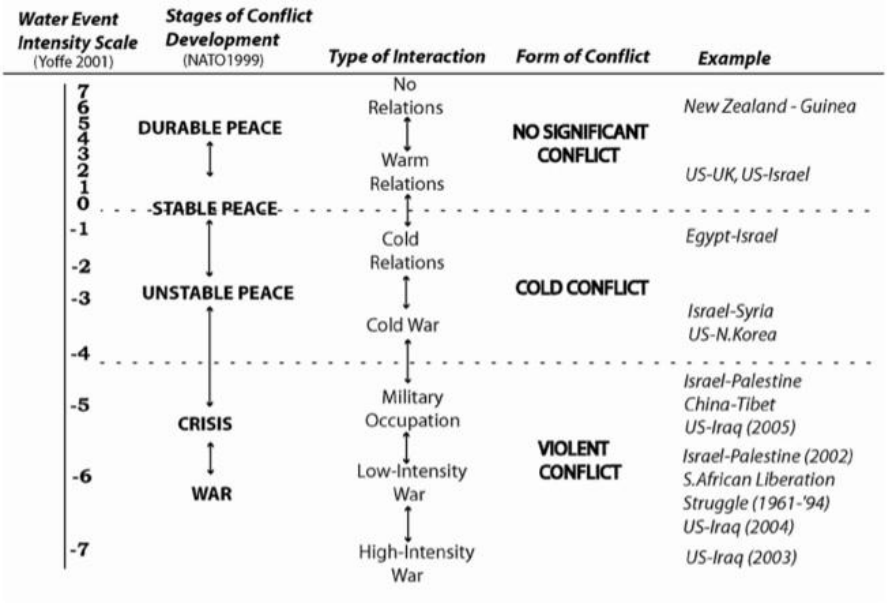


Table 2: The Water (Basins at Risk) Intensity Scale and description of events (Yoffe *et al.* 2003)[3]

BAR Scale	Anti-logged recentered scale	Event description
+7	**198.3**	Voluntary unification of into one nation
+6	**130.4**	Major strategic alliance (regional or international), i.e. international freshwater treaty
+5	**79.4**	Military, economic or strategic support
+4	**43.3**	Non-military economic, technological, or industrial agreement, i.e. legal, cooperative actions between nations that are not treaties; cooperative projects for watershed management, irrigation, poverty alleviation
+3	**19.8**	Cultural or scientific agreement or support (non strategic), i.e. agreements to set up cooperative working groups
+2	**6.6**	Official verbal support of goals, values or regime
+1	**1.0**	Minor official exchanges, talks, or policy expressions – mild verbal support
0	**0.0**	Neutral or non-significant acts for the international situation
-1	**-1.0**	Mild verbal expressions displaying discord in interaction, i.e. both unofficial and official, including diplomatic notes of protest
-2	**-6.6**	Strong verbal expressions displaying discord in interaction, i.e. official interactions only
-3	**-19.8**	Diplomatic/economic hostile actions, i.e. unilateral construction of water projects against another country's protests; reducing flow of water to another country, abrogation of a water agreement
-4	**-43.3**	Political/ military hostile actions
-5	**-79.4**	Small scale military acts
-6	**-130.4**	Extensive war acts causing deaths, dislocation, or high strategic cost
-7	**-198.3**	Formal declaration of war

[3] The BAR Scale values follow an exponential transition (as illustrated by the column Anti-logged re-centred scale) from 0 to +7 (-7) to capture the greater extremes of the scale. For example, the transition from small scale military acts (-5) to extensive war acts (-6) is much greater than the transition from mild to strong verbal hostility (-1 to -2).

2. Objectives

2.1 Primary objective

The primary objective of this review is to describe the nature and coverage of empirical research exploring the links between freshwater shocks and scarcity and conflict/collaboration since 1990.

2.2 Secondary objectives

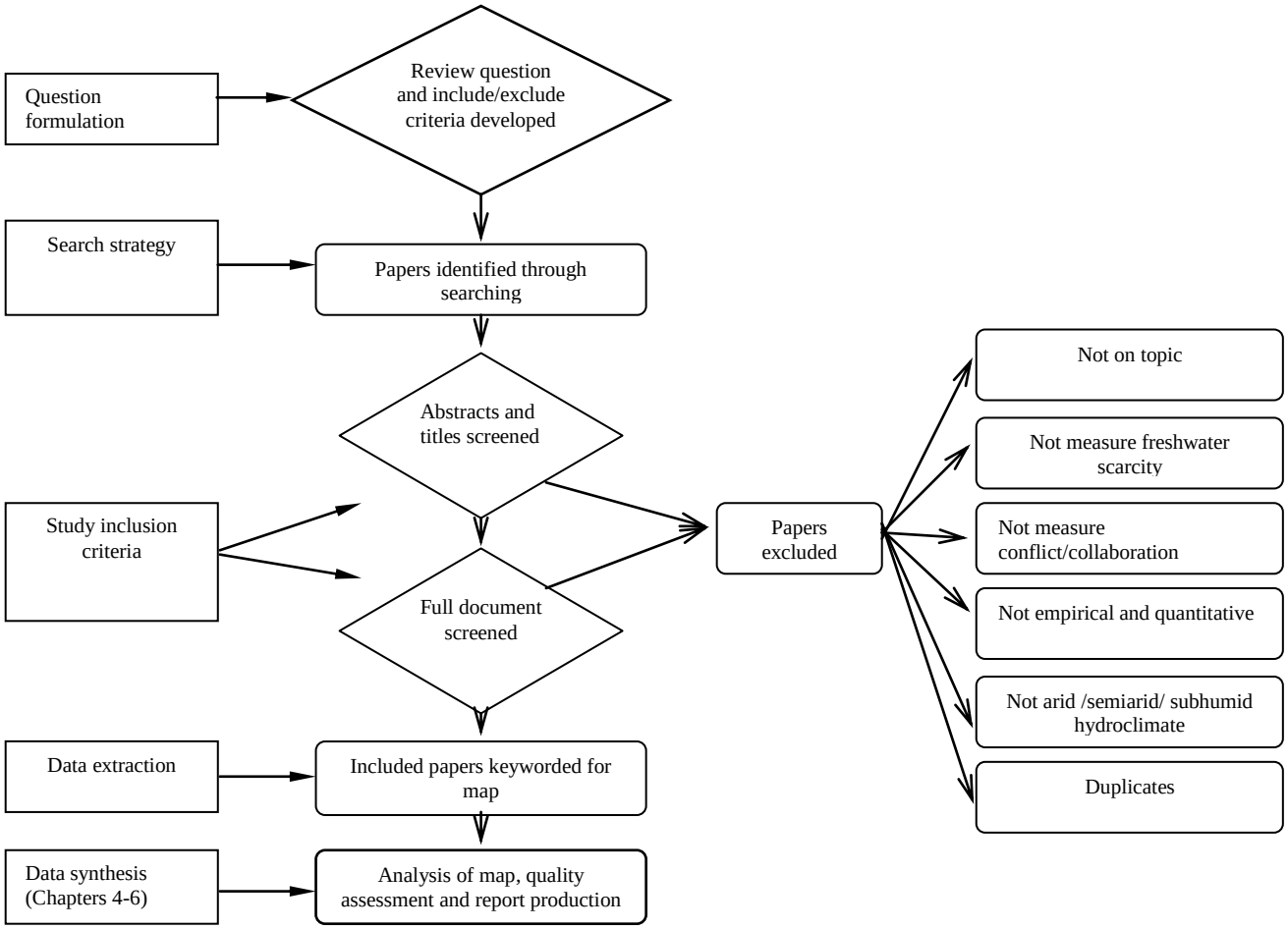
The secondary objectives are to:

- Provide an overview of research activity in the area for different users of research such as practitioners, academics, policymakers, students and the public;
- Inform decisions on what future research might usefully address by identifying gaps in the literature;
- Improve access to knowledge by supporting identification of high quality study design;
- Provide a resource for future systematic reviews in the field.

3. Methods

This chapter describes the methods used in conducting this systematic review. Figure 3 provides an overview of the stages of the review and it is described in detail below.

Figure 3: Review process and operationalisation of methods



3.1 Question formulation

The Department for International Development identified the need for an impartial and independent systematic review to map and evaluate the evidence that scarcity and shocks in freshwater resources cause conflict instead of promoting collaboration.

This systematic review aims to identify and systematically map all published and unpublished research to address the following primary question:

> '*What is the evidence that scarcity and shocks in freshwater resources cause conflict instead of promoting collaboration?*'

The question originally posed in the DFID call for systematic review proposals was: What is the evidence that scarcity and shocks in renewable natural resources and climate change cause conflict instead of promoting collaboration?

Our scoping knowledge map, however, revealed a high volume of literature addressing this question. Reflecting the user group's research priorities, we proposed the reformulation of the research question to specifically refer to shocks and scarcity in freshwater resources.

3.2 Search strategy

Following an initial survey of literature and development of a knowledge map using reference lists from previous reviews (Buhaug *et al*., 2008; Carius, 2006; Dabelko *et al*., 2000; Gleditsch, 1998; Parry *et al*. 2007; Khagram and Ali, 2006; Mason *et al*., 2008; McCarthy *et al.*, 200; Nordås and Gleditsch, 2007; Salehyan, 2008), we identified potentially relevant studies spread across both grey and academic literature.

A search strategy was developed to identify both academic and grey literature. Here, grey literature refers to documents produced and published by governmental agencies, academic institutions and other groups that are not distributed or indexed by commercial publishers. Our survey of previous reviews was used to test the efficacy of the search strategy outlined below.

3.2.1 Search terms and search strings

Following the development of a knowledge map for a subset of the literature, we identified the following search terms from analysis of keywords, title and abstracts.
Two sets of search terms were used, with individual terms separated by Boolean 'OR' operators and sets combined using 'AND'. Wildcard symbols (indicated by a '*') were used where appropriate. These are shown in Table 3. A full record of our search strategy is presented in Appendix B.

Table 3: Initial search terms

	Search terms (searches were carried out using Boolean operators and wildcards)
Exposure terms	water*, riparian*, aquifer*, aqua*, dam, dams, hydrolog*, hydroelectric*, groundwater, drought*, river*, lake*, stream, streams, reservoir*, flood*, irrigat*, rain*, baseflow*, precipitation, fresh*, basin*, flow, drylands
Outcome terms	conflict*, dispute*, insurgen*, war*, violen*, securit*, terror*, strife, peace*, govern*, coercion, cooperat*, "co-operat*", collaborat*, collective, geopolitic*, "international relation*" allocat*, distribut*, shar*, mediat* governance, treaty, treaties, agreement*, manag*

Search strings were piloted on large database (Web of Science) and one subject specific database (Water Conflict and Cooperation Bibliography). Search strings were then revised and developed iteratively for each database (see Appendix B).

3.2.2 Databases and source of grey literature

The list below identifies general-purpose electronic databases used to identify both academic and grey literature. The search strategy used for these databases are shown in full in Appendix B.

- Web of Science
- JSTOR
- Indian Citation Index
- African Journals Online
- BIOSIS Previews
- SCIRUS (ScienceDirect, SAGE publishing, IOP publishing)
- Directory of Open Access Journals (DOAJ)
- PAIS International
- Water Conflict and Cooperation Bibliography
- Biblio.pacinst.org

3.2.3 Internet searches

In addition to a search of academic literature databases we also performed an internet search using the following meta-search engines:

- http://www.alltheweb.com
- http://www.scholar.google.com
- http://www.google.com
- http://www.dogpile.com

The first 50 hits (Word and/or PDF documents where they can be separated) from each Internet search was examined. We also hand-searched the bibliographies of key relevant studies and reviews (although none were systematic) to identify any additional literature.

3.2.4 Other searches

Bibliographies of included material were searched for relevant references. We also sought additional unpublished literature in consultation with recognised experts and practitioners.

The search was also extended to specialist websites. These included: Eldis, Science and Development Network, World Bank, UNEP, Institute for Environmental Security, International Peace Research Institute; African Peace and Conflict Network, Environmental Change and Security Project, Adelphi Research and the World Health Organisation.

All references retrieved from the computerised datasets were exported into bibliographic software package Mendeley prior to assessment of relevance using the inclusion criteria outlined in section 3.3.

3.3 Study inclusion criteria

3.3.1 Time frame

Our inclusion criteria specified studies must be published from 1990 onwards. The time restriction has been applied as the first wave of research into environmental-conflict nexus began in the early1990s (Dabelko, 2004). Additionally, as this is a rapid review with a limited timeframe, it is necessary to limit the time scale.

3.3.2 Language

Foreign language searches were not carried out. The purpose of this review is to carry out a comprehensive search of the literature. Time constraints meant that to include other languages

other than English may compromise the comprehensiveness of the search. This decision was supported by the review user group and methodological experts. As systematic reviews are evolving processes, we would welcome continuation of this work that focuses on languages other than English.

3.3.3 Operationalisation of study inclusion criteria

Members of the review team then applied the remaining inclusion criteria. Two rounds of screening were conducted using first Mendeley and second EPPI Reviewer 4.

The initial round of screening was conducted using information provided by the electronic databases, the study title and, where available, the abstract.

At the second stage of screening, the team applied the same criteria to the full text of each report that was not excluded in the first round of the screening and was available to the review team by Monday 17th January 2011.

The criteria applied by the review team were operationalised using the codes shown in Table 4. Codes were applied to the My Tags field of Mendeley to record the process of exclusion. Coding was applied in the order shown in Table 4.

Table 4: Coding for screening studies[4]

Code	Description
S	Exclude scope: not about freshwater resource scarcity and conflict or collaboration
P	Exclude population: not about human populations
F	Exclude exposure: not about freshwater scarcity
C	Exclude outcome: not measure conflict or collaboration
E	Exclude study type: not quantitative and empirical
G	Exclude: not in a semi-arid/arid hydro climate
L	Exclude language: not in English Language
D	Exclude date: published prior to 1990
I	Include
Q	Query for later consensus

To be considered for inclusion in this study, a primary study has to match key concepts in the review question (see § 1.2).

Relevant subject(s): Any study that includes human populations in arid, semiarid and dry subhumid hydroclimates. Studies that only include nations outside these climatic zones will be excluded. Global studies will, however, be included.

Regions were classified according to the Köppen-Geiger Climate Classification (see Appendix A).

Types of exposure: Any study where a measure of sudden (shocks) or long-term scarcity of freshwater resources is used as the explanatory variable. Studies that only consider freshwater quality will be excluded. Both physical and social scarcity of freshwater resources will be considered.

Types of outcome: Studies where a measure of human conflict or collaboration as the dependent variable at the micro level (within communities), micro-micro level (between communities), micro-macro (between communities and private/state institutions), and macro-macro (between states).

Types of study: Our initial knowledge map has shown that data about the relationship between NRR scarcity and conflict and collaboration is available from a wide range of different studies including both qualitative and quantitative designs.

To be included, a study had to be empirical and quantitative in nature, such as an observational, quantitative study analysing freshwater scarcity as an independent variable. We

[4] The codes for approximately the first 60% of studies excluded during the first phase were not retrievable due to an error with *Mendely My Tags* field. These have therefore been reported as "not on topic".

excluded literature that was: qualitative, theoretical, methodological, editorial, commentary, book reviews, policy documents, textbooks, bibliographies, and position papers.

Language: Studies should be published in English.

Date: Studies should be published after 1990.

Two reviewers tested repeatability of the study inclusion criteria on 15% (100) of the studies screened at full text. A Kappa analysis was undertaken to quantify the repeatability for the second phase of screening. The results are shown in Table 5. Where there was divergence, the reviewers then discussed the conflicting papers. The lead reviewer also checked a random sub-sample of excluded studies.

Review team discussions following the Kappa test identified that the main reason for disagreement between included and excluded studies related to identifying whether both the dependent and independent variables required by the inclusion criteria were met. Additionally, Reviewer I included several studies that were not quantitative. In discussion with Reviewer 1, it was clear that they had been acting overcautiously with studies they were unsure about. As was identified in the protocol, when reviewers were uncertain about including/excluding studies, the study was recorded as such, and discussed within the review team in order to arrive at a decision.

Table 5 : Comparison between reviewers and Kappa Test results

		Reviewer 2		
		Exclude	Include	
Reviewer 1	Exclude	74	9	Observed Kappa 0.52
	Include	6	11	

3.4 Assessment of studies

The rapid review identified high volume of literature at the scoping stage, and precluded a full critical appraisal of the literature. At the outset, we anticipated conducting a survey, by presenting experts with a complete list of all study designs identified in the mapping phase and asking them to rank the studies for their appropriateness for addressing the systematic review question.

The heterogeneity between studies revealed in the review, particularly in relation to the independent and dependent variables meant that we revised this initial methodological step and revised our assessment strategy to include the following steps.

- We consulted with several content experts in order to identify an "ideal" research design for the review question. The results of this consultation are presented in §5.2.
- Based on these discussions, we devised an assessment in order to rank methodological approaches. Here, all studies were coded depending on their methodological techniques. These were then ranked according to the accuracy of the method and their scientific rigour. A description of the assessment framework is presented in Table 6.
- Following the assessment of the methodological approach, a second assessment framework for the method employed and reporting within each study was devised. This allows an objective assessment of each study, for example, how well the study was executed, in addition to the more general confidence score of the methodological approach. A range of assessment areas were defined, and various criteria specific to each area were assigned. As this review examined multiple spatial scales, it was necessary to modify the assessment framework for each spatial scale.

- Table **7** shows the assessment framework employed and highlights where modifications were made for different spatial scales.
- The assessment for methodological approach and method and clarify of reporting were combined to provide an overall rating from *low* to *very high*. For studies that scored 5 or above for the methodological approach, the assessment framework for precise methods and reporting was applied (see Table 7). Studies were classed as very high to low based on the framework presented in

Table **8**. Full details of the assessments are presented in Appendix D1-4.

A discussion of the implications of this assessment framework for future work is presented in Chapter 6.

Table 6: Assessment framework for analytical approach

Relative rating of method [5]	Rank	Method	Description
very low → very high	1	Observational/ descriptive statistics	Method involves the collection of observations and their analysis using descriptive statistics. Causality not tested and no statistical significance testing
	2	Analysis of Variance, t-test	The statistical significance of the difference between means is tested. Causality is not tested.
	3	Statistical correlation	Quantitatively examines the relationship between two random variables, and the strength of relationship is presented. Causality is not tested.
	4	Bivariate analysis	Assesses the relative strength of an independent variable in predicting variability in a response variable. Causality is examined.
	5	Multivariate regression with a limited set of explanatory variables	Tests a mechanism for causation, but a weak identification strategy (e.g. does not consider other social, economic *and* political explanatory variables).
	6	Multivariate regression with rich set of explanatory variables AND time varying water scarcity measure.	A rich set of explanatory variables (time trends and country fixed effects for social, economic and political drivers) implies a better identification strategy as it reduces the potential of selection and omitted variable bias.
		Multivariate regression with rich set of explanatory variables AND geographical variation.	
	7	Multivariate regression with rich set of explanatory variables, time varying water scarcity measure AND geographical variation	

[5] Increasing rank signals greater accuracy and scientific robustness of methodological approach.

Table 7: Assessment framework for method and reporting

	Description	Criteria		
		Not done (low)	**Partially done (medium)**	**Done (high)**
Method description (**all spatial scales**)	The ease at which the methodological approach can be extracted from the manuscript, and the replicability of the study.	Not given/ unclear	Mentioned	Clear/ very clear
Theoretical framework and prediction to be tested (**all spatial scales**)	The presence and clarity of a theoretical framework and hypothesis / hypotheses to be tested.	Not given/ unclear	Mentioned	Clear/ very clear
Clarity of reporting (**all spatial scales**)	The ease at which results can be extracted from the manuscript	Unable to extract evidence	Requires effort	Clear/very clear
Statistical significance of results clearly presented (**all spatial scales**)	The ease at which results of statistical significance tests can be extracted from the manuscript	Unable to extract evidence	Requires effort	Clear/very clear
Directly links freshwater issues to response variable (**transboundary rivers only**)	Studies using, for example the 'onset of a militarised interstate dispute' do not assess whether these conflicts are actually linked to freshwater issues, whilst events data (e.g. TFDD) captures collaborative or conflictive events related to freshwater issues.	Not done	n/a	Done
Diversity of independent variable (**transboundary rivers only**)	Zawahri and Gerlak (2009) argue that both cooperation and conflict should be studied jointly, as both interactions might occur simultaneously in the same river basin.	Binary (e.g. conflict/no conflict)	Measures conflict AND collaboration	Measures degree of conflict and collaboration along a scale
Basin disaggregation (**transboundary rivers only**)	This means that states with multiple basins are not aggregated into one unit (e.g. dyad-year). Difference between dyad-year and basin-dyad-year. Studies that use dyad-year rather than basin-dyad-year as the unit of analysis means States with multiple basins are aggregated into one unit. As such this design does not allow for conclusion as to whether specific basins (e.g. those that are densely populated) are more prone to be the subject of bilateral treaties than others / cause of interactions (Kalbhenn, 2009).	Unit of analysis is dyad-year	n/a	Unit of analysis is dyad-basin-year
Spatial disaggregation (**intrastate level only**)	Does not use aggregate country-level datasets for dependent and/or independent (water scarcity measure) variable. There are three reasons for these criteria. First, states rarely have a uniform hydroclimates (see Appendix A); therefore analyses that use aggregate country level data will not capture this variability, potentially leading to over or under estimation of the explanatory variable. Second, as precipitation is a spatially diverse meteorological variable, studies examining acute scarcity using high temporal resolution data but with low spatial resolution will fail to capture this spatial variability. Third, this is also a better estimation strategy, as it will increase variability within the datasets. Spatial disaggregation at the intrastate level is discussed in more detail in §4.5.	Not done	Done for dependent OR independent variable	Done for both dependent AND independent variable

Table 8: Framework for overall study assessment

Overall study assessment	Description
Very high	Studies meeting all criteria and with a methodological rank of 5 or above.
High	Studies meeting all but one of the criterion and with a methodological rank of 5 or above.
Moderate	Studies meeting all but two of the criteria and with a methodological rank of 5 or above.
Low	• Studies failing to meet more than two of the criteria and with a methodological rank of 5 or above. • All studies with a methodological approach rank of 4 or below.

3.5 Data extraction

All reports that met the inclusion criteria that were available were then coded using EPPI Reviewer 4. The coding was based on generic, methodological and review specific keywords and was used to extract data for the systematic map and assessment of studies. Studies were coded using the key wording tool shown in Appendix C. As no systematic mapping exercise has been done in this topic area before, we based our keywording on our initial knowledge map and used generic keywords from Gough *et al*., (2004).

The coding tool was piloted on 5 studies to ensure consistency. The results were then reviewed to address any inconsistencies and revisions to the review-specific codes tool were also made at this stage. Additionally, the lead reviewer independently checked the coding of all studies included.

3.6 Data synthesis

Following the SCIE Systematic Mapping Guidance (Clapton *et al*., 2009), the data synthesis and presentation will describe the extent and focus of the literature identified. Specifically the following will presented and discussed:

- A standardised flow chart of literature records within systematic map;
- Graphic presentations to represent different categories comparatively;
- A discussion and presentation of results from the quality assessment. The results of the map are structured by spatial scale of analysis: transboundary river basins, intrastate and inter-/intra-community;
- Gaps in research highlighted;
- Implications of results in the context of future climate change;
- Limitations of the map;
- Uses of the map

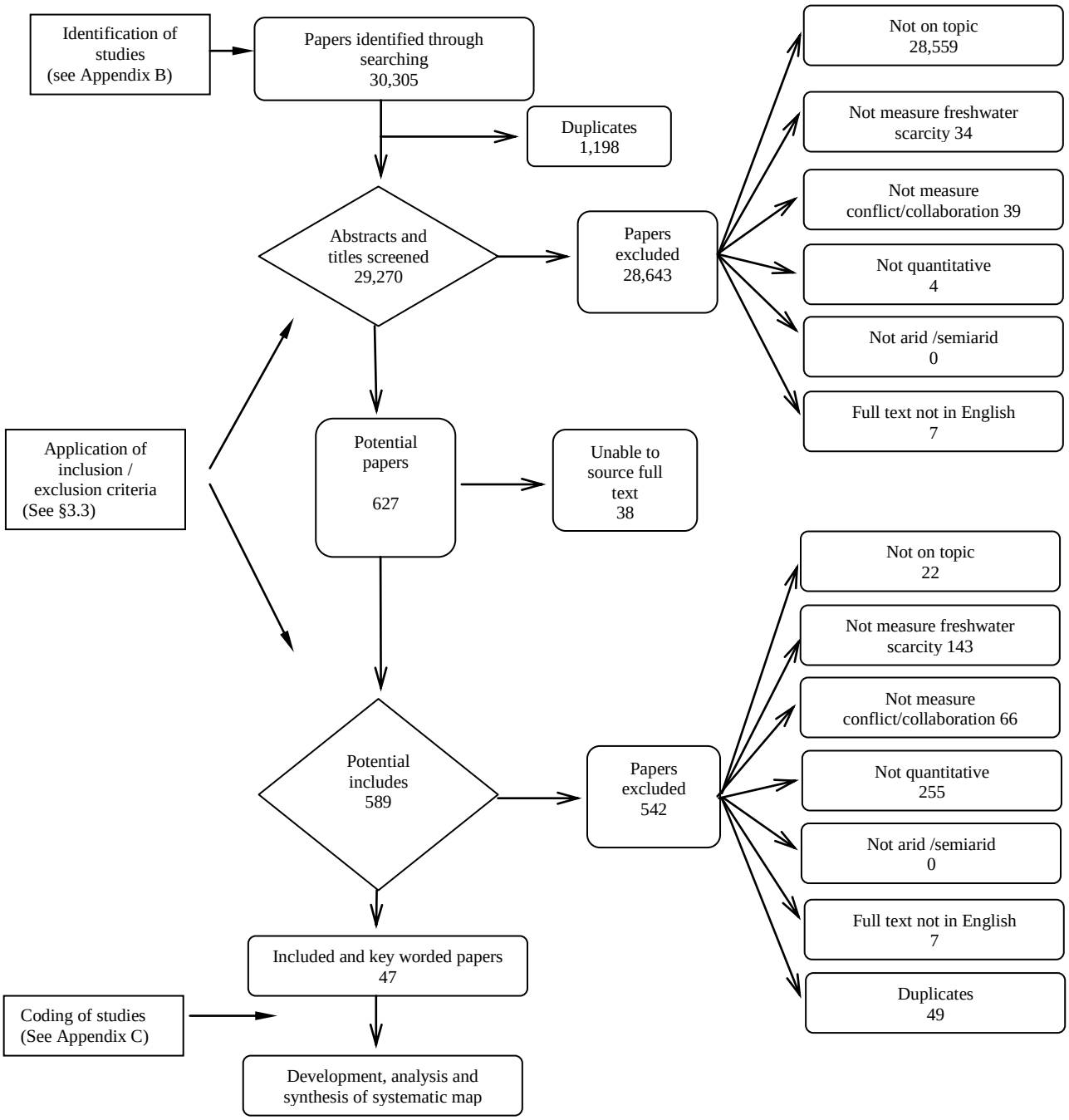
4. Results

Section 4.1 of this chapter reports the numbers of studies identified at each stage of search, the source of studies included in the review, and the publication status of the included studies. Section 4.2 presents the characteristics of these studies based on the methodological and review specific key wording tools broadly defined as conceptual framework/pathway, context, outcomes and research design.

4.1 Review statistics

Following approval of the protocol in November 2010, we finalised searches by the 10th of December 2010. Despite the specific search strategy, and attempts to refine the syntax and search terms, ISI Web of Knowledge generated 20,159 hits alone. Along with the additional searches, we sourced 30,502 hits. The largest proportions (96%) of hits were generated from general-purpose electronic databases. The remaining 1,051 hits were sourced from specialist websites, our web search and literature from experts. After de-duplication the total population of studies were n=29,270. Following our initial screening of abstracts and titles in Mendeley, a total of 627 studies were imported into EPPI- Reviewer 4 for screening at full-text.

Figure 4: Filtering of papers from searching to synthesis



4.2 Systematic map

The remainder of this chapter focuses on the characteristics of the studies identified as meeting the inclusion criteria of the review. The studies are mapped using the results of the coding stage (see Appendix E). There may be instances where totals of the coding counts exceed 47, as many of the keywords are not mutually exclusive.

A number of studies examine the impact of additional environmental explanatory variables, such as land degradation/soil availability or interannual temperature variability. The focus of this review, however, is freshwater scarcity and conflict. As such, the results from these additional analyses have not been reported in this review.

First the distribution of studies across different spatial scales and a map of different theoretical frameworks identified are presented. The reporting of the remainder of the systematic map is organised by spatial scale of analysis (see Table 1 in Chapter 1, for definitions). Studies at inter-/intra-community levels are presented in the same section.

This is then followed by a summary of additional studies identified where precipitation and drought variables were used as instrumental variables in econometric analyses to explore the link between economic growth and civil war. These studies were not included in the map. They do, however, provide a useful insight into the multiple causal pathways for the outbreak of civil war. The chapter concludes with a summary of the findings of the systematic map.

4.2.1 Spatial scale of analysis

Table 9 shows the distribution of studies across different spatial scales (see Table 1 for definitions). Of the studies identified, 38% (n=18) specifically focussed on transboundary river basins. Just one study explored inter-state conflict that was not specifically related to transboundary river basins. The remaining 29 studies explored intra-state interactions related to freshwater scarcity. One study (Hendrix and Salehyan, 2010) performed an analysis at both the national and inter-community level. As such, the coding is not mutually exclusive.

Table 9: Spatial scale of analysis

Spatial scale	Count
Intra-community	7
Inter-community	7
Intra-state	15
Inter-state – not transboundary river basins	1
Transboundary river basins	18
Of which n=2 (dyad)	*18*
Of which n>2 (not mutually exclusive)	*6*

4.2.2 Map of theoretical frameworks

Table 10 presents a map of the seven theoretical frameworks identified within the included studies. The map presents a description of the causal pathway, and the expected outcome from exposure to freshwater scarcity. Here, 'theoretical framework' refers to theory that forms the basis of the hypothesis for the study. It is recognised that the coding of studies by theoretical framework requires the 'broad' definition of a theoretical framework. In reality, many studies have a much more nuanced theoretical framework that builds on previous work from both the environmental security and international relations literature. Authors of studies may also disagree with our classification of their theoretical framework, however, this is a necessary step in order to group multiple studies, and assess the robustness of the evidence supporting each broad theoretical framework. These are further discussed in the following sections.

It is also noted that some studies may test more than one theoretical framework. As such, classifications are not mutually exclusive.

Table 10: Map of theoretical frameworks within the included literature

Theoretical framework	Spatial-scale	Description of causal pathway	Predicted outcome from exposure to scarcity
Neo-Malthusian	Inter-/ intrastate	**Scarcity ➔ Social Effects ➔ Conflict** Resource scarcity is caused by insufficient supply, increasing demand or unequal distribution. This can generate social effects (weak institutions, *resource capture* and *ecological marginalisation*). Social effects interact with one another, with a positive feedback into environmental scarcity. The resulting "grievance", migration and/or instability lead to violent conflict. *Ingenuity* (capacity to adapt) is limited due to the lowering of human capital, exacerbating inequalities (religious, class, ethnic, linguistic). This amplifies the potential for conflict. Variants include a focus on demographics and environmental stress.	Conflict
Cornucopian /neo-liberal	Inter-/ intrastate	**Scarcity ➔ Innovation/ Market Forces ➔ Scarcity Overcome** If resource scarcity does occur, technological innovation, efficiency, conservation or other forms of human ingenuity and cooperation (including institutions and trade interdependence) will overcome it. In other words, there is an assumption that humans can adapt to scarcity through market mechanisms (pricing), technological innovation or other means. For example, neo-liberalists are interested in absolute gains.	Cooperation
Eco-violence	Inter-/Intrastate	**Fall in economic productivity ➔ Social effects ➔ Conflict➔ Fall in economic productivity ➔…** Poor economic conditions and the structure of the political economy may increase the probability of intra- and interstate conflict, and such conflict may in turn increase the probability of recessions and affect economic growth. (there are different causal pathways within this too).	Conflict
Common property management	Inter-/Intrastate	**Institutional failure ➔ Poor Governance/ Ill- Defined Property Rights ➔ Scarcity ➔Conflict** Resource users create institutional arrangements and management regimes that help them allocate benefits equitably. Resource related conflict results from poorly defined and/or poorly governed property, which leads to scarcity -*tragedy of the commons*- and conflict. Conflict is therefore a result of institutional failure. Research tends to focus on locally situated, small user groups and communities.	Under certain conditions, scarcity will lead to cooperation
Scarperation	Inter-/Intrastate	**Abundance/ Extreme scarcity ➔ Absence of cooperation** The relationship between cooperation and freshwater scarcity is curvilinear with an "inverted-U" shape. Cooperation is most likely to take place when the resource is neither abundant (no impetus for cooperation) nor highly scarce (when there is little of the resource to divide among the parties or the degradation too costly to manage). Rather, formal coordination in the form of an international water treaty is most likely to ensue at levels of moderate (or relative) scarcity.	Cooperation likely when resource "moderately scarce"
River orientation	Transboundary river basins	**Cross-boundary rivers / Shared Basin + Scarcity ➔ Conflict** Dyads with rivers running across, rather than along state boundaries are more likely to lead to scarcity-related conflict. Shared river basins are more likely to give rise to scarcity-related conflict.	Conflict
Prospect theory	Inter-/intrastate	**Uncertainty ➔ Cooperation** Leaders prefer certain rather than uncertain outcomes, even if the latter could result in better benefits in the long-term. Treaties (cooperation), can increase certainty for policymakers within a state, and are therefore likely to emerge in situations of scarcity.	Cooperation

4.3 Interstate: Transboundary river basins

The following sections describe the systematic map of included studies examining the relationship between shocks and scarcity in freshwater resources and conflict or collaboration in transboundary river basins. Of the 47 included studies, 18 explored the relationship between freshwater scarcity and conflictive or cooperative interactions at the interstate spatial scale, but particularly focussed on transboundary river basins. As will be shown, these studies vary widely in their theoretical perspectives and the dependent and independent variables used. Given this, any comparison between studies is done so cautiously. Following a description of the map, a brief narrative review of the studies and discussion is presented.

4.3.1 Contextual information, transboundary river basins

Just over 70 per cent of the literature has been published in the past five years; with only one included study published pre-2000. This implies this is a growing field. All included studies at this spatial scale considered dyad (bilateral) interactions, while 6 also examined multilateral interactions (see Table 11). The dominance of dyads as the unit of analysis is largely due to methodological challenges of examining interactions between more than two states in multivariate analyses (Dinar, 2009).

More recent studies have started to use the dyad-basin as a unit of analysis. Kalbhenn (2009) argues that if a state has multiple shared basins, the dyad-year aggregates these all into one unit. As such this design does not permit the examination of whether specific basins (e.g. those that are densely populated or have different geophysical characteristics) are more prone to bilateral treaties/ conflictive interactions than others or have different drivers of interactions. Given this, we included basin disaggregation as a criterion in our assessment framework (see

Table 7). Seven of the 18 studies do not specifically disaggregate inter-state interactions into basins.

Table 11: Spatial scale, transboundary river basins

Dyad/ Multilateral	Study identifier	n
n=2	All	18
n>2	De Stefano (2010); Hamner (2009); Stinnett & Tir (2009); Spector (2000); Wolf (1998); Yoffe *et al*. (2003).	6

The vast majority of studies utilise global datasets (16 out of 18), while two (Brochmann and Hensel, 2007; Hensel and Brochmann, 2008) explored North, South and Central America, Western Europe the Middle East (see Table 12). As such, no study included considered interactions in a single transboundary river basin or focussed exclusively on particular regions. However, three studies (see

Table 18) control for regional differences, specifically MENA and SSA regions (Brochmann and Gleditsch, 2006a; 2006b; Gleditsch et al., 2006). These two regions were isolated due to their arid hydroclimates, but are also considered to be socially, politically and economically unstable, and therefore, hypothesised to be at greater risk of conflictive interactions.

Table 12: Location of study, transboundary river basins

Geographical coverage	Study identifier	n
Global	Brochmann & Gleditsch (2006a); Brochmann & Gleditsch (2006b); De Stefano (2010); Dinar (2009); Dinar *et al* (2010); Dinar *et al*. (2007); Furlong *et al*. (2006); Gleditsch *et al*. (2006); Hamner (2009); Hensel *et al* (2006); Spector (2000); Stinnett & Tir (2009); Tir & Ackerman (2009); Toset *et al*. (2000); Wolf (1998); Yoffe *et al*. (2003).	16
Americas, Western Europe, Middle East	Brochmann & Hensel (2008); Hensel & Brochmann (2007)	2

4.3.2 Systematic map

This section provides an overview of all 18 studies included in this analysis that examined transboundary river relations. Table 13 presents a summary of the systematic map. The full systematic map is presented in Appendix E.

The focus of the summary map is the theoretical framework employed, the independent variable used to characterise water scarcity, the characteristics of the resource scarcity (progressive or acute); the dependent variable (measure of conflict or collaboration or both); the method rank based on the criteria set out in Table 6, the reported outcome (significant, not significant) and the descriptive outcome (direction of relationship and level of significance). The final column provides an overall weight of the study based on the method rank and the assessment of the clarity in reporting the methods and results and the type of independent variable employed. Appendix D.1 presents a full account of the methodological approach ranking and method and reporting assessment for transboundary rivers.

Table 13: Summary of systematic map, transboundary river basins.

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome*	Descriptive outcome**	Overall study assessment[6]
Brochmann and Gleditsch (2006a)	None presented	**Drought** (when one or both states have experienced a drought at any time during the past 5 years, CRED)	Acute	**Cooperation** (treaty existence)	**4**	**Significant**	**Positive and significant** (0.01) relationship between dyads affected by drought and treaty existence.	**Low** (has a panel, but does not use country fixed effects or time trends for this analysis)
				Cooperation (cooperative water events)		**Significant**	**Positive and significant** (0.01) relationship between cooperative water events and drought.	
				Conflict (conflictive water events)		**Significant**	**Positive and significant** (0.01) relationship between conflictive water events and drought.	
				Conflict and Cooperation (all water events)		**Significant**	**Positive and significant** (0.01) relationship between water events (both conflictive and cooperative) and drought.	
				Cooperation (treaty existence)	**7**	**Significant**	**Positive and significant** (0.01) relationship between treaty existence and drought over the period 1975-2000.	**Moderate**
Brochmann and Gleditsch (2006b)	Cornucopian	**Drought** (when one or both states have experienced a drought at any time during the past 5 years,	Acute	**Cooperation** (dyadic trade)	**4**	**Significant**	**Positive and significant** (0.01) relationship between drought experienced by at least one state and dyadic trade – drought in a shared basin means dyads trade more.	**Low**

[6] See Appendix D.1 for full assessment of transboundary river studies

		CRED)		**Cooperation** (joint memberships in international organisations)		**Significant**	**Negative and significant** (0.01) relationship between joint membership of IGOs when drought is experienced by at least one state – drought in a shared basin reduces the joint joining of IGOs	
Brochmann and Hensel (2008)	Neo-liberal	**WSI** (water supply – water discharge and runoff)	Progressive	**Cooperation** (onset of peaceful negotiations)	**4**	**Significant**	**Negative and significant** (0.01) relationship between negotiation onset claims and basin runoff.	**Low**
		WSI (water supply – water discharge and runoff)		**Non-violent conflict** (river claim between dyads)		**Significant**	**Negative and significant** (0.01) relationship between river claims and basin runoff. Also a p**ositive and significant** (0.01) relationship between river claim and water demand.	
De Stefano (2010)	None presented	Water quantity 'event'	Undefined	**Conflict / Cooperation** (water event intensity scale)	**1**	**n/a**	Water quantity and infrastructure were the most controversial water events, but comparison of 1948-1999 hydro political relations to 2000-2008 shows cooperation is dominant outcome from reported water events, including those in the MENA region.	**Low**
Dinar *et al*. (2007)	Scarperation, river orientation	**WSI** (water availability per capita)	Progressive	**Cooperation** (Treaty existence)	**7**	**Not reported**		**High**
		WSI (water availability per capita squared)				**Not reported**		
		WSI (water availability per capita)		**Cooperation** (Number of treaties)		**Significant**	**Positive and significant** (≤ 0.1) relationship in all 6 models	

		WSI (water availability per capita squared)				**Significant**	**Negative and significant** (≤0.05) in all 6 models. Implies a curvilinear relationship between treaty formation and basin precipitation variability.	
		WSI (water availability per capita)		**Cooperation** (number of water allocation treaties)		**Significant**	**Positive and significant** (0.05) relationship in both models	
		WSI (water availability per capita squared)				**Significant**	**Negative and significant** (0.05). Implies a curvilinear relationship between treaty formation and basin precipitation variability.	
Dinar (2009)	Scarperation	**WSI** (water scarcity using the water poverty index)	Progressive	**Cooperation** (treaty existence)	**2**	**Not significant**	Differences in ratios are not statistically significant between low or high probability dyads[7]	**Low**
				Cooperation (number of water treaties in a basin)		**Significant**	Differences in ratios are statistically significant between low or high probability dyads – high probability dyads are more likely to have a greater number of treaties.	
				Cooperation (existence of water allocation treaties)		**Not significant**	Differences in ratios are not statistically significant between low or high probability dyads	
				Cooperation (number of water allocation treaties)		**Not significant**	Differences in ratios are not statistically significant between low or high probability dyads	

[7] Where low-probability dyads are dyads that are expected to have a low probability of cooperation (both riparians in the dyad have low scarcity or both riparians in the dyad have high scarcity) and high-probability dyads are expected to have a high probability of cooperation (both riparians in the dyad have moderate scarcity, or one riparian in the dyad has moderate or high scarcity).

Dinar *et al.* (2010)	Scarperation, neo-liberal	**Meteorological variable** (basin precipitation variability)	Acute	**Cooperation** (treaty formation)	**7**	**Significant**	**Positive and significant** (≤ 0.1) relationship. Negative sign in the square of the explanatory variable	**Very high**
		Meteorological variable (square of basin precipitation variability)				**Significant**	**Negative and significant** (0.1). Implies a curvilinear relationship between treaty formation and basin precipitation variability.	
		WSI (variability of basin runoff				**Significant**	**Positive and significant** (≤ 0.1) relationship. But only for two of the three models.	
		WSI (square of variability of basin runoff				**Significant**	**Negative and significant** (0.05), but only in one of the three models. Weakly implies a curvilinear relationship between treaty formation and basin precipitation variability.	
		Meteorological variable (basin precipitation variability)		**Cooperation** (number of treatie)		**Significant**	**Positive and significant** (≤ 0.1) relationship.	
		Meteorological variable (square of basin precipitation variability)				**Significant**	**Negative and significant** (0.1), but only in one of the three models. Weakly implies a curvilinear relationship between treaty formation and basin precipitation variability.	
		WSI (variability of basin runoff				**Significant**	**Positive and significant** (≤ 0.05) relationship for two of the three	
		WSI (square of variability of basin runoff				**Significant**	**Negative and significant** (≤ 0.05), implies a curvilinear relationship between treaty number and basin precipitation variability.	

Furlong *et al* (2006)	Neo-Malthusian, river orientation	**WSI** (availability of freshwater, individual and shared)	Static measure	**Violent conflict** (incidence of MID, ≥1 fatality)	**5**	**Significant**	**Positive and significant** (0.01) relationship between violent conflict and individual and shared water scarcity for both bivariate and multivariate analyses.	**High**
Gleditsch *et al.* (2006)	Neo-Malthusian, river orientation	**Meteorological variable** (climate normal of precipitation, individual and shared)	Progressive	**Violent conflict** (onset of MID)	**4**	**Significant**	**Positive and significant** (0.05) relationship between violent conflict and dry climates for both bivariate and multivariate analyses.	**Low**
		Drought (CRED, individual and shared)	Acute	**Violent conflict** (onset of MID)		**Not Significant**	No significant relationship observed for both bivariate and multivariate analyses.	
Hamner (2009)	Prospect	**Drought** (PDSI, contemporaneous and lagged by 1 year) *individual drought*)	Acute	**Cooperation** (formation of a treaty specifically addressing freshwater as a resource: hydropower and navigation[8])	**7**	**Significant**	**Positive and significant** (≤ 0.05) relationship between drought (contemporaneous and lagged) and treaty formation. The likelihood of treaty formation is greater when water is abundant.	**Very high**
		Drought (PDSI, contemporaneous, *shared drought*)		**Cooperation** (formation of a treaty specifically addressing freshwater as a resource: hydropower and navigation)		**Significant**	**Negative and significant** (≤ 0.05) relationship between drought and treaty formation (mild and moderate drought only). The likelihood of treaty formation is greater when water is abundant.	

[8] Activities involve dams, riverbank maintenance and who pays for it, and the distribution of benefits from electricity generation by the dams.

		Drought (PDSI, contemporaneous and lagged by 1 year, *individual drought*)	**Cooperation** (formation of a treaty specifically addressing freshwater as a resource: water supply, quality and irrigation treaties[9])	**Significant**	**Positive and significant** (0.05) relationship between lagged PDSI (dry) and treaty formation. **Negative and significant** (0.05) relationship between 3-year average PDSI (wet).
		Drought (PDSI, contemporaneous and lagged by 1 year, *shared drought*)	**Cooperation** (formation of a treaty specifically addressing freshwater as a resource: water supply, quality and irrigation treaties)	**Significant**	**Positive and significant** (0.05) relationship between drought and treaty formation (mild and moderate drought only). The likelihood of treaty formation is greater when water is scarce.
		Drought (PDSI, contemporaneous and lagged by 1 year, *individual drought*)	**Cooperation** (formation of a treaty specifically addressing freshwater as a resource: water supply treaties only[10])	**Not significant**	

[9] Activities involve environmental concerns, pollution, dumping waste, fertiliser/effluent concerns (especially from agricultural activity), and water supply treaties.

[10] Only treaties that specifically divide freshwater among riparians with specific allocated amounts.

		Drought (PDSI, contemporaneous and lagged by 1 year, *shared drought*)		**Cooperation** (formation of a treaty specifically addressing freshwater as a resource: water supply treaties only)		**Significant**	**Positive and significant** (0.01) relationship between drought and treaty formation (mild and moderate drought only). The likelihood of treaty formation is greater when water is scarce.	
Hensel *et al*. (2006)	Neo-Malthusian	**WSI** (challenger state's average annual water use as a percentage of its total renewable resources)	Progressive	**Cooperation** (bilateral negotiations[11])	**7**	**Not significant**	No significant relationship observed for both water scarcity and water demands	**High**
				Cooperation (third party conflict management[12])		**Significant**	**Positive and significant** (0.01) relationship. Likelihood of third party conflict management for challenger state with greater scarcity. But, a **negative and significant** (0.1) relationship between third party conflict management and water demands.	
				Cooperation (effectiveness of peaceful conflict management[13])		**Not significant**	No significant relationship for scarcity levels. But, weakly **positive and significant** (0.1) relationship for challenger state with higher water demands.	

[11] Exclusively involve negotiations between two claimants

[12] Involve a third party whose activity can range from non-binding good offices, mediation, inquiry or conciliation to legally binding arbitration or adjudication.

[13] For example, bilateral negotiations, talks with non-binding third party assistance, or binding arbitration or adjudication.

				Violent conflict (MID)		**Significant**	**Positive and significant** (0.05) relationship. MID more likely when challenger state experiences greater water scarcity. No significant relationship for water demands proxy.	
Hensel and Brochmann (2008)	Neo-Malthusian, river orientation	**WSI** (basin discharge)	Progressive	**Non violent conflict** (outbreak of river claim[14])	**7**	**Significant**	**Negative and significant** (0.01). River claims are more likely to begin when water is scarce (for both basin discharge and runoff). River claims are also more likely to begin when demand for water is greater (0.01).	**High**
		WSI (basin runoff)				**Significant**		
		WSI (basin discharge)		**Violent conflict** (MID specifically attempting to resolve river claims)		**Significant**	**Negative and significant** (0.01). Militarisation of a claim is more likely when water is scarce (both basin discharge and runoff). Militarisation of a claim is more likely when demand for water is greater (0.01). Treaties have a pacifying effect, as river claims are significantly (0.05) less likely to become militarised when a treaty related to the river issue (e.g. water quantity) exists.	
		WSI (basin runoff)				**Significant**		
Spector (2000)	Unclear	**WSI** (water inequality indicator between riparian states)	Progressive	**Cooperation** (treaty existence)	**1**	**N/A**	The greater the difference in access to safe water between dyad-pairs, the more likely a cooperative agreement.	**Low**

[14] Explicit contention between official government representatives of two or more nation-states regarding the use or abuse of international river waters.

Stinett and Tir (2009)	Neo-Malthusian	**WSI** (average per capita water availability for each treaty signatory)	Progressive	**Cooperation** (institutionalised cooperation)	**7**	**Significant**	**Negative and significant** (0.01) relationship between water quantity and institutionalised cooperation.	**Very high**
Tir and Ackerman (2009)	Neo-Malthusian	**WSI** (per capita freshwater availability)	Progressive	**Cooperation** (water quantity treaty existence)	**7**	**Significant**	**Positive and significant** (0.01) relationship between water quantity treaties and water availability.	**High**
				Cooperation (water quality treaty existence)		**Significant**	**Positive and significant** (0.05) relationship between water quality treaties and water availability.	
				Cooperation (water quantity and quality treaty existence)		**Significant**	**Positive and significant** (0.01) relationship between water quantity and quantity treaties and water availability.	
				Cooperation (all river treaty existence)		**Significant**	**Positive and significant** (0.05) relationship between all river treaties and water availability.	
Toset *et al*. (2000)	Neo-Malthusian, river orientation	**WSI** (static measure of per capita freshwater availability)	Progressive	**Violent conflict** (MID)	**3**	**Significant**	**Positive and significant** (0.01) relationship between MID and dyads with joint water scarcity, or where one riparian experiences water scarcity.	**Moderate**
					6	**Significant**	**Positive and significant** (0.01) relationship between MID and dyads with joint water scarcity, or where one riparian experiences water scarcity.	

Wolf (1998)	N/A	Water quantity 'event'	N/A	**Conflict/ Cooperation** Water supply treaty existence	**1**	**N/A**	Shared freshwater resources are hardly ever a major cause of conflict, and that cooperative events between riparian states outnumber conflict events.	**Low**
Yoffe *et al.* (2003)	Neo-Malthusian	**WSI** (Freshwater availability per capita)	Progressive	**Cooperation/ Conflict** (BAR scale)	**3**	**Not significant**		**Low**
		WSI (social water stress, capacity adjusted water per capita)				**Significant**	**Positive and significant** (<0.1) relationship between annual average basin score (BAR) and social water stress.	
		Meteorological variable (type of climate)			**1**	**N/A**	The average annual basin score (BAR) of arid basins are similar to that of basins in most other climate zones	
		Meteorological variable (Annual basin precipitation)				**N/A**	Most cooperative years were those in which rainfall was close to average basin precipitation. Very dry years were marginally more cooperative than wet/very wet years.	

**Not significant* *No significant relationship observed*
**Significant* *Significant relationship observed*
***Figures in parenthesis highlight the level of statistical significance*

4.3.3 Analysis of systematic map

The pre-2005 literature was dominated by non-statistical comparisons, related to observations made from emerging datasets on transboundary water treaties and disputes (see Table 14). For example, the highly cited paper by Wolf (1998) examines trends from the Transboundary Freshwater Dispute Database developed at Oregon State University, but does not attempt to examine causality. This particular study was scored 'low' in our study assessment. However, as Table 14 shows, the majority of included studies used multivariate regressions in order to test the explanatory power of specific theoretical perspectives using a large number of observations (large-N studies).

Table 14: Methodological approaches, transboundary rivers

Methodological approach	Rank	Study identifier	n
Simple descriptive statistics	**1**	De Stefano (2010); Spector (2000); Wolf (1998)	**3**
ANOVA, t-tests	**2**	Dinar (2009)	**1**
Statistical correlation	**3**	-	**0**
Bivariate regression		Yoffe et al. (2003)	**1**
Multivariate regression with a limited set of explanatory variables	**4**	Brochmann & Gleditsch (2006a); Brochmann & Gleditsch (2006b); Brochmann & Hensel (2008); Gleditsch et al. (2006);	**4**
Multivariate regression with rich set of explanatory variables	**5**	Furlong et al. (2006)	**1**
Multivariate regression with rich set of explanatory variables AND time varying water scarcity measure.	**6**	-	**0**
Multivariate regression with rich set of explanatory variables AND geographical variation.		Toset et al. (2000)	**1**
Multivariate regression with rich set of explanatory variables, time varying water scarcity measure AND geographical variation	**7**	Dinar et al. (2010); Dinar et al. (2007); Hamner (2009); Hensel & Brochmann (2008); Hensel et al. (2006); Stinnett & Tir (2009); Tir & Ackerman (2009)	**7**

4.3.3.1 Theoretical frameworks, transboundary river basins

Three main theoretical frameworks dominate the transboundary literature (see

Table 15). These include neo-Malthusian, cornucopian/neo-liberal and river orientation (see Table 10 for definitions). The earlier literature (pre-2007) was dominated by neo-Malthusian theory that regards scarcity as a dominant risk factor to conflictive interactions. More recently, however, there has been an increase in the consideration of theoretical frameworks more common to the international relations discipline. For example, six studies consider cornucopian/ neo-liberal theory.

Three studies (led by the same author) have examined the 'Scarperation' theory that argues the relationship between cooperation and scarcity follows a curvilinear 'inverted-U' relationship, where cooperation is most likely to emerge in conditions of moderate scarcity. When water is abundant there is no need for cooperation (i.e. Keohane's (1984) "harmony" in the context of water quantity). Conversely during high levels of scarcity, conflict is more likely to arise as states try to secure water for their needs. However, the lack of studies examining this theory outside this specific research team suggests that it may not, as yet, be recognised by the wider research community.

The empirical support for the theoretical frameworks presented in

Table 15 is discussed in the narrative review in §4.3.4.

Table 15: Theoretical frameworks, transboundary river basins

Theoretical framework	Study identifier	n
Neo-Malthusian	Furlong *et al* (2006); Gleditsch *et al*. (2006); Hensel *et al* (2006); Hensel &Brochmann (2007) ; Stinnett & Tir (2009) ; Tir & Ackerman (2009) ; Toset *et al*.(2000) ; Yoffe *et al*. (2003) ; Yoffe *et al* (2003).	7
Cornucopian / neo-liberal	Brochmann & Gleditsch (2006b); Brochmann & Hensel (2008); Dinar *et al* (2007, 2010) ; Hensel & Brochmann (2007); Hensel *et al* (2006) ; Tir & Ackerman (2009)	9
Prospect	Hamner (2009)	1
Scarperation	Dinar *et al*. (2007, 2009, 2010)	3
River orientation	Dinar *et al* (2007); Furlong *et al* (2006) ; Gleditsch *et al* (2006) ; Hensel &Brochmann (2007) ; Toset *et al* (2000)	5
Unclear	Brochmann & Gleditsch (2006a); Spector (2000)	2
N/A	De Stefano (2010); Wolf (1998);	2

4.3.3.2 Dependent variables, transboundary river basins

The systematic map reveals that included studies employ a multitude of different dependent variables (see Table 16). This implies there is, as yet, no common definition for either conflict or collaboration within the field.

Table 16 shows that dependent variables employed cover a spectrum of interactions from cooperation to violent conflict and employ a wide range of direct or proxy measures. Additionally, included studies have also examined different stages of interactions such as the formation of treaties, onset of claims, re-negotiation of treaties already in place or institutionalisation of treaties.

Table 16 shows the main dependent variables identified in the included studies. Indicators of cooperation dominate the studies, with 14 studies considering the relationship between scarcity and cooperation. Of these 14 studies, three employ the 15 point Basins at Risk (BAR) scale (Yoffe *et al*., 2003; see also

Figure 2 in Chapter 1) and therefore consider both conflictive and cooperative interactions. A further two studies consider both violent conflict and cooperative interactions but do not employ a scale measure. Only two studies specifically consider non-violent conflict, defined as the onset of river claims. Both studies also consider cooperative interactions. Only three studies consider violent conflict alone.

Table 16: Dependent variables, transboundary river basins

Description	Description	n*
Cooperation	Total number of individual studies considering cooperation	**11**
Treaty formation/ existence	Formation or existence of treaties (Brochmann & Gleditsch 2006a; Dinar *et al*, 2007; Dinar 2009; Dinar *et al* 2010; Hamner, 2009; Spector, 2000; Tir & Ackerman, 2009; Wolf 1998)	8
Proxies	Dyadic trade and joint IGO membership (Brochmann & Gleditsch, 2006b); Additive index of institutional features contained in each agreement (Stinnett & Tir, 2009); number of treaties signed between riparian states (Dinar *et al*., 2007; 2010); share of water allocation issues (Dinar *et al*., 2007).	5
Negotiation onset	Peaceful attempts to settle river claims including both strictly bilateral and third-party mediated negotiations (Brochmann & Hensel, 2008; Hensel *et al*., 2006)	2
Effectiveness of peaceful conflict management	Whether bilateral negotiations, talks with non-binding third part assistance, or binding arbitration or adjudication were able to end the claim in question (Brochmann & Hensel, 2008; Hensel *et al*., 2006)	2
Institutionalisation of treaties	An additive index of institutional features contained in each agreement including: monitoring, enforcement, conflict resolution and, international organisation (Stinnett & Tir, 2009)	1
Non-violent conflict	River claims between dyads: explicit contention between two or more states riparian states over the use of an international river (Hensel & Brochmann, 2008; Brochmann & Hensel, 2008; Hensel *et al*.2006).	**3**
Violent conflict	Militarised International Disputes with a minimum of one fatality from the ICoW dataset (Furlong *et al*., 2006; Hensel & Brochmann, 2008; Gleditsch *et al*., 2006; Hensel, 2006; Toset *et al*)	**5**
Scale measure	Basins of Risk scale, where 1 through 7 is defined as a cooperative event and -1 through -7 is considered a conflictive event (Brochmann & Gleditsch, 2006a; De Stefano *et al*., 2010; Yoffe *et al*., 2003).	3

* *The sum exceeds the total number of studies at this spatial scale as a number studies use multiple measures of cooperation or conflict.*

4.3.3.3 Independent variables, transboundary river basins

From the 18 studies included, six types of independent variables related to freshwater scarcity were identified (see Table 17). Categories identified include: variations in precipitation and runoff; water stress indices; social water stress indicators; drought or reported 'water events'. These indicators also vary from static measures of scarcity (one time surveys with no temporal variation), to those that are time varying and capture progressive scarcity and shocks, although rarely both. The multiple indicators of freshwater scarcity illustrate the lack of a common definition of scarcity in the field.

Of the types of scarcity defined in Chapter 1 (natural, anthropogenic and social), 17 of the studies consider natural scarcity. Only one study considers an indicator related to social scarcity (measure of water inequality between riparian states), however this study was ranked 'low' in the quality assessment (Spector, 2000).

Table 17 shows that the most common measure of freshwater scarcity is the Water Stress Index (per capita freshwater availability). A further three studies consider a water stress indicator that includes social parameters. Two specifically use the Water Poverty Index that weights the Water Stress Index with the Human Development Index (HDI), while only one considers inequality in access to safe water between riparian states.

However, Hamner (2009) argues that the WSI measure introduces problems of multicollinearity[15] if population measures are included in multivariate analyses. Researchers have tended avoid water stress indicators that integrate social parameters to avoid endogeneity. Only one study used a scarcity indicator, which captured access to freshwater resources, yet this ranked low in our quality assessment.

Due to concerns of introducing endogeneity into multivariate analyses that dominate the quantitative research, measures of freshwater scarcity proxies that are exogenous are increasingly being used.[16] These include variables such as inter-annual rainfall variability and the Palmer Drought Severity Index (PDSI).[17]

Three studies use meteorological variables related to precipitation to measure freshwater scarcity. A further five define scarcity as shared drought (between riparian states) or experience of drought. While four of the five use CRED[18] reported drought, one study uses a number of scarcity indicators based on the PDSI (Hamner, 2009). However, it is worth noting that the CRED indicator of drought also considers the capacity of a state to mitigate and adapt

[15] Multicollinearity occurs when two or more explanatory variables within the regression model are highly correlated.

[16] The importance of using an independent variable that is truly independent from the dependent variables and not correlated to them.

[17] The PDSI is a drought index developed by Palmer (1965) that compares the actual amount of precipitation received in an area during a specified period with the normal or average amount expected during that same period. The PDSI is based on a procedure of hydrologic or water balance accounting by which excesses or deficiencies in moisture are determined in relation to average climatic values. Values taken into account in the calculation of the index include precipitation, potential and actual evapotranspiration, infiltration of water into a given soil zone, and runoff. See: http://amsglossary.allenpress.com/glossary/search?id=palmer-drought-severity-index1 (last accessed, July 10, 2011).

[18] Events meet the CRED definition of disaster if one or more of the following criteria are met: 1) 10 or more people were reported killed; 2) 100 people were reported affected; 3) declaration of a state emergency; and/or 4) it led to calls for international assistance see http://www.emdat.be/criteria-and-definition).

to dry conditions, and therefore potentially introduces endogeneity in to the econometric models (Hendrix and Salehyan, 2010).[19]

While there has been a move towards using meteorological variables to deal with potential endogeneity within econometric studies, the relationship between inter-annual variability in precipitation, and or surface run-off, are poor predictors of surface water availability within States (Gizelis & Wooden, 2010).

The systematic map also suggests that the majority of studies fail to distinguish between progressive (long-term) or acute (shocks) scarcity, often using measures of scarcity either have a low temporal resolution or are static. However two studies (Hamner, 2009; Gleditsch et al., 2006) distinguish between progressive scarcity and acute scarcity. Gleditsch et al. (2006) for example considers long-term scarcity measured by 30-year precipitation climate normals[20] and drought experienced over the past 5-years. Hamner (2009) uses the PDSI to distinguish between progressive scarcity (multi-year drought) and shocks (an annual measure of drought). While not specifically discussing the difference between progressive scarcity and shocks, Dinar *et al.*(2010) uses a measure that captures the degree of water supply variability to examine whether higher levels of variability are linked to more cooperative interactions.

Two studies exclusively consider 'water quantity events' reported in the International Water Events Dataset. Based on the BAR scale, the intensity of cooperative or conflictive interactions related to 'water quantity' claims are reported. Both studies only, however, examine historical trends in water quantity related interactions and were ranked 'low' in the quality assessment (De Stefano, 2010; Wolf 1998).

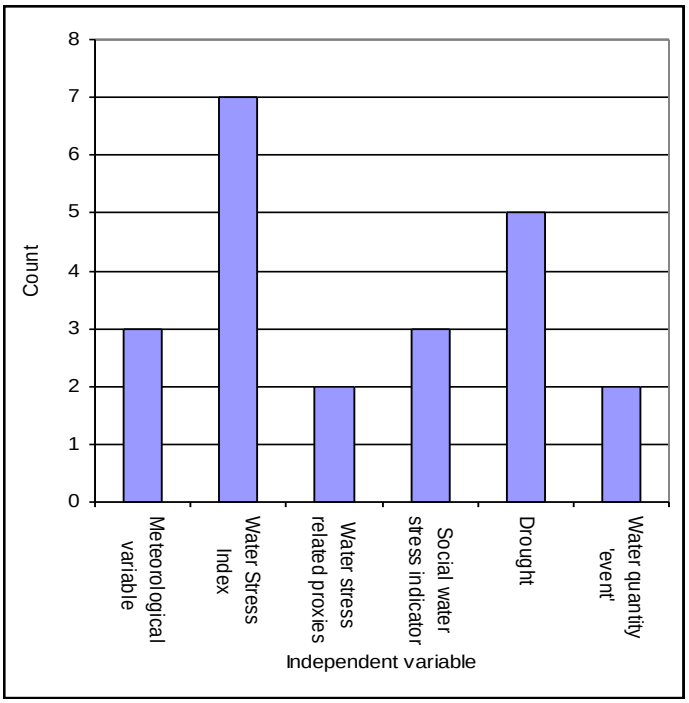
Table 17: Independent (freshwater) variables, transboundary river basins

Independent variable	Description	n
Meteorological variables	Average rainfall over a 30-year period (Gleditsch *et al.*, 2006); interannual precipitation and runoff variability (Dinar *et al*., 2010); annual basin precipitation (Yoffe *et al*., 2003)	**3**
Water Stress Index	Per capita freshwater availability (Dinar *et al*., 2007; Furlong *et al*., 2006; Hensel & Brochmann, 2008; Stinnett & Tir, 2009; Tir & Ackerman, 2009; Toset *et al*., 2000; Yoffe *et al*., 2003)	**7**
Water stress related indicators	Water discharge and runoff; water demand and population density (Brochmann & Hensel, 2008; Hensel *et al*., 2006).	**2**
Social Water Stress Index	Water Poverty Index: per capita freshwater availability weighted with the HDI (Dinar *et al*., 2009; Yoffe *et al*., 2003); average difference in percentage population with access to safe water between top two riparians (Spector, 2000)	**3**
Drought	Drought in the past five years (CRED) (Brochmann & Gleditsch, 2006a; Brochmann & Gleditsch, 2006b; Gleditsch *et al*., 2006); Palmer Drought Severity Index: current year, past year, three-year moving average, shared drought (Hamner, 2009)	**5**
Water quantity 'event'	Water quantity 'event' reported in the International Water Events Dataset (De Stefano, 2010; Wolf 1998).	**2**

Figure 5: Independent (freshwater) variables, transboundary river basins

[19] CRED data for drought are not highly correlated with rainfall deviation measure. There is also a political criteria for inclusion in the CRED dataset, suggest that CRED-based variables may be endogenous to other control variables in the model.

[20] Climate normals refer to 30-year averages and refer to either seasonal or annual climatic conditions.



4.3.3.4 Additional explanatory variables, transboundary river basins

The majority of studies (16 of the 18) include multiple additional explanatory variables (both independent and control variables) within their analyses. De Stefano *et al.* (2010) and Dinar (2009) are the only two included studies that do not include additional explanatory variables. De Stefano *et al.* (2010) examines temporal trends in transboundary river interactions, while Dinar (2009) uses a simple ANOVA study design to explore the 'Scarperation' theoretical framework.

Table 18 presents other explanatory variables considered in 16 of the 18 included analyses. The variables are codified according to whether they measure economic, political/social or geographical factors. A brief description of the variable is presented where necessary, and the final column presents the number of studies using these variables.

Table 18: Other independent/ control variables, transboundary river basins

Economic	**Description**	**n**
Level of economic development	*GDP or energy consumption as a proxy*	7
Wealth	*GDP/capita*	4
Trade interdependence	*Trade between shared basin states*	6
River salience	*An indicator/ set of indicators that capture the value (social, economic, and/or environmental) of the river to a riparian state.*	4
Material Capabilities Composite Index	*Annual values for total population, urban population, iron and steel production, energy consumption, military personnel, and military expenditure of all state members*	4
Agriculture as a % of GDP	-	1
Labour force	*Levels of employment*	1
HDI	*Human Development Index*	1

Political/ social	**Description**	**n**
Regime type	*Describes whether state is democratic, autocratic or in transition.*	12
Alliances	*Entente/ military/diplomatic relations*	9
Major power/ power asymmetry	*Ratio of GDP per capita between basin/dyads, the ratio of their population densities, natural logarithm of the ratio of - -vis the weaker state's capabilities.*	7
Peace history	*Usually operationalised as a decay function from the last conflictive interaction, from the year the state gained independence, or the logged number of years since the last MID*	5
Existing treaties	*Existence of transboundary river treaties*	5

Shared IGO membership	*Riparian states share membership of IGOs*	3
Governance	*Corruption Perception Index*	2
Military capabilities	*Military personnel and military expenditures*	2
Population density	*Population per unit area*	1
Population growth	*Temporal variation of population*	1
Population of dyad	*Total population of dyad*	3
Adequacy of national water legislation	-	1
Failed settlement attempts	*Failed attempts to settle a river claim*	1

Geographical	**Description**	**n**
Proximity	*Distance between capitals and contiguity*	3
Variations in political boundaries	*Time varying political maps over the period of study (recognising that boundaries also evolving).*	
Shared basin	-	3
Upstream/downstream (1)	*Percentage basin in upstream state*	2
Upstream/downstream (2)	*River crosses state boundary*	4
Length of river	-	2
Boundary river	*River forms a boundary between states*	4
Boundary length	*Length of river boundary*	1
Mixed river	*Cross-boundary and boundary river*	3
Basin size	*Physical size of basin*	3
Percentage shared area of basin	-	1
Number of riparians	*Number of states that share a river*	1
Number of dams in basin	-	1
Dam density	*Number of dams/km^2*	1
MENA	*Distinguishes between events in the Middle East and North Africa and the rest of the world*	3
SSA	*Distinguishes between events in Sub-Saharan Africa and the rest of the world*	3

A number of other factors are also considered, although not systematically and are dependent on the theoretical framework considered. Again, this further compounds direct comparison between outcomes of studies. As yet, the field has not agreed on a theoretical framework, or set of empirically established contextual variables considered to be important predictors of riparian state interactions at the transboundary level.

However, given that almost all included studies at this spatial scale consider multiple additional economic, political, social and geographical explanatory variables. This implies that the relationship between freshwater scarcity and conflict/cooperation is not viewed as simple or direct.

4.3.3.5 Quality of studies

As shown in Table 19 half of included studies in this analysis were ranked as low. All of these studies were graded 'low', as their methodological approach rank fell below the threshold. Brochmann and Gleditsch (2006b) were ranked as both low and moderate. This is because the authors performed a number of analyses, most of which did not use a panel. Only one of the analyses within the paper used a panel, however, this was classed as 'moderate' as the authors failed to present a clear theoretical framework for their overall analysis, and used dyad-year as the unit of analysis rather than the dyad-basin-year.

As such, just under half of the included studies reached a rank of high (n=5) and very high (n=3). Only these eight studies will be considered in the brief summary review below. Full details of the assessment of studies can be found in Appendix D.1.

Table 19: Overall assessment of study quality

Study Rank	**n**	**Study identifier**
Very high	3	Dinar *et al*. (2010); Hamner (2009); Stinnett & Tir (2009);
High	5	Dinar *et al*. (2007); Furlong *et al*. (2006); Hensel & Brochmann (2008); Hensel *et al*. (2006); Tir & Ackerman (2009)
Moderate	2	Brochmann & Gleditsch (2006a); Toset *et al*. (2000)

Low	9	Brochmman & Gleditsch (2006a; 2006b); Brochmann & Hensel (2008); De Stefano *et al.* (2010); Dinar (2009); Gleditsch *et al*. (2006); Spector (2000); Wolf (1998); Yoffe *et al*. (2003)

4.3.4 Discussion

The following section presents a brief discussion of the findings presented above, specifically focussing on the studies that were classed as 'high' or 'very high' (see Table 19). A description and brief outcome of the studies are presented in Table 20.

The discussion is broken down into three sections: what is the evidence, quality of studies, and gaps in research.

Table 20: Summary of findings of high-ranking studies, transboundary rivers

Study rank	Study identifier	Specific theoretical framework / hypothesis	Method	Outcome
Very high	Dinar et al (2010)	**Scarperation**: Expect cooperation to be most likely during moderate levels of water supply variability and decreases during low and high levels of water supply variability.	Econometric analysis examining the impact of water supply variability on 'treaty cooperation' between dyads (1961-1990) using a global sample.	Results suggest water supply variability in international bilateral basins creates an impetus for cooperation and support the existence of a curvilinear relationship between water supply variability and treaty cooperation.
	Hamner (2009)	**Prospect**: Expects a state experiencing a period of acute scarcity to experience an increase in the likelihood of the formation of a treaty addressing water issues with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.	Uses a longitudinal (1948-2001) econometric analysis to examine the impact of drought on the likelihood of water treaty formation between a dyad, using a global sample.	Results suggest states are more likely to enter into water treaties during times of water stress. Specifically, bilateral treaties are more likely to come into being during a drought shared by both signatory states.
	Stinnett & Tir (2009)	**Neo-Malthusian**: expect water availability per capita to have a negative impact on the institutionalisation of rivers (cooperation)	Longitudinal (1950-2002) econometric analysis to examine the impact of water scarcity and other factors on the institutional cooperation of rivers, for a global sample.	Results suggest institutionalisation of river treaties is associated with water scarcity.
High	Dinar et al (2007)	**Scarperation**: Expect long-term water supply variability will lead to enduring cooperation between river riparians.	Longitudinal (1961-1990) econometric analysis examining the impact of water scarcity on 'treaty cooperation' between dyads, for a global sample.	Results suggest a curvilinear relationship that reaches statistical significance between water scarcity and 'treaty cooperation.
	Furlong et al. (2006)	**Neo-Malthusian**: expect, ceteris paribus, countries with water scarcity are more likely to exhibit dyadic conflict. And, water scarcity increases the extent to which river sharing is associated with dyadic conflict behaviour.	Longitudinal (1816-1992) econometric analysis to explore the relationship between contiguous territories with shared rivers, water scarcity and conflict, using a global sample.	Observe a positive and significant relationship between violent conflict and individual and shared water scarcity.
	Hensel & Brochmann (2008)	**Neo-Malthusian**: expect river claims to be more likely to being and more likely to become militarised once begun where water resources are less plentiful; and river claims are more likely to	Longitudinal (1900-2001) econometric analysis, examines the conditions under which states are most likely to begin explicit disagreements over rivers. When river claims do emerge, also examine the	Greater levels of scarcity and greater demands on water increase the risk of both claim onset and militarisation. River treaties have mixed effects on claim onset, but significantly reduce miltarisation.

Study rank	Study identifier	Specific theoretical framework / hypothesis	Method	Outcome
		begin, and more likely to become militarised once begun, where demands on water resources are greater,	conditions under which these claims are likely to be militarised, for a global sample	
	Hensel et al. (2006)	**Neo-Malthusian**: expect water scarcity to increase the likelihood of militarised conflict and peaceful settlement attempts, and reduce the likelihood of the end to a river claim.	Using a longitudinal (1900-2001) econometric analysis, examines the relationship between water scarcity and conflict/cooperation and the impact of existing institutional arrangements on pacifying conflictive outcomes for a global sample.	Greater water scarcity increases the likelihood of both militarised conflict and peaceful third party settlement attempts. River specific institutions reduce militarised conflict and increase the effectiveness of peaceful settlement attempts.
	Tir & Ackerman (2009)	**Neo-Malthusian**: expects water availability to reduce the likelihood of river treaties; and water scarcity increases the extent to which river-sharing is associated with dyadic conflict behaviour.	Uses a longitudinal (1948-2000) econometric analysis to examine factors that hinder the emergence of formalised river cooperation for a global sample	Water scarcity has a positive and significant relationship between river treaty existence for all river treaties. The relationship is strongest, however for river treaties specifically relating to water quantity.

4.3.4.1 What is the evidence?

The systematic map presented in Table 13 and Table 20 above suggests that the 'water wars' narrative at the transboundary level is unsubstantiated. It is worth noting, however, that only 5 of the 18 studies consider both collaborative and conflictive interactions (Brochmann and Gleditsch, 2006a; De Stefano, 2010; Hensel *et al*., 2006; Wolf, 1998; Yoffe *et al*., 2003). Only one study (Hensel *et al*., 2006) is ranked 'high', and no study that ranked 'very high' specifically considered both types of interactions.

However, the overall picture the summary of the highest-ranking studies present is that institutionalisation of river treaties is both a product of scarcity and as well as acting a pacifying effect on conflictive interactions. Only one study claims that MID increases in risk with scarcity along (Furlong *et al*., 2008). However, the authors did not consider collaborative interactions, so their analysis only provides a partial view of the scarcity-conflict nexus at this spatial scale. Furthermore, the authors only employ a static measure of water scarcity, an inadequate measure, given that water availability is often both temporally and spatially very variable. Given the limitations of the analysis by Furlong *et al*. (2008), this implies that the most robust literature reviewed here, does not support the neo-Malthusian theoretical framework.

Two of the highest-ranking studies instead present evidence in support of 'Scarperation' (a curvilinear relationship exists between scarcity and collaborative interactions, Dinar *et al*., 2010) and 'prospect' (leaders prefer certain outcomes rather than uncertain outcomes, even if the latter could result in better benefits in the long-term). The third highest-ranking study (Stinnett and Tir, 2009), finds no support for the neo-Malthusian theoretical framework.

This implies that there is no broad consensus on a theoretical framework to explain the relationship between scarcity and interstate interactions. This is also true for definitions of scarcity, conflict and cooperation. And until such consensus is arrived at, studies will not be able to be compared in a systematic way.

The lack of consensus is ultimately driven by availability of data, and whilst this may explain the methodology selected, it fails to address the question of whether NRR scarcity results in conflict of collaboration.

Although ranked 'low' in our quality assessment, it is useful context to highlight that studies exploring historical trends in transboundary water conflicts find that conflictive interactions are rare (De Stefano *et al*., 2010; Wolf, 1998; Yoffe *et al*., 2003). Instead, cooperation, usually defined in these studies as an absence of violent conflict or the existence of transboundary river agreements (treaties) is the most commonly observed outcome. Given this, research has tended to examine conditions under which treaties form, and the effectiveness of existing treaties for forestalling future conflicts. As discussed in our conceptual framework however, a simple treaty or no treaty relationship cannot address the many dimensions to state interactions, which are the subject of the review question.

Water scarcity is not considered to be the sole driver of interstate interactions in relation to transboundary river basins. Almost all studies recognise the importance of a multitude of additional explanatory variables, and all studies testing causality include these.

While this is a growing field of research, the relative unsystematic nature of study design implies this field is in need of substantial methodological development.

4.3.4.2 Gaps in the research

Although De Stefano *et al.* (2010) was ranked 'low' in the quality assessment of studies, their analysis of trends in water related events provides some useful context to future research priorities, particularly with a view to understanding collaborative outcomes. It is noted, however, this study does not present any significance testing nor attempts to test causality of scarcity and conflict. It is simply a observational study examining contemporary (the most recent decade) trends in transboundary river interactions between and within states and comparing this to historical trends over the past 50 years. The authors used English language media-reported events to investigate instances of conflict and cooperation over international water resources during the last 60 years.

De Stefano *et al.* (2010) found that from 1948-1999 and 2000-2008, there has been a move towards less cooperative interactions between some countries. However, almost all negative events reported from 2000 through 2008 were mild verbal expressions of discord through diplomatic-economic hostile actions. And, there was little evidence of the extremes of the BAR scale. Of all the regions analysed, only North America and Europe show an increase in 'water events'. In particular, in North America, there has been an increase in non-violent (legal) conflicts related to water rights or treaties. The MENA region, often assumed to at high risk of conflictive interactions, showed no increase in negative interactions, and cooperative interactions now outweigh conflictive ones.

Of the 14 world basins with the highest number of interactions, only four reported an increase in positive (cooperative) events. These include: Jordan, Tigris-Euphrates/Shatt al Arab, Danube and Ganges-Brahmamaputra-Megha.

Of all the different types of 'water events', the authors found that:

- Infrastructure and water quantity are consistently the most conflictive, while flood control, joint management and technical aspects, have become increasingly cooperative; and
- There has been an increase in groundwater disputes.

Our search failed to identify any studies exploring the relationship between conflict or cooperation between states over groundwater aquifers, implying a gap in the research. However, Hamner (2009) argues that groundwater is insufficiently mapped for large-scale tests, as such this gap may simply due to data limitations. However, as noted in Chapter 1, increasing demands on groundwater, and shrinking reservoirs means that this may become an area of increasing concern.

In addition, very few studies have explored the difference between acute scarcity (shocks) and progressive scarcity. This differentiation is important as a number of scholars have argued this lead to different societal outcomes (Hamner, 2009; Zeitoun, 2006). For example, Zeitoun

(2006) argues that if changes in water quantity occur at speeds greater than society / political institutions can adapt, conditions for conflictive interactions may be more likely to occur. The study of shocks, therefore, also offers the opportunity to explore new hypotheses about the resilience of treaties. This has implications for the datasets currently available, and their temporal resolution.

Recent work by Dinar *et al* (2007, 2009, and 2010) has identified a curvilinear (inverted-U) relationship between the likelihood of cooperation and water scarcity. This implies that the relationship is non-linear. In order to explore this theory in greater detail, however, would also require a higher temporal resolution of freshwater scarcity indicators. This relationship implies there is a threshold between moderate scarcity and extreme scarcity whereby the likelihood of conflictive interactions increases. It is noteworthy that two of these studies were ranked high and very high in our assessment of studies. Yet, other research teams have not covered the theoretical basis for this relationship. While this is a more recent theory compared to the more common neo-Malthusian school of thought, this may indicate little interest in this theory from the wider research community. However, as climate change projections imply an amplification of hydroclimates (Fung *et* al 2011) this relationship may suggest more conflictive interactions are likely in the future. Clearly this is an area for further investigation.

Finally, while not included in our study due to the absence of an exposure term, one study examined the compliance with a treaty to assess cooperation (Bernauer and Sigfried, 2008)). The authors developed an indicator to measure compliance of riparian states to the treaty within the Naryn/Syr Basin. This implies that whilst treaties may exist, this does not necessarily imply the action of collaboration between states. This appears to be an area ripe for further analysis, given that global environmental change, and the pressure of economic development (see §1.2.1) is likely to lead to increased demand on water resources. Existing treaties may be placed under further pressure, and an understanding of the conditions that enhance or undermine the functioning and adaptive capacity of these institutional arrangements should be a key concern.

4.4 Interstate: Other

Just one of the 47 included studies explored the relationship between freshwater scarcity and interstate conflict, although it was not specifically related to transboundary river basins. This study is ranked as 'moderate' (see Appendix D.1 for full details of assessment) in our assessment of study quality and is briefly described below.

Stalley (2003) performed an econometric analysis to explore whether States suffering from scarcity were more likely to be involved in militarised international conflict. Specifically, the author tests the relationship between involvement in interstate conflict using MID[21] as the dependent variable, and progressive scarcity using per capita freshwater availability[22] as one of a number of other environmental scarcity independent variables. Other independent variables included: population density, soil degradation, fish catch, vulnerability (land burden and subsistence farmers) and an aggregate measure of environmental scarcity. Regime type, economic development, economic openness, geographic opportunity, military capability, peace years were controlled for. The analysis broadly tests a neo-Malthusian theoretical framework, and was global in coverage, with the country-year as the unit of analysis.

The author finds no significant relationship between freshwater scarcity and involvement in interstate conflict.

4.4.1Discussion

As there is only one study we have identified that examines the relationship between freshwater scarcity that is not specifically related to transboundary rivers, there is sufficient evidence from which to draw firm conclusions about the impact of scarcity on interstate militarised conflict. Furthermore, the relationship between freshwater scarcity and collaborative interactions has not been examined.

However, this would be a worthwhile field to explore further. Scholars are increasingly linking human migration to environmental scarcity. Transboundary migration often occurs between contiguous states (Raleigh and Jordon, 2009; Theisen *et al*. 2010), and exploration of the collaborative or conflictive (violent or non-violent) interactions could be an interesting area for further research, particularly in terms of predicting the nature of international aid support under such circumstances (e.g. conflict management or institutional support). This highlights a research gap in the quantitative literature. However, as this review has only considered the quantitative literature, there are limitations to this conclusion. The lack of research in this area also implies a lack of interest or funding within the environmental security field for exploring this relationship.

[21] ICoW defines militarised international disputes (MID) as, "explicit threats to use force, display of force, mobilisation of force, or the use of force short of war."

[22] The annual internal water resources comprised of the average flow of rivers and groundwater generated from precipitation – coded as high (≥ 20.1), medium (5.1-20) and low (0-5): in 1000s of m^3.

4.5 Intrastate: National level

The following section briefly summarises the systematic map of included studies classified as 'intrastate, national level'. This includes cross-national studies where the State is the unit of analysis. Studies that used spatially disaggregated data with spatial units at the sub-national level have also been included in this category. Those that specifically explored interactions at the inter-community and intra-community level are presented separately in §4.6.

4.5.1 Contextual information

Of the 15 intrastate studies included, the majority (60%) were based in the African continent (see Table 21). Five of these studies focussed exclusively on SSA, while with the remaining studies were global in coverage. The geographical bias is due to a long history of research exploring the conditions that lead to civil war in African states (see for example Blattman and Miguel, 2010). Additionally, the contention that Africa is the most vulnerable region to climate change was regularly cited a key motivator of research in this particular geographical region.

Table 21: Region of analysis, national level (mutually exclusive)

Location of study	Study identifier	n
Global	Bernauer *et al*. (2010); Gizelis & Wooden (2010); Hauge & Ellingsen (1998); Levy *et al*. (2005); Raleigh & Urdal (2007); Theisen (2008)	6
Africa	Buhaug & Theisen (2010); Hendrix & Salehyan (2010); Kevane & Gray (2008); Theisen *et al*. (2010)	4
SSA	Buhaug (2010); Burke *et al*. (2009); Burke *et al*. (2010); Couttenier and Soubeyran (2010); Hendrix & Glaser (2007)	5

4.5.2 Systematic map

This section provides an overview of all 15 studies included in this review that specifically examined the impact of freshwater scarcity on intrastate interactions at the national level. Table 13 presents a summary of the systematic map. The full systematic map is presented in Appendix E.

As for transboundary rivers, the focus of the summary map is the theoretical framework employed, the independent variable used to characterise water scarcity, the characteristics of the resource scarcity (progressive or acute); the dependent variable (measure of conflict or collaboration or both); the method rank based on the criteria set out in Table 6, the reported outcome (significant, not significant) and the descriptive outcome (direction of relationship and level of significance). The final column provides an overall weight of the study based on the method rank and the assessment of the clarity in reporting the methods and results and the type of independent variable employed. Appendix D.2 presents a full account of the methodological approach ranking and method and reporting assessment for intrastate interactions.

Table 22: Summary of systematic map, intrastate level

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
Bernauer et al (2010)	Eco-violence	**Drought** (Standardised Precipitation Index, 6)	Acute	**Violent** (onset of civil conflict)	**7**	**Not significant**	-	**Low**
		Meteorological variable (yearly moving average of precipitation)	Progressive			**Not significant**	-	
Buhaug (2010)†	Unclear, but analysis implies Neo-Malthusian	**Meteorological variable** (interannual precipitation variability: change since the previous year)	Acute	**Violent conflict** (onset of civil war, ≥1000 battle deaths)	**7**	**Not significant**	There is no significant relationship between any of the precipitation variables across the models. Also estimate the probability of civil war (five variants) for 6 alternative climate measures, based on 1,000 simulations for each model specification. For all but one of the specifications, the 0.05 confidence band is not exceeded, however, there is no consistent direction of the relationship across the models. The only model and specification that returns a significant relationship (0.05) implies major civil wars are more likely in the years following unusually wet periods.	**Low**
		Meteorological variable (absolute precipitation)				**Not significant**		
		Meteorological variable (precipitation anomaly: change compared to the long-term mean annual levels)				**Not significant**		
		Meteorological variable (interannual precipitation variability: change since the previous year)		**Violent conflict** (onset of civil war, ≥25 battle deaths)		**Not significant**		
		Meteorological variable (Precipitation anomaly: change compared to the long-term mean annual levels)				**Not significant**		
		Meteorological variable (absolute precipitation)				**Not significant**		
Buhaug & Theisen (2010)	Neo-Malthusian	**Drought** (Standardised Precipitation Index, 6)	Acute	**Violent conflict** (onset of civil war)	**7**	**Not significant**	-	**Low**
		Drought (geographic share of the country				**Not significant**	-	

[23] See Appendix D1 for full assessment of transboundary river studies.

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
		experiencing drought)						
		Meteorological variable (rainfall deviation from the long-term country average)				**Not significant**	-	
		Meteorological variable (interannual change in rainfall)				**Not significant**	-	
Burke et al (2009) †	Neo-Malthusian	**Meteorological variable**: (interannual precipitation variability)	Acute	**Violent conflict** (incidence of civil war ≥ 1000 battle deaths)	**7**	**Not significant**	No statistical significance is identified for the precipitation independent variables. However a **positive and significant** (0.1) relationships is observed for contemporaneous temperature interannual variability.	**Low**
		Meteorological variable: (interannual precipitation variability, lagged by 1 year)				**Not significant**		
Burke et al (2010) †	Neo-Malthusian	**Meteorological variable**: (interannual precipitation variability, CRU data)	Acute	**Violent conflict** (onset and incidence of civil war ≥ 1000 battle deaths)	**7**	**Not significant**	No statistical significance is identified for the precipitation independent variable. However a **positive and significant** (0.1) relationships is observed for contemporaneous temperature interannual variability.	**Low**
		Meteorological variable: (interannual precipitation variability, lagged by 1 year, CRU data)				**Not significant**	No statistical significance is identified for the precipitation independent variables. However a **positive and significant** (0.1) relationships is observed for temperature interannual variability, lagged by 1 year.	
		Meteorological variable: (interannual precipitation variability, UDel data)				**Not significant**	No statistical significance is identified for the precipitation independent variable. However a **positive and**	

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
							significant (0.05) relationships is observed for contemporaneous temperature interannual variability.	
		Meteorological variable: (interannual precipitation variability, lagged by 1 year, UDel data)				**Significant**	**Positive and significant** relationship (0.1) between civil war incidence and interannual precipitation lagged by 1 year.	
		Meteorological variable: (interannual precipitation variability, CRU data)		**Violent conflict** (onset and incidence of civil war ≥ 25 battle deaths AND ≥ 1000 battle deaths)		**Significant**	**Positive and significant** relationship (0.1) between civil war incidence and contemporaneous precipitation, but not for civil war onset.	
		Meteorological variable: (interannual precipitation variability, lagged by 1 year, CRU data)				**Not significant**	-	
Couttenier and Soubeyran (2010)	None presented	**Drought** (PDSI, 1945-2005)	Acute	**Violent conflict** (onset of civil war, ≥ 1,000 battle deaths in one year)	**7**	**Significant**	**Positive and significant** relationship (0.05) between civil war incidence and drought (with country fixed effects, country specific time trends and both country fixed effects and specific time trends)	**Low**
		Drought (PDSI, 1945-1976)				**Not significant**	-	
		Drought (PDSI, 1977-2005)				**Significant**	**Positive and significant** relationship (0.05) between civil war incidence and drought (with country fixed effects, country specific time trends and both country fixed effects and specific time	

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
							trends)	
Gizelis & Wooden (2011)	Neo-Malthusian	**Meteorological variable** (Internally renewable freshwater resources per capita based on 5-year rainfall averages)	Progressive	**Violent conflict** (onset of civil war)	**7**	**Not significant**	-	**Moderate**
		Other (interactive term of democracy and freshwater resources per capita)				**Significant**	**Negative and significant** (0.01). Implies that institutions influence the ability of states to adapt their freshwater needs by mitigating possible conflicts of interest that could escalate to intrastate wars. Democratic institutions are also more likely to be present in countries with greater availability of freshwater resources per capita.	
Hauge & Ellingsen (1998)[24]	Neo-Malthusian	**WSI** (average annual flow of rivers and groundwater generated from precipitation)	Progressive	**Violent conflict** (onset of civil war)	**6**	**Significant**	**Positive and significant** (0.05) relationship between low freshwater availability and the onset of civil war.	**Moderate**
				Violent conflict (incidence of internal armed conflict)		**Significant**	**Positive and significant** (0.05) relationship between low freshwater availability and the onset of civil war.	
Hendrix & Glaser (2007)	Neo-Malthusian	**WSI** (freshwater availability per capita)	Progressive	**Violent conflict** (onset of civil war)	**7**	**Significant**	**Positive and significant** (0.001) relationship between freshwater availability per capita and the onset of civil war.	**Moderate**

[24] Theisen (2008) unable to replicate the results reported by Hauge & Ellingsen (1998).

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
		Meteorological variable (interannual rainfall variability)	Acute			**Not significant**	-	
		Meteorological variable (interannual rainfall variability lagged by 1 year)				**Significant**	**Negative and significant** (0.01) relationship between interannual rainfall lagged by 1- year and civil war onset.	
Hendrix & Salehyan (2010)[25]	Propose five possible mechanisms related to: water salience, price, rural-urban tensions, migration, pressure on state services and assistance and more general macroeconomic impacts.	**Meteorological variable** (extreme deviations from normal rainfall, linear and square terms)	Acute	**Violent conflict** (onset of civil war)	**7**	**Significant**	**Positive and significant** relationship (0.01) for all forms of conflict reported	**Moderate**
		Meteorological variable (extreme deviations from normal rainfall, lagged by 1 year, linear and square terms)				**Not significant**	-	
		Drought (CRED)				**Not significant**	-	
		Drought (CRED, lagged by 1 year)				**Not significant**	-	
		Flooding (CRED)				**Not significant**	-	
		Flooding (CRED, lagged by one year)				**Significant**	**Negative and significant** relationship (0.1) between flooding event, lagged by one year and civil conflict onset.	
		Meteorological variable (extreme deviations from normal rainfall, linear and square terms)		**All events**		**Significant**	**Positive and significant** relationship (0.01) between the square of the rainfall deviation term and all social conflict for reduced and full	

[25] Hendrix and Salehyan (2010) performed an analysis that used dependent variables that were both at the intrastate level (onset of civil war) and the micro level (communal violence). The results of the micro level analyses are presented in §4.6.

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
							model.	
		Meteorological variable (extreme deviations from normal rainfall, lagged by 1 year, linear and square term)				**Not significant**	-	
		Drought (CRED)				**Not significant**	-	
		Drought (CRED, lagged by 1 year)				**Not significant**	-	
		Meteorological variable (extreme deviations from normal rainfall, linear and square terms)		**Violent events**		**Significant**	**Positive and significant** relationship (0.05) between the square of the rainfall deviation term and violent events for reduced and full model.	
		Meteorological variable (extreme deviations from normal rainfall, lagged by 1 year, linear and square terms)				**Significant**	**Positive and significant** relationship (0.1) between the square of the lagged rainfall deviation term and non-violent events for the full model only	
		Drought (CRED)				**Not significant**	-	
		Drought (CRED, lagged by 1 year)				**Not significant**	-	
		Meteorological variable (extreme deviations from normal rainfall, linear and square terms)		**Non-violent events**		**Significant**	**Positive and significant** relationship between the square of the rainfall deviation term and non-violent events for reduced (0.05) and full model (0.01).	

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
		Meteorological variable (extreme deviations from normal rainfall, lagged by 1 year, linear and square terms)				**Not significant**	-	
		Drought (CRED)				**Not significant**	-	
		Drought (CRED, lagged by 1 year)				**Not significant**	-	
		Meteorological variable (extreme deviations from normal rainfall, linear and square terms)		**Government-targeted events**		**Significant**	**Positive and significant** relationship between the square of the rainfall deviation term and government-targeted events for reduced (0.05) and full model (0.01).	
		Meteorological variable (extreme deviations from normal rainfall, lagged by 1 year, linear and square terms)				**Not significant**	-	
		Drought (CRED)				**Not significant**	-	
		Drought (CRED, lagged by 1 year)				**Not significant**	-	
Kevane & Gray (2008)	None	**Meteorological variable** (interannual precipitation variability, structural breaks)	Acute	**Violent conflict** (onset of internal armed conflict)	**1**	**n/a**	-	**Low**
Levy et al (2005)	Neo-Malthusian	**Meteorological variable** (interannual rainfall lagged by 1 year)	Acute	**Violent conflict** (low level violent conflict)	**7**	**Not significant**	The results for the low level conflict were not reported quantitatively, but were referred to in the conclusion section of the document.	**Low**
		WSI (average surface water per capita)	Progressive			**Not significant**		

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
		Meteorological variable (interannual rainfall variability)	Acute	**Violent conflict** (high level violent conflict)		**Not significant**	-	
		Meteorological variable (interannual rainfall variability lagged by 1 year)	Acute			**Significant**	**Negative and significant** relationship (0.01) between interannual rainfall lagged by 1-year and high level conflict (when rainfall was significantly below normal). The year after a dry year is significantly more likely to experience the outbreak of high intensity internal conflict.	
		Meteorological variable (interannual rainfall variability lagged by 2 years)	Acute			**Not significant**	-	
		Meteorological variable (rainfall cumulative 2-year totals)	Acute			**Not significant**	-	
		WSI (average surface water per capita)	Progressive			**Not significant**	-	
Raleigh & Ural (2007)	Neo-Malthusian	**WSI** (local freshwater scarcity)	Progressive	**Violent conflict** (prevalence of civil internal violent conflict)	**2**	**Significant**	**Positive and significant** (≤ 0.1) relationship between local freshwater scarcity across all models.	**Very high**
Theisen (2008)	Neo-Malthusian	**Meteorological variable** (Interannual rainfall lagged by 1 year)	Acute	**Violent conflict** (onset of civil conflict, ≥25 battle deaths)	**7**	**Not significant**	Also, unable to replicate the results of Hauge and Ellingsen (1998).	**Low**
		WSI (freshwater per capita)	Progressive			**Not significant**		
Theisen *et al*.	Neo-	**Drought**	Acute	**Violent conflict**	**7**	**Not**		**Very high**

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1 = lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment[23]
(2010)	Malthusian	**Drought** (21 alternative drought variables)		(onset of civil war)		**significant**	None of the 21 alternative drought indicators obtain statistical significance with a 0.05 level of uncertainty. The parameters also fail to indicate a consistent direction of the relationship.	

Not significant* ***No significant relationship observed*

Significant ***Significant relationship observed***

*****Figures in parenthesis highlight the level of statistical significance***

† Buhaug (2010) is a response to Burke et al. (2009) and Burke et al (2010) is a response to Buhuag (2010)

4.5.3 Analysis of systematic map

The following section examines the systematic map presented in Table 22. As for transboundary rivers, interest in quantitative analyses of the scarcity-conflict-collaboration nexus has been growing in recent years. The earliest study included in this review is from 1998 (Hauge and Ellingsen, 1998), but the majority of studies have been published from 2007 onwards.

As Table 23 shows, just one of the 15 included studies was use a methodological approach that fell below the rank 5 threshold (Kevane and Gray, 2009). The remaining 14 studies have been coded with a methodological approach of 7, implying that multivariate regression with multiple social, political and economic control variables is the most common method within the quantitative literature at this spatial scale.

Table 23: Methodological approaches, national level

Methodological approach	Rank	n	Study identifier
Simple descriptive statistics	**1**	**1**	Kevane & Gray (2008)
ANOVA, t-tests	**2**	**0**	
Statistical correlation	**3**	**0**	
Bivariate regression		**0**	
Multivariate regression with a limited set of explanatory variables	**4**	**0**	
Multivariate regression with rich set of explanatory variables	**5**	**0**	
Multivariate regression with rich set of explanatory variables AND time varying water scarcity measure.	**6**	**0**	
Multivariate regression with rich set of explanatory variables AND geographical variation.		**0**	
Multivariate regression with rich set of explanatory variables, time varying water scarcity measure AND geographical variation	**7**	**14**	Bernauer et al. (2010); Buhaug (2010); Buhaug & Theisen (2010); Burke et al. (2009); Burke et al. (2010); Couttenier & Soubeyran (2010); Gizelis & Wooden (2010); Hauge & Ellingsen (1998); Hendrix & Glaser (2007); Hendrix & Salehyan (2010); Levy et al. (2007); Raleigh & Urdal (2007); Theisen (2008); Theisen et al. (2010)

4.5.3.2 Theoretical frameworks, national level

The neo-Malthusian framework dominates analyses at the national level.

Table **24** shows that almost two thirds of the included studies employ this theoretical framework. Only one other theoretical framework was considered (Eco-Violence) as four studies either did not specify a theoretical framework, or it was unclear.

Table 24: Theoretical frameworks, national level

Theoretical framework	Study identifier	n
Neo-Malthusian	Buhaug & Theisen (2010); Burke *et al*. (2009); Burke *et al*. (2010); Gizelis & Wooden (2010); Hauge & Ellingsen (1998); Levy *et al*. (2005); Raleigh & Urdal (2007); Theisen (2008); Theisen *et al*. (2010)	**9**
Eco-violence	Bernauer *et al*. (2010); Hendrix & Glaser (2007)	**2**
Unclear	Buhaug (2010); Couttenier and Soubeyran (2010); Hendrix & Salehyan (2010)	**3**
None	Kevane & Gray (2008)	**1**

4.5.3.3 Dependent variables, intrastate level

As Table 25 shows, no study included has so far explored the relationship between cooperation and freshwater scarcity at the intrastate level. This represents a clear gap in the research. Only one study (Hendrix and Salehyan, 2010) explored the relationship between freshwater scarcity and non-violent conflict and communal violence in addition to violent conflict. However, the dependent variable, communal violence, specified intercommunity conflict. Given this, results of this part of their analysis are reported in §4.6. Non-violent conflict referred to contentious collective action such as protests, riots and strikes.

Table 25: Dependent variables, national level

Dependent variable	Description	Study identifier	n
Domestic armed conflict	Greater than 25 battle deaths per year (UCDO/ PRIO project)	Bernauer *et al*. (2010); Buhaug (2010); Buhaug & Theisen (2010); Burke *et al*. (2010); Gizelis & Wooden (2010); Hauge & Ellingsen (1998); Hendrix & Salehyan (2010); Levy *et al*. (2010; Raleigh & Urdal (2007); Theisen (2008); Theisen *et al*. (2010)	11
Civil war	Greater than 1,000 battle deaths per year	Buhaug (2010); Burke *et al*. (2009); Burke *et al*. (2010); Couttenier and Soubeyran (2010); Hauge & Ellingsen (1998); Hendrix & Glaser (2007); Levy *et al*. (2005)	6
Non-violent conflict	Contentious collective action such as protests, riots and strikes	Hendrix & Salehyan (2010)	1
Other	Darfur conflict and any conflict measured by the UCDO/PRIO project	Kevane & Gray (2010)	1

4.5.3.4 Independent variables, national level

The systematic map reveals that included studies employ a number of different independent variables (see Table 25). However, the majority of studies employ interannual variability in precipitation as a measure of scarcity (n=9), various indicators of drought (n=6) and the Water Stress Index. However, only one study uses a social water stress indicator. In contrast to transboundary river research, this implies that studies at the national level tend to examine the impact of acute scarcity on conflict rather than progressive scarcity.

Table 26: Independent variables, national level

Independent variable (freshwater) not mutually exclusive	Description	n
Meteorological variable	Precipitation using various measures (Bernauer *et al*., 2010; Buhaug, 2010; Burke *et al*., 2009; 2010; Gizelis & Wooden, 2010; Hendrix & Glaser, 2007; Hendrix & Salehyan, 2010; Kevane & Gray, 2008; Levy *et al*., 2005;)	**9**
Water Stress Index	Per capita freshwater availability (Gizelis & Wooden, 2010; Hauge & Ellingsen, 1998; Hendrix & Glaser, 2007; Levy *et al*., 2005; Raleigh & Urdal, 2007; Theisen, 2008)	**6**
Social Water Stress Index	Water dependency ratio (Gizelis & Wooden, 2010)	**1**
Drought	Standardised precipitation index, coded drought as 3 consecutive months with at least 1 standard deviation below normal, or 2 consecutive months with at least 1.5 standard deviations below normal (Buhaug & Theisen, 2010; Theisen *et al*., 2010); CRED (Bernauer *et al*.,2010; Buhaug, 2010; Hendrix & Salehyan, 2010)	**6**

4.5.3.5 Additional explanatory variables, national level

A broad range of other independent and control variables were included in the studies, and the frequency of these are detailed in Table 27.The variables are codified according to whether they measure economic, political/social or geographical factors. A brief description of the variable is presented where necessary, and the final column presents the number of studies using these variables.

Table 27: Other independent/ control variables, national level

Economic	**Description**	**n**
Level of development	GDP per capita	9
Income inequality	Gini coefficient	1
Annual GDP	-	2
GDP growth	-	2
Trade openness	-	1
Oil exporting nation	-	4
Infant mortality rate	-	5
Agricultural productivity	Ratio of crop production index over % of irrigated land.	1
Political/ social		**n**
Regime type	Measure of political institutions from Polity IV dataset	11
Political stability	Decay function from last regime change.	4
Governance	Institutionalised democracy	1
Peace history	Decay function from last civil war/ number of consecutive years since 1980	4
Ethno-political marginalisation	Marginalisation of ethnic groups	3
Post-Cold War	Years since the collapse of the Cold War system	1
Urbanisation	Percentage of the total population that lives in urban centres.	1
UK Colony	Historically a UK colony	1
French Colony	Historically a French colony	
Other		**n**
Temperature change	-	4
Flood events	-	1
Population	-	9
Population growth	-	5
Mountainous terrain	-	3
Regional variation	Dummy variable with Europe serving as the baseline category	1
Deforestation	-	1
Land/soil-degradation	-	4
Climate suitability for Eurasian climate	Climate suitability for heavy grass agriculture that typifies the Eurasian land mass.	1
Distance to nearest international border	-	1

4.5.3.6 Quality of studies

Just over half of included studies in this analysis were ranked as low (see Table 28). Only one study fell below the methodological threshold of 5 in the methodological approach rank (Kevane and Gray, 2008). The remainder of the studies failed to spatially disaggregate the independent (freshwater scarcity measure) and dependent variables and also failed to present a clear theoretical framework (Buhaug, 2010; Buhaug and Theisen, 2010; Burke *et al*., 2009; 2010; Couttenier and Soubeyran, 2010; Theisen, 2008) or the clarity of reporting was low (Bernauer *et al*., 2010; Levy *et al*. 2005).

Studies that were ranked as 'moderate' met all the assessment criteria but the authors did not utilise spatially disaggregated independent (specifically measures of freshwater scarcity) and dependent variables (Gizelis and Wooden, 2010; Hauge and Ellingsen (1998); Hendrix and Glaser, 2007; Hendrix and Salehyan, 2010).

While almost all included literature at the national level applies country-level designs, we have argued earlier that spatial disaggregation, specifically of water scarcity and conflictive or collaborative interactions may increase the robustness of the study. First, states rarely have uniform hydroclimates (see Appendix A; Theisen *et al*. 2010), therefore analyses that use aggregate country level data for water scarcity may not capture this variability. This could potentially lead to the over- or under-estimation of the explanatory variable. This is particularly true, as precipitation is a spatially diverse meteorological variable, studies examining acute scarcity using high temporal resolution data will fail to capture this spatial variability (Buhaug and Lujala, 2005). This could also apply to indicators of access to freshwater that may be unrelated to climatic variations. Second, as civil wars and conflict tend to be quite limited in spatial extent; aggregate statistics may not be representative of the conflict zones (Buhaug, 2010). Third, this is also a better estimation strategy, as it will increase variability within the datasets.

While we do recognise there may be theoretical frameworks that require country-level data for political, social and economic explanatory variables, linking a geo-referenced data on freshwater scarcity and conflict or collaboration, provides a more direct way of examining whether a link exists. As Buhaug and Theisen (2010) argue,

> '*...when theory predicts local mechanisms and characteristics conductive to violence, such as political discrimination, economic marginalisation, and crucially, high or increasing environmental degradation, a disaggregated research design should be adopted.*'

The two highest-ranking studies (ranked as 'very high') met all the assessment criteria and had the highest methodological approach rank (Raleigh and Urdal, 2007; Theisen *et al*, 2010)

As such, just under half of the included studies reached a rank of moderate (n=4) and very high (n=2). These six highest-ranking studies will be considered in the brief summary review below. Full details of the assessment of studies can be found in Appendix D.2.

Table 28: Overall assessment of study quality

Study Rank	n	Study identifier
Very high	**3**	Raleigh & Urdal (2007); Theisen *et al* (2010)
High	**0**	-
Moderate	**4**	Gizelis & Wooden (2010); Hauge & Ellingsen (1998); Hendrix & Glaser (2007); Hendrix & Salehyan (2010)
Low	**8**	Bernauer *et a.l* (2010); Burke *et al* (2009; 2010); Buhaug (2010); Buhaug & Theisen (2010); Couttenier & Soubeyran (2010); Kevane & Gray (2008); Levy *et al.* (2005); Theisen (2008)

Table 29: Summary of findings of high-ranking studies, national level

Study rank	Study identifier	Specific theoretical framework / hypothesis	Method	Outcome
Very high	Raleigh & Urdal (2007)	Neo-Malthusian: expect areas with high freshwater scarcity are more likely to experience armed conflict the greater the population growth.	Using geo-referenced data for the sub-national level uses an econometric, longitudinal analysis (1990-2004) to examine the relationship between local resource scarcity and conflict (land degradation and freshwater availability) for a global sample.	While land degradation has a moderate to small effect on the incidence of conflict, local freshwater scarcity significantly increases the likelihood of conflict. The effect is stronger in low-income nations with higher population growth.
	Theisen et al (2010)	Neo-Malthusian: Expect drought to increase the local risk of civil war and expected to be a 'threat-multiplying' shock to already conflict-prone societies (i.e. ethno-political exclusion)	Use a longitudinal (1960-2004) econometric analysis and a high-resolution gridded dataset of that combines geo-referenced and annualised precipitation data with data on the point location of civil war onset and the location-specific drought measures. Allow for direct and conditional relationships, where the effect of drought is contingent on various socio-political characteristics at the local as well as the national level.	Find that drought is unrelated to the short-term risk of civil war. Instead, the local risk of civil war can be explained by socio-political and geographic factors: a politically marginalised population, high infant mortality, proximity to international borders and high local population density.
	Gizelis & Wooden (2010)	Neo-Malthusian: expect water resource scarcity to increase the probability of intrastate wars; and water resource scarcity to contribute to the emergence of autocratic regimes	A longitudinal (1981-2000) econometric analysis to examine the direct and indirect impact of water scarcity on conflict by systematically exploring how intervening factors, such as political institutions might influence the impact of water scarcity on the probability of conflict.	Do not find support for a direct relationship between water scarcity and conflict. However, authors find that institutions influence the ability of states to adapt to their freshwater needs by mitigating possible conflicts of interest that could potentially escalate to intrastate wars. Also find that the availability of water resources can affect the nature and effectiveness of domestic institutions.
	Hauge & Ellingsen (1998)	Neo-Malthusian: expect countries with low freshwater per capita to be more likely to experience domestic armed conflict that countries with a high freshwater availability per capita	A longitudinal (1980-1992) analysis to examine the effects of land degradation, freshwater scarcity, population density and deforestation on interstate conflict at the country level for a global sample.	Results suggest that all factors have a significant impact on the incidence of conflict, including freshwater scarcity. However a later study by Theisen (2008) was unable to replicate these results, questioning the robustness of this finding.

Study rank	Study identifier	Specific theoretical framework / hypothesis	Method	Outcome
	Hendrix & Glaser (2007)	Neo-Malthusian: Expects that higher levels of rainfall relative to previous years will be associated with higher returns to agriculture and therefore lower risk of conflict.	A longitudinal (1981-2002) econometric analysis to examine the impact of both long-term trends and short-term shocks in water availability on the onset of civil war in Sub-Saharan Africa.	Results suggest interannual variability lagged by one year (shocks) in rainfall is a more significant determinant of conflict than measures of climate, land degradation and freshwater resources (long-term trends). Local freshwater scarcity (WSI) is positively and significantly associated with the likelihood of conflict. Additionally, positive changes in rainfall significantly decrease the conflict risk in the following year.
	Hendrix & Salehyan (2010)	No formal theoretical framework, but discusses five plausible mechanisms. Hydro-meteorological disasters may lead to: (1) conflict between consumers due to water salience or desertification; (2) price disputes between rural producers and urban consumers and food price inflation; (3) migration from stressed areas may lead to competition for resources, employment and cultural tensions; (4) strains on government revenues due to the reduction of the tax base and increase demands for services and assistance from disasters; and (5) negative macroeconomic impacts may lead to civil conflict and social disorder.	A longitudinal (1999-2009) econometric analysis to examine the impact of hydro-meteorological disasters (droughts and floods), on civil conflict as well as on civil unrest in Africa (only large-scale conflict is reported here, as the smaller-scale communal conflict is discussed in §4.6).	Find that rainfall variability has a significant effect on both large-scale and smaller-scale instances of political conflict; some evidence that rainfall is correlated with civil war and insurgency, although wetter years are more likely to suffer from violent events. Very high and very low rainfall years increase the likelihood of all other types of political and social conflict indicating the existence of a curvilinear relationship. But, discrete hydro-meteorological events (drought and floods) are not robustly associated with civil or social conflict. However, 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 than scarce rainfall.

4.5.5 Discussion

The following section presents a brief discussion of the findings presented above, with specific reference to the highest ranking studies summarised in Table 29.

The discussion is broken down into three sections: what is the evidence, quality of studies, and gaps in research.

4.5.5.1 What is the evidence?

The vast majority of studies identified were multivariate regression analyses with a specific focus on Africa, and SSA in particular. Two studies had an overall ranking of 'very high' in the quality assessment, as they utilised geo-referenced and spatially disaggregated datasets (Raleigh and Urdal, 2007; Theisen *et al*. 2010). Of these studies, only one reports that progressive freshwater scarcity (WSI) is a strong predictor of violent conflict (Raleigh and Urdal, 2007). Conversely, Theisen *et al*. (2010) concludes that acute freshwater scarcity

(drought) is unrelated to the short-term risk of civil war. Instead, the authors argue that local risk of civil war can be explained by socio-political and geographical factors, a politically marginalised population, high infant mortality, proximity to international borders and high local population density. Heterogeneity between these two studies, however, means that the results are not directly comparable. In particular, Raleigh and Urdal (2007) examine the impact of progressive freshwater scarcity on violent conflict, whilst Theisen *et al*. (2010) uses a measure of acute scarcity. As has been suggested, the social response to these different types of scarcity may lead to different outcomes (Bogale and Korf, 2008; Hendrix and Glaser, 2007; Hendrix and Salehyan, 2010).

The remaining studies weighted as 'moderate' in the quality assessment also revealed contradictory results. While Hauge and Ellingsden (1998) found a significant relationship between progressive freshwater scarcity and violent conflict, Hendrix and Glaser (2007) found that acute scarcity (interannual precipitation variability) was a more significant predictor of violent conflict, but only when other economic, political and demographic are controlled for. It is noted, however, that the analysis performed by Hauge and Ellingsden (1998) was not replicable in a later analysis by Theisen (1998). Theisen (1998) also performed an additional analysis with updated data and the expansion of control variables. The authors still found no significant relationship between freshwater scarcity. As such, the results presented by Hauge and Ellingsden (1998) are questionable, as the relationship observed does not appear to be robust.

In a later analysis, Hendrix and Salehyan (2010) find that rainfall variability has a significant effect on both large-scale instances of political conflict (government-targeted conflict). While there is some evidence that rainfall is correlated with civil war and insurgency, wetter years are more likely to suffer from violent events. Very high and very low rainfall years increase the likelihood of all other types of political and social conflict (violent, non-violent and government-targeted conflict) indicating the existence of a curvilinear relationship. However, the relationship is strongest with respect to violent events, which are more responsive to abundant than scarce rainfall. The authors do not observe a significant relationship between discrete hydrometeorological events (floods and drought using CRED data) for any type of conflict. It is noted, however, that CRED data for drought are not highly correlated with rainfall deviation measures. There is also a political criteria for inclusion in the CRED dataset, suggest that CRED-based variables may be endogenous to other control variables in the model.

Control variables used by Hendrix and Salehyan (2010) tended to fail to perform as expected in explaining the incidence of conflictive events. This suggests that fixed effects models remove all the cross-sectional variation from the dataset, and as such, there is not sufficient variation in regime type, economic development and growth and population and population growth at the country-level to explain within-country variation in the incidence of conflictive events.

The results presented by Gizelis and Wooden (2010) suggest that there is no significant direct relationship between progressive scarcity and violent conflict, although their results implied that strong institutions have a pacifying effect on violent conflict. The authors conclude that institutions influence the ability of states to adapt their freshwater needs by mitigating possible conflicts of interests that could potentially escalates to intrastate war. However, freshwater scarcity is found to have a significant influence on the nature and effectiveness of such institutions.

Due to heterogeneity between studies, caution should be exercised when drawing conclusions across the studies at this spatial scale. However the lack of consistent results implies the research so far is at odds with traditional neo-Malthusian theoretical framework at this spatial scale.

4.5.5.2 Quality of studies

Although only one study failed to meet a methodological approach rank of 5, and the remaining studies were all ranked as 7 (the highest rank), only two studies were classed as very high. This is because spatial disaggregation of the dependent variable (conflict/collaboration) and measure of freshwater scarcity were included in the assessment of study quality.

Due to increasing availability of geo-referenced and spatially disaggregated data, there has been an increase in the number of studies using GIS to spatially resolve their analyses, particularly in relation to dependent variables and independent environmental variables. These studies recognise that scarcity and other explanatory variables are not homogeneous and do not necessarily affect a country equally, and conflictive interactions are not necessarily countrywide.

4.5.5.3 Gaps in the research

The wide majority of studies examined the relationship between freshwater scarcity and violent conflict defined as civil war onset or incidence. And, no study examined the relationship between freshwater scarcity and collaborative interactions at this spatial scale. Although, Hendrix and Salehyan (2010) did explore the relationship between freshwater scarcity and non-violent conflict. Given this, exploring collaborative interactions or different types of conflict other than civil war onset is a clear research gap. This is due to limitations of datasets with global or regional coverage about cooperative interactions. While the Social Conflict in Africa Dataset[26], used by Hendrix and Salehyan (2010) provides a richer dataset of conflictive interactions for the African continent, there is still no wide-spread or systematic reporting of collaborative interactions relating to freshwater in Africa or globally. Development of a systematic reporting methodology at this level would therefore appear to be a research priority.

Given the focus of studies, being predominantly Africa-centric and in particular SSA, there is a clear geographical bias in the current literature. This is primarily because the focus of NRR and conflict has developed from research into determinant of civil war in Africa. Also, given that our search strategy was limited to English language studies, whether this is a gap in the overall literature is unknown at this stage.

The majority of studies use variations in precipitation as a proxy for freshwater scarcity. This approach has been favoured as it reduces potential of endogeneity within analyses, as interannual variations in rainfall are exogenous (at least in the short-term). However, this approach may only be useful in specific geographical regions. It has been argued that the relationship between rainfall and conflict may be mediated through changes in economic growth (see Table 42). This has been applied mainly to SSA, and it is argued that this is an appropriate identification strategy as agriculture is mainly rainfed and irrigation technologies are limited in this region. As such, the relationship between economic prosperity and variations in rainfall relationship is believed to be relatively direct. However, this is a generalisation that is questionable and may not be applicable outside SSA. This also fails to take into account access to surface or groundwater (e.g. distribution). And, as such, does not capture socially constructed scarcity.

Variables that consider social scarcity have tended to be avoided in multivariate analyses as they create estimation problems within the econometric models. This means endogeneity has to be controlled for complicating the methodology. While this is a limitation of the

[26] SCAD contains information on instances of: *'contentious collective action such as protests, riots and strikes; but includes also intragovernmental 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; and extra-governmental violence, or violence by non-state, organised militant group against individuals, rival communal groups, or other social actors not involving the state*.' (Hendrix and Salehyan, 2010)

econometric methodology, it is also a clear gap that needs to be considered. If the explanatory variable used does not capture actually experienced scarcity, then conclusions drawn cannot be considered to be robust.

4.6 Micro level: the inter- and intra-community levels

The following section briefly summarises the systematic map of included studies classified as 'intercommunity' and 'intracommunity. Studies focussing at this scale examine interactions where all or most of the individuals within each community may present a united front in their interactions with a neighbouring community (intercommunity), or examine interactions over a very small area between members of the same community (intracommunity). Here, community refers to both communities of place and interest.

4.6.1 Contextual information

Of the 47 included studies, 14 (30%) were conducted at the micro-level. Seven studies focussed on intracommunity interactions, while seven focussed on intercommunity interactions (see Table 30).

As detailed above, there is also a similar geographical bias at this spatial scale of analysis, with the majority of studies being conducted in Africa (see Table 31). However, this bias is only apparent at the intercommunity level where all included studies were based in Africa. It is noted that due to the inclusion of only English language studies, this may be due to a review bias.

Table 30: Spatial scale, micro-level interactions

Spatial scale	Study identifier	n
Intracommunity	Araral (2009); Bardhan (2000); Dayton-Johnson (2000); Funder *et al*. (2010); Meinzen-Dick *et al*. (2005); Makape (2005); Wutich (2009).	7
Intercommunity	Fayankinnu (2005); Hendrix & Salehyan (2010); Meier *et al*. (2007); Raleigh & Kniveton (2010); Theisen & Brandsegg (2007); Witsenberg & Roba (2003).	7

Table 31: Location of study, micro-level interactions

Geographic location	Study identifier	n
Central America	Mexico (Dayton-Johnson, 2000)	1
South America	Bolivia (Wutich, 2009)	1
Africa	Hendrix & Salehyan (2010); Botswana (Makepe, 2005); Karamoja Cluster (Meier *et al*., 2007); Kenya (Theisen, 2010; Witsenberg & Roba, 2003; Raleigh & Kniveton; 2010); Nigeria (Fayankinnu, 2005); Sub-Saharan Africa (Theisen and Brandsegg, 2010); Zambia (Funder *et al*, 2010)	9
South Asia	India (Bardhan, 2000; Meinzen-Dick *et al*., 2005)	2
South East Asia	Philippines (Araral, 2009)	1

4.6.2 Systematic map

This section provides an overview of all 14 studies included in this review that specifically examined the impact of freshwater scarcity on intrastate interactions at the micro-level. Table 32 and Table 33 present a summary of the systematic map for the intercommunity level and intracommunity level respectively. The full systematic map is presented in Appendix E.

The focus of the summary map is the theoretical framework employed, the independent variable used to characterise water scarcity, the characteristics of the resource scarcity (progressive or acute); the dependent variable (measure of conflict or collaboration or both); the method rank based on the criteria set out in Table 6, the reported outcome (significant, not significant) and the descriptive outcome (direction of relationship and level of significance). The final column provides an overall weight of the study based on the method rank and the assessment of the clarity in reporting the methods and results and the type of independent variable employed. Appendix D.3 presents a full account of the methodological approach ranking and method and reporting assessment for intrastate interactions.

Table 32: Reported outcomes, micro-level interactions, intercommunity level

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1= lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment
Fayankinnu (2005)	Neo-Malthusian	**Meteorological variable** (dry season)		**Non-violent / violent**	**1**	**n/a**	Water scarcity generates social conflict between "indigenes" and students. However, coping strategies have been developed, and conflict management reduced the rate of conflict between the two communities.	**Low**
Hendrix & Salehyan (2010)	Propose five possible mechanisms related to: water salience, price, rural-urban tensions, migration, pressure on state services and assistance and more general macroeconomic impacts.	**Meteorological variable** (extreme deviations from normal rainfall, linear and square terms)	Acute	**Non-violent/ violent conflict** (non-government targeted)	**7**	**Significant**	**Reduced form[27]:** no significant relationship. **Full set of control variables[28]: positive and significant** relationship (0.1) between squared rainfall term and non-government targeted conflict.	**High**
		Meteorological variable (extreme deviations from normal rainfall, lagged by 1 year, linear and square terms)				**Not significant**	-	
		Drought (CRED)				**Not significant**	-	

[27] Reduced form refers to a limited set of control variables (only includes lagged dependent variable, present and lagged indicators of rainfall deviation, and time trends and period dummies.)

[28] Full set of control variables refers to the full suite of control variables (lagged dependent variable, present and lagged indicators of rainfall deviation, time trends and period dummies, polity, population and economic control variables).

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1= lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment
		Drought (CRED, lagged by one year)				**Not significant**		
Meier *et al.* (2007)	Neo-Malthusian	**Meteorological variable** (precipitation)		**Violent conflict** (organised raids)	**3**	**Not significant**	-	**Low**
				Violent conflict (livestock losses)		**Not significant**		
				Violent conflict (human deaths)		**Not significant**		
Raleigh & Kniveton (2010)	Unclear	**Meteorological variable (precipitation)**	Acute	**Violent conflict**	**2**	**Significant**	Increases in rainfall significantly correlated to higher communal violence	**Low**
Theisen (2010)	Neo-Malthusian	**Meteorological variable** (% deviation of precipitation from previous year)	Acute	**Violent conflict** (intercrops violence ≥ 25 deaths a year)	**6**	**Significant**	**Negative and significant** (0.01) relationship between violent conflict and percentage change in precipitation from the previous year. Violent conflict is less likely in wetter years following drier years. Not robust to different model specifications.	**Very high**
		Meteorological variable (% deviation of precipitation from previous year, lagged by 1				**Not significant**	-	

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1= lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment
		year)						
		Meteorological variable (deviation from mean rainfall)				**Not significant**	-	
		Meteorological variable (% deviation of precipitation from previous year, lagged by 1 year)				**Significant**	**Positive and significant** relationship (0.01) between deviation in precipitation from the mean rainfall, lagged by one year. Violent conflict is more likely in the year after wetter years. Robust to different specifications.	
Theisen & Brandsegg (2007)	Neo-Malthusian	Meteorological variable (average rainfall (2001-2005))	Acute	**Violent conflict** (non-state conflict)	**7**	**Significant**	**Positive and significant** relationship (0.05) between violent conflict and average rainfall – higher levels of rainfall increase the risk of violent conflict.	**Very high**
		Meteorological variable (% change in rainfall (2001-2005 compared to 1997-2000)				**Not significant**	-	
		Meteorological variable (SD rainfall (2001-2005)				**Not significant**	-	

Study identifier	Theoretical framework	Independent variable	Characteristic of scarcity	Dependent variable	Method rank (1= lowest, 7 = highest)	Reported outcome	Descriptive outcome	Overall study assessment
Witsenberg & Roba (2003)	Neo-Malthusian	**Meteorological variable** (rainfall variability and rainfall variability lagged by 1 year)	Acute	**Violent conflict** (armed incidents and killings) Violent conflict	**3**	**Not significant**	-	**Low**
		Drought (drought years, 1year after drought years normal years, wet years, average and wet years following drought)			**1**	**n/a**	Although no significant testing is performed and standard deviations are high, twice as many people are killed in wet years than drought years, both in relative and absolute terms. Wet or average years following a drought do not show more armed incidents and killings. Less people are killed in wet years following droughts than in wet years in general.	
		Drought (drought years, 1 year after drought)			**1**	**n/a**	Years of drought have relatively lower numbers of incidents and deaths than wetter years. There is a decrease in the relative number of deaths in years following a drought, and a sharp increase in the second year after a drought.	

**Not significant* *No significant relationship observed*
Significant *Significant relationship observed*
***Figures in parenthesis highlight the level of statistical significance*

Table 33: Reported outcomes, micro-level interactions, intracommunity level

Study identifier	Theoretical framework	Dependent variable		Independent variable	Method rank (1= lowest, 7 = highest)	Reported outcome*	Descriptive outcome	Overall study assessment **
Araral (2009)	Common property management	Social water stress indicator (cropping intensity)	Progressive	**Cooperation** (monetary free riding)	**3**	**Significant**	**Curvilinear and significant** relationship (0.01) between collective action (monetary free-riding) and scarcity is The results imply cooperation is more difficult when water is extremely scarce or abundant.	**Low**
		Social water stress indicator (cropping intensity)		**Cooperation** (free riding in labour contribution)		**Not significant**	The relationship between free riding in labour contribution and the proxy for water scarcity is not significant.	
Bardhan (2000)	Common property management	Social water stress indicator (number of months a year farmers in the *ayacut* have access to water)	Progressive	**Cooperation** (quality of maintenance of irrigation channels)	**3**	**Significant**	**Positive and significant** (0.1) relationship between access to water and quality of maintenance of irrigation channels is observed.	**Low**
				Cooperation (absence of conflict in water allocation in the *ayacut* in the past 5 years)		**Not significant**	**Positive** relationship exists between the absence of conflict in water allocation in the ayacut in the past 5 years and access to water, however it is not significant at the 0.1 level or below.	
				Non-violent (extent of violations in water-allocation rules)		**Not significant**	**Negative** relationship exists between extent of violations in water-allocation rules and access to water, however it is not significant at the 0.1 level or below.	

Study identifier	Theoretical framework	Dependent variable		Independent variable	Method rank (1= lowest, 7 = highest)	Reported outcome*	Descriptive outcome	Overall study assessment **
Dayton-Johnson (2000)	Common property management	Social water stress indicator (irrigation supply)	Progressive	**Cooperation** (three measures of irrigation canal-cleaning performance)	**3**	**Not significant**	Relationship between canal maintenance and irrigation supply is not significant, however, indicators of inequality are positively and significantly associated with uncooperative behaviour.	**Low**
Funder *et al.* (2010)	Not clear	Meteorological variable (wet and dry season)	Acute	**Cooperation/ Non-violent**	**1**	**No significance test employed**	Water competition involves both conflictive and cooperative events often in dynamic succession. Conflict mainly between different types of water users than within user groups. The majority of cooperative events take place during the dry season; implying water scarcity leads to cooperative interactions as well as conflictive ones.	**Low**
Meinzen-Dick *et al.* (2005)	Common property management	Social water stress indicator (location along irrigation canal, density of wells)	Progressive	**Cooperation** (Water User Associations)	**3**	**Not significant**	Neither water scarcity (tail of the irrigation canal) or abundance (head of the irrigation canal) had a significant effect on presence of Water User Associations. The density of wells was not examined.	**Low**
				Cooperation (collective representation/ lobbying activities)		**Significant**	**Negative and significant** (0.05) relationship is observed between abundance (head of the irrigation canal) and the likelihood of collective representation. But is not significant for water scarcity (tail of irrigation canal) and density of wells (abundance).	

Study identifier	Theoretical framework	Dependent variable		Independent variable	Method rank (1= lowest, 7 = highest)	Reported outcome*	Descriptive outcome	Overall study assessment **
				Cooperation (maintenance of minor irrigation canals)		**Not significant**	Neither water scarcity (tail of the irrigation canal) or abundance (head of the irrigation canal, density of wells) had any significant effect on the maintenance of minor irrigation canals.	
Makepe (2005)	Common property management	Social water stress indicator (water shortage during the dry season)	Acute	**Cooperation** (5 indicators of collective action)	**4**	**Significant**	**Positive and significant** (0.1) relationship between water shortage during dry season on one indicator of collective action (the number of meetings held in the past year). The other indicators of collective action (percentage of meetings attended in the past year, disputes in the past year, presence of defaulters and severity of punishment) are not significant.	**Low**
		Social water stress indicator (alternative water source to the borehole syndicate during the wet season)				**Not significant**	There is a negative relationship between alternative water sources during the wet season and collective action, however this is not significant.	
		Social water stress indicator (water shortage during the dry season)		**Cooperation** (two indices of collective action)		**Significant**	**Positive and significant** (0.1) relationship between water shortage during dry season and both the 'Members not following rules index' and the 'Greater activities in meetings index'.	

Study identifier	Theoretical framework	Dependent variable		Independent variable	Method rank (1= lowest, 7 = highest)	Reported outcome*	Descriptive outcome	Overall study assessment **
		Social water stress indicator (alternative water source to the borehole syndicate during the wet season)		**Cooperation** (two indices of collective action)		**Not significant**	There is a negative relationship between alternative water sources during the wet season and both indices of collective action, however neither are significant.	
Wutich (2009)	Common property management	Meteorological variable (wet and dry season)	Acute	**Cooperation** (Neighbourhood Council attendance)	**1**	**n/a**	Participation in the Neighbourhood Council falls during the dry season (community members), but increases for non-community members	**Low**
				Cooperation (social networks using food sharing as a proxy)	**2**	**Not significant**	An increase in social network activity at the beginning of the dry season, but as the dry season advanced, network activity fell. Social network activity resumed when the dry season ended. But, no significant difference between social interaction and wet and dry seasons. This implies that social exclusion was not heightened during periods of severe water scarcity.	

**Not significant* *No significant relationship observed*
Significant *Significant relationship observed*
***Figures in parenthesis highlight the level of statistical significance*

4.6.3 Analysis of systematic map

The following section examines the systematic map presented in Table 32 (intercommunity) and Table 33(intracommunity). The majority of studies identified were published during or after 2005 with half of the studies published in the past 3 years. Only three studies were published prior to this (Bardhan, 20000; Dayton-Johnson, 2000; Witsenberg and Roba, 2003). As for the other spatial scales described above, this implies this is a growing field. Unlike national level analysis, the methodological approaches are more varied. Only three studies exceed the methodological approach threshold of 5 (Hendrix and Salehyan, 2010; Theisen, 2010 and Theisen & Brandsegg, 2007).

Table 34: Methodological approaches, micro-level[29]

Methodological approach	Rank	n	Study identifier
Simple descriptive statistics	**1**	**4**	Fayankinnu (2005); Witsenberg & Roba (2003); Funder (2010); Wutich (2009)
ANOVA, t-tests	**2**	**2**	Wutich (2009); Raleigh & Kniveton (2010)
Statistical correlation	**3**	**1**	Witsenberg & Roba (2003)
Bivariate regression		**5**	Meier et al. (2007); Araral (2009); Bardhan (2000); Dayton-Johnson (2000); Meinzen-Dick et al. (2005)
Multivariate regression with a limited set of explanatory variables	**4**	**1**	Makepe (2005)
Multivariate regression with rich set of explanatory variables	**5**	**0**	-
Multivariate regression with rich set of explanatory variables AND time varying water scarcity measure.	**6**	**1**	Theisen (2010)
Multivariate regression with rich set of explanatory variables AND geographical variation.		**0**	-
Multivariate regression with rich set of explanatory variables, time varying water scarcity measure AND geographical variation	**7**	**2**	Hendrix & Salehyan (2010); Theisen & Brandsegg (2007)

4.6.3.2 Theoretical frameworks, micro-level

As Table 35 shows the common property management theoretical framework (see Table 10 for definitions) dominated analyses at this spatial scale. Six of the 14 studies employed this framework. A further five studies examined the neo-Malthusian theoretical framework. Hendrix and Salehyan (2010) did not present a formal theoretical framework, although the authors suggested five plausible mechanisms.

Table 35: Theoretical frameworks, micro-level interactions

Theoretical framework	Study identifier	n
Common property management	Aral (2009); Bardhan (2000); Dayton-Johnson (2000);; Meinzen-Dick *et al* (2005); Makepe (2005); Wutich (2009)	**6**
Neo-Malthusian	Fayankinnu (2005); Meier *et al* (2007); Theisen (2010); Theisen & Brandsegg (2007); Wistenberg & Roba (2003)	**5**
Other	Hendrix and Salehyan (2010)	**1**
Not clear	Funder *et al* (2010); Raleigh and Kniveton (2010)	**2**

4.6.3.3 Dependent variables

The dominant dependent variable at the micro-level is cooperation, with seven of the 14 studies examining this outcome (see Table 36). All seven of these studies use a diverse array

[29] As some studies used multiple methodological approaches, the categories are not mutually exclusive.

of proxies for cooperation, such as joint maintenance of irrigation systems, participation or sharing of pasture. Only one study examined non-violent conflict, while two studies explored both non-violent and violent conflict. None of the included studies considered all three types of interactions, however.

Table 36: Dependent variables, micro-level interactions

Dependent variable	Description	n
Cooperation	Araral, 2009; Bardhan, 2000; Dayton-Johnson, 2000; Funder *et al*., 2010; Makepe, 2005; Meinzen-Dick *et al*., 2005; Wutich, 2009	**7**
Non-violent conflict	The use of charms, verbal assault, breaking of water containers (Fayankinnu, 2005); challenges to access (Funder *et al*., 2010); livestock raiding (Wistenberg & Roba; 2002)	**3**
Violent conflict		**7**
Non-state conflicts	≥ 25 battle deaths (Theisen & Brandsegg, 2007, Theisen, 2010); physical violence (Fayankinnu, 2005); armed attack, murder (Wistenberg & Roba; 2003); non-government conflict (SCAD)(Hendrix & Salehyan, 2010); communal violence Raleigh and Kniveton, 2010).	**6**
Proxies	Human deaths, livestock losses, organised raids (Meier *et al*., 2007)	**1**

4.6.3.4 Independent variables

The majority of studies used either a meteorological related variable or a social water stress indicator (see Table 37). Studies using a meteorological indicator of freshwater scarcity tended to use seasonal precipitation variability (i.e. dry season), while four studies employ indicators of interannual precipitation. However, as the majority of studies at this spatial scale collect data from field studies, proxies of social water stress are also common at this level. Three studies specifically measure access to water (Bardhan, 2000; Dayton-Johnson, 2000; Meinzen-Dick *et al*., 2005).

Table 37: Independent variables, micro-level interactions

Independent variable	Description	n
Meteorological variable	Interannual precipitation (Hendrix and Salehyan, 2010; Meier *et al*., 2007; Raleigh and Kniveton, 2010; Theisen, 2010); dry season (Fayankinnu, 2005; Funder *et al.* 2010; Witsenberg & Roba, 2003; Wutich, 2009)	**8**
Drought	Witsenberg & Roba (2003)	**1**
Water stress indicator	Water stress in dry season (Makepe, 2005)	**1**
Social water stress indicator	Location along canal (Meinzen-Dick *et al*., 2005); density/number of wells (Fayankinnu, 2005; Meinzen-Dick *et al*., 2005); irrigation supply (Dayton-Johnson, 2000); cropping intensity (Araral, 2009); access to irrigation (Bardhan, 2000)	**6**

4.6.3.5 Additional explanatory variables

Of the 14 included studies, 11 considered additional exploratory variables. Due the small population of studies and the context specific nature of the variables, unlike previous sections, we were not able to codify these in the same way. As such, a full list of additional explanatory variables is presented in

Table 38.

The additional explanatory variables depend on the theoretical framework proposed. Given that common property management is the dominant theoretical frameworks employed at this level; the most common exploratory variables reflect empirically established contextual variables considered important for this theory. These include proxies of wealth, levels of inequality, community heterogeneity, governance and local institutions. Studies employing

multivariate regression techniques, however, used similar control variables to those at the intrastate level (Hendrix and Salehyan, 2010; Theisen, 2010; Theisen & Brandsegg, 2007).

Table 38: Additional explanatory variables, micro-level interactions

Study identifier	Other independent variables
Araral (2009)	Distance to market; age of irrigation association (IA); group size; origin of IA (self-organised/ government assistance); gender; wealth; governance structure of IA.
Bardhan (2000)	Group size; group heterogeneity; inequality; villages located at the tail end of irrigation system; connection of village to urban areas/transport/telephone; access to water outside ayacut; age of water-user association; hiring of guards for monitoring and enforcement; cost shared proportional to landholding; farmer perception of water rules.
Dayton-Johnson (2000)	Group size, economic inequality, social heterogeneity (number of different villages from which the users are drawn), local wages (proxy unit for cooperation due to opportunity cost), government constructed system.
Fayankinnu (2005)	n/a
Funder *et al* (2010)	n/a
Hendrix & Salehyan (2010)	Democracy (Polity 2); population and population growth; per capita GDP; GDP growth.
Meinzen-Dick *et al* (2005)	Presence of temples; number of graduates and presence of leaders.
Makepe (2005)	Number of households who are members of syndicates; heterogeneity in cattle ownership; average herd size per member; total distance to major market where cattle are sold; membership in other village organisations; age of syndicate; years of schooling of the chairman; presence of hirers; percentage of women members; turnover ratio of membership.
Meier *et al* (2007)	Peace indicator scores (alliances, exchanges, mitigation, initiatives); conflict indicator scores (aggravators, pressure, provocation); vegetation, forage.
Raleigh & Kniveton (2010)	n/a
Theisen (2010)	Population density; temperature; ethnicity; election year; non-monetary measure of poverty; dummy variable to capture whether the cell has one or more district national boundary or not.
Theisen & Brandsegg (2007)	Democracy; population and population change; stability (years since the country last experienced civil conflict); proximity national capital for each grid cell; proximity to civil war (civil war in neighbouring states); proxy of level of development (infant mortality rate); marginalisation (mean of IMF for each grid cell subtracted from UNICEF national mean); spill over effects (conflict in neighbouring grid cells)
Witsenberg & Roba (2003)	n/a
Wutich (2009)	Home ownership; social relationships.

4.6.4 Quality of studies

Table 39 and 40 present the results of the overall assessment of study quality for the intercommunity and intracommunity level respectively. At the intercommunity level, three of the seven studies reach an overall study rank of 'very high' (Theisen, 2010; Theisen & Brandsegg, 2007); and 'high' (Hendrix and Salehyan, 2010). All three studies had a methodological approach rank of 7. The remainder of the studies at the intercommunity level were ranked as low as their methodological rank fell below the threshold of 5.

At the intracommunity level, all studies were ranked 'low' in the overall assessment of study quality. While methodologies varied, none exceed the methodological approach rank of 5.

Four studies used bivariate regression analyses (Araral, 2009; Bardhan 2000; Dayton-Johnson, 2000; Meinzen-Dick *et al*. 2005), while only one study used a multivariate regression approach (Makepe, 2005) the author only used a limited number of explanatory variables. The remaining studies used either simple descriptive statistics (Funder *et al*. 2010; Wuitch, 2009) or an ANOVA approach (Wuitch, 2009).

In the following section, we summarise the findings of the highest-ranking studies (n=3) at the intercommunity level only, as all studies at the intracommunity level were classed as 'low'. A full account of the assessment is presented in Appendix D.4, and details of the studies not presented in detail can be found in the full systematic map in Appendix E.

Table 39: Overall assessment of study quality, intercommunity

Study Rank	n	Study identifier
Very high	**2**	Theisen (2010); Theisen & Brandsegg (2007);
High	**1**	Hendrix and Salehyan (2010)
Moderate	**0**	-
Low	**4**	Fayankinnu (2005); Meier *et al*. (2007); Raleigh and Kniveton (2010); Witsenberg & Roba (2003)

Table 40: Overall assessment of study quality, intracommunity

Study Rank	n	Study identifier
Very high	**0**	
High	**0**	
Moderate	**0**	
Low	**7**	Araral (2009); Bardhan (2000); Dayton-Johnson (2000); Funder *et al*. (2010); Meinzen-Dick *et al*. (2005); Makepe (2005); Wutich (2009);

Table 41: Summary of findings of high-ranking studies, intercommunity

Study rank	Study identifier	Specific theoretical framework / hypothesis	Method	Outcome
Very high	Theisen (2010)	Neo-Malthusian: Expects both that drier years are more violent than wetter years. But, based on earlier research also expects drier years to be less violent than wetter years.	Longitudinal (1989-2004) econometric spatially disaggregated analysis to examine the link between various indicators of interannual precipitation variability and violent conflict in Kenya.	Positive and significant (0.01) relationship between violent conflict and percentage change in precipitation from the previous year and deviation in precipitation from the mean rainfall, lagged by on year. This implies that violent conflict is more likely in wetter years and the year following wetter years.
	Theisen & Brandsegg (2007)	Neo-Malthusian	Longitudinal (2002-2005) spatially disaggregated econometric analysis exploring the relationship between resource scarcity and internal armed conflict on smaller-scale internal conflicts with no direct state involvement, so called non-state conflicts for SSA.	Find higher levels in rainfall coincide with a higher risk of conflict onset.

High	Hendrix and Salehyan (2010)	No formal theoretical framework, but discusses five plausible mechanisms. Hydro-meteorological disasters may lead to: (1) conflict between consumers due to water salience or desertification; (2) price disputes between rural producers and urban consumers and food price inflation; (3) migration from stressed areas may lead to competition for resources, employment and cultural tensions; (4) strains on government revenues due to the reduction of the tax base and increase demands for services and assistance from disasters; and (5) negative macroeconomic impacts may lead to civil conflict and social disorder.	A longitudinal (1999-2009) econometric analysis to examine the impact of hydro-meteorological disasters (droughts and floods), on non-governmental conflict in Africa (only non-government directed conflict is reported here, governmental conflict, non-violent conflict and violent conflict is discussed in §4.5).	No significant relationship is observed between non-government conflict and interannual rainfall variability in the reduced form model (e.g. no country fixed effects, but includes a time trend). In the full model, there is weak (significance, magnitude and strength) support for a curvilinear relationship, between very dry and very wet rainfall extremes and non-government targeted conflict. But the relationship is both significant and strongest between rainfall abundance and non-government-targeted conflict.

4.6.5 Discussion

The following section presents a brief discussion of the findings presented above, with specific reference to the highest-ranking studies, summarised in

Table **41**. The discussion is broken down into three sections: what is the evidence, quality of studies and gaps in research.

4.6.5.1 What is the evidence?

While heterogeneity between studies and the low ranking of the majority of the studiers precludes a clear synthesis of studies, it is noteworthy that the majority of studies that test causality find that scarcity is not a significant predictor of social interactions, either cooperative or conflictive.

Of the studies ranked ‘very high’ and ‘high’ in the quality assessment the majority imply that scarcity is not a significant predictor of social interactions at this level (Theisen, 2010; Theisen and Brandsegg, 2007; Hendrix and Salehyan, 2010). And more broadly, the literature is not supportive of a scarcity-conflict link. In fact, all three highest-ranking studies find the opposite to be true, where abundance of rainfall appears to be a stronger predictor of conflictive interactions. In particular, Hendrix and Salehyan (2010) finds weak support for a curvilinear relationship between very dry and very wet rainfall extremes and non-government targeted conflict (communal violence). Due to the small population of studies, and heterogeneity, we are unable to draw any firm conclusions regarding this relationship.

Despite all the intracommunity studies having an overall rank of ‘low’ in our assessment of studies we briefly summarise the findings from this spatial scale. All but one study examines the relationship between scarcity and cooperative interactions within the common property management theoretical framework. Only one study (Makepe, 2005) finds that scarcity is a significant predictor of cooperative interactions. Two studies find that scarcity is not a significant predictor of cooperation (Dayton-Johnson, 2000; Meinzen-Dick *et al*., 2005) while one study finds that scarcity reduces cooperation (abundance is a significant predictor of cooperation) (Bardhan, 2000). One of the more recent studies (Araral, 2009) observes a curvilinear relationship between collective action and scarcity, much like the ‘Scarparation’ relationship observed at the transboundary level (Dinar *et al*., 2007; 2009; 2010). The remaining two studies (Funder *et al*. 2010; Wuitch, 2009) did not examine causality, however, their conclusions were mixed.

4.6.5.2 Gaps in the research

The systematic map shows that quantitative research exploring the relationship between freshwater scarcity and conflict or collaboration at the intercommunity and intracommunity levels is limited. As discussed earlier, this may be due to limitations of review, as we only included English language studies. Despite this, our systematic map implies that the research at this level is not well developed. This is perhaps because research at this level is resource intensive and requires costly fieldwork. As such, research has tended utilise national-level datasets, and more recently, geo-referenced, spatially disaggregated datasets. However analyses at the country-level may miss or discount more immediate effects at the local level.

Examining the relationship between scarcity and social interactions at this level provides detail, particularly relating to local contextual factors that cannot be captured using national aggregated or spatially resolved data. Additionally, more meaningful proxies of scarcity can be determined at these spatial scales, as opposed to reliance on more abstract indicators (Meier *et al*., 2007).

The wider application of smaller scale studies to other areas is limited. But this should not detract from future research in this area as these studies are a critical addition to the field.

At the intercommunity level, given that all studies were conducted in Africa, there is a discernible gap in the literature exploring other continents. Additionally, at this spatial scale only one study examined cooperative interactions, and no study examined the full range of possible outcomes (i.e. violent conflict, non-violent conflict and collaboration). Yet at this level of analysis there is the opportunity to understand both conflictive and collaborative interactions. And, given dearth of collaborative literature, future analyses at this spatial scale could make a significant contribution to understanding the social dynamics at play.

4.7 Studies using rainfall/ drought as instrumental variables[30]

We identified six econometric studies that used rainfall or drought exposure as an instrumental variable to examine the relationship between the impact of economic shocks or changes in population and conflict. In one case, however, democratic improvement was analysed rather than conflict (Brückner and Ciccone, 2009). All but one of these studies was conducted in SSA. The other study focussed on Brazil (Hildalgo *et al*., 2010), and explored the relationship between economic shocks and land invasions.

Rainfall or drought indicators are regularly used in these types of analyses to control for the possible reverse causality of economic growth and violent conflict (Miguel *et al*., 2004). Rainfall/ drought instrumental variables are particularly favoured in SSA because agrarian irrigation is not widely practiced in this region. Rainfall therefore has a strong correlation with economic prosperity and growth.

After discussion with the review team and several experts, it was concluded that these studies be excluded, as the hypotheses being tested was the impact of economic shocks or population growth on the onset of civil conflict (in the case of Brückner and Ciccone (2009) democratic improvement). However, given that these studies illustrate the multi-causality of outbreaks of civil conflict, we summarise these excluded studies in Table 42.

[30] Whether to include these studies or not caused much contention between the review group and other consulted experts. At this stage we have not included in the main review, however, we highlight the studies, as they address the research question, albeit indirectly. However, these studies may provide some insight into the causal relationship between water scarcity and civil conflict.

Table 42: Studies identified that used rainfall/ drought as an instrumental variable for shocks in economic growth / population change

Study	Research design	Outcome
Miguel et al (2004)	Explores the impact of economic shocks on civil conflict in 41 African nations using deviations in annual precipitation as an instrumental variable.	Growth strongly negatively related to civil conflict. A negative growth shock of five percentage points increases the likelihood of conflict by one-half the following year.
Jensen & Gleditsch (2009)	Re-examines Miguel et al. (2004), but restrict conflict data to states with conflict on their own territory	Revised methodology of Miguel *et al*. (2004) reduces the estimated impact of economic growth on civil war. Argue spatial correlations in rainfall growth and participation in civil conflicts induce a stronger apparent relationship in the misclassified data.
Ciccone A (2008)	Follows Miguel et al. (2004) in using rainfall as an exogenous source of economic shocks in SAA countries. But, empirical specifications take into account that rainfall shocks are transitory.	Conflict is most probable following years with exceptionally high rainfall levels. Correlation been low levels of rainfall and conflict is an artefact of the particular rainfall growth measure that all studies employ.
Brückner & Ciccone (2009)	Explores the impact of economic shocks on democratic improvement in SSA using rainfall shocks as an instrumental variable.	Find a 25% drop in rainfall increases the probability of a transition to democracy during the following two years by around 3 percentage points. A 5% fall in income due to low rainfall raises the probability of democratization by 7 percentage points. Also find that rainfall does not affect transitions from democracy to autocracy.
Fiala (2009)	Examines the relationship between economic growth and civil conflict using rainfall shocks as an instrumental variable for 121 countries from 1982-1999,	Statistically significant results suggesting a positive rainfall shock leads to higher growth supporting the theory that conflicts arise when greater benefits to appropriation. However, too much rainfall is detrimental to the economy.
Hildalgo et al. (2010)	Examines the relationship between land invasions and economic shocks in Brazil using rainfall as an instrumental variable.	Adverse economic shocks, instrumented by rainfall, cause the rural poor to invade and occupy large landholdings.
Brueckner (2010)	Examines the impact of population size on conflict using a randomly occurring drought as an instrumental variable to generate exogenous variation in population size for 37 SSA countries.	Instrumental variable estimates yield that a 5% increase in population size raises the risk of civil conflict by around six percentage points

5. Discussion

The following section discusses the results of the systematic map presented in Chapter 4. While each spatial scale has been discussed separately, the aim of this section is to bring together the findings and present common themes that have emerged.

Our discussions held with several experts during the course of this review exploring ideal study designs, which then informed the quality assessment are also reflected below. In the final section we discuss the limitations of the review.

5.1 Evidence that scarcity and shocks in freshwater resources lead to conflict instead of promoting collaboration and reasons for variation

From a set of 589 studies identified after the first round of screening, we identified just 47 relevant studies exploring the relationship between freshwater scarcity and either conflictive or collaborative interactions. Of the 47 studies, 19 explored interstate interactions. Just one examined interstate conflict in relation to freshwater scarcity, while the remaining 18 were specifically related to transboundary river basins. At the intrastate level, 15 studies examined the relationship at the national level, while the remaining 13 explored interactions at the sub-national level.

The systematic map suggests research into the impact of freshwater scarcity and conflict/ collaboration is growing. This is true at all spatial scales examined, apart from state-state interactions that were not specifically related to transboundary river basins. However, there is little consensus on the impact of scarcity on social interactions at multiple levels and this is true across all three spatial scales examined (interstate, national-level, micro-level). This because the research in this field is still at the formative stage, and is limited by data availability.

The reasons for heterogeneity between studies have been discussed in detail in the preceding chapter, for each of the spatial scales. We find that divergent definitions of conflict/collaboration, scarcity, theoretical frameworks, models, time-scales, explanatory variables and use if interactive terms are key reasons for variations between study outcomes. The high degree of heterogeneity between studies, within and between different spatial scales precludes a meta-analysis or narrative synthesis of the literature. As such, we do not attempt to draw conclusions regarding the direction of the relationship.

At the intrastate level, we identified a clear geographical bias. The majority of studies focussed on Africa. This follows a long history of research exploring the conditions that lead to civil war in African states (see for example Blattman and Miguel, 2010). Additionally, the contention that Africa is the most vulnerable region to climate change has been a key motivation for research in this particular region.

The majority of multivariate regression analyses that dominate the quantitative literature do not assume a direct or simple relationship between scarcity, conflict or collaboration. No study weighted as ‘high’ in our quality assessment considered a direct link between freshwater scarcity and conflict or collaboration. Instead scarcity is generally viewed as one of a set of social, economic, political, historical and geographical variables. Additionally, a number of studies at the interstate (transboundary river basins), intrastate and micro level observed that it is not scarcity, but abundance that is a more significant predictor of conflictive outcomes.

5.1.1 Theoretical frameworks

The systematic map identifies 7 broad theoretical frameworks that were used within the included literature. While each study maybe based on a broad interpretation of a theoretical framework, we also recognise that individual analyses will incorporate small variations theory. Our broad classification of theoretical frameworks reveals that neo-liberal, neo-Malthusian and common property management theoretical frameworks are most commonly used. But, it is only the neo-Malthusian theoretical framework has been adopted across all

spatial scales. Neo-liberal and common property management are used at the interstate (transboundary river basins) and intracommunity levels respectively.

The popularity of the neo-Malthusian theoretical framework has its roots in the extensive empirical case study work of Homer-Dixon (1991; 1994; 1998; 1999) and Baechler and Spillman, (1996) and appears to have had a significant impact on research in this field. Yet the causal pathway posited by this theory, i.e. that environmental scarcity (supply, demand and structural) drives social effects that in the absence of ingenuity (adaptive capacity) leads to conflict, is not widely supported within the literature identified in this review.

We believe at this stage, we have not identified a sufficient body of literature using other theoretical frameworks to determine if they have greater explanatory power than the neo-Malthusian framework. There does, however, appear to be a need for further theory building.

5.1.2 Collaboration – conflict spectrum

As posited in the conceptual framework presented in Chapter 1, the spectrum of conflict and collaboration is not a one-dimensional plane, but is rather a multidimensional concept spanning from harmony to violent conflict and including, distributions of power, transparency, levels of compliance, resource salience and cultural norms between the two or more parties involved. These additional dimensions are important, as the absence or the attempt to prevent conflict may, as Turner (2004) argues, mask extant unequal power relations. Given this, conflict and collaboration are not necessarily mutually exclusive.

For example, harmony is defined as the absence of conflict, where two (or more) parties can achieve their own goals without the need for communication (Keohane, 1984). While collaboration implies some behavioural adjustment to other's interests, and there may be differences in power or cost of the cooperative arrangement to the parties involved. Conflict, can be both non-violent and violent. But it can also be a precursor to collaboration. It is also not necessarily a negative interaction; for example, it could play be an important role in redistribution of power.

For example, Ruelas-Monjardin et al. (2009) argue that conflict can lead to new social and institutional arrangements and more enduring relationship between parties that leads to consensus, helps reduce isolation, unites individuals and creates mechanisms for the maintenance and/or readjustment of the balance of power.

An earlier systematic review (albeit limited) found that there was a strong bias in water research towards focussing on conflictive outcomes (e.g. Gupta and van der Zaag , 2009). The systematic map partially supports this view. At the intrastate level, no study considered the impact of scarcity on collaborative interactions. While, at the transboundary and micro-levels, the distribution between collaborative and conflictive interactions was much more balanced. However, spatial scales rarely considered multiple outcomes in the same analyses. Instead, binary variables such as treaty/no treaty or conflict/ no conflict are most commonly employed.

It is only at the micro-level (i.e. intercommunity, intracommunity interactions) that multiple dimensions of the collaboration-conflict spectrum are explored. Here, multiple indicators of collaboration are observed and analysed such as sharing, participation in local institutions or compliance with local institutional rules.

There was a clear bias towards the study of conflict for included studies at the national level. This is possibly due to limitations in identifying non-violent conflict or collaborative actions at this spatial scale. While Buhaug and Theisen (2010) state that data on non-violent conflicts and local violent events are increasingly being collected in a systematic manner (for example the Non-State Conflict Dataset, Social Conflict in Africa Dataset) this does not address the lack of data for collaborative interactions.

It is much more straightforward to build datasets of non-violent and violent conflict as these are unusual events against a background of 'normal' social interactions (e.g. harmony). The transboundary river basin literature has benefited from rich datasets of claims, treaties and

conflict, developed over the past decade and spanning at least the last 100 years (e.g. the Transboundary Freshwater Dispute Database[31]). If replicated for intrastate conflicts at multiple spatial scales, this would be of substantial value to future research. Although this would require a significant level of coordination and monitoring, and there may be problems with detection of low-level non-violent conflict and collaborative events. This suggests that in order to better understand the dynamics of collaborative interactions fieldwork rather than analysis from afar is required.

5.2 Ideal study design

In order to develop the quality assessment for the included studies, we asked several active researchers in the field, what they considered to be the ideal study design in order to better understand the causal relationship between scarcity and conflict or collaboration. The discussions are summarised below.

While the majority of studies identified in this review were multivariate analyses, researchers we interviewed argued that although these studies afford the opportunity to provide statistical evidence, they are insufficient for theory building and can often over generalise. As such they may fail to capture regional dynamics or historical contexts, thus reducing the external validity of the research. While small-N case studies can provide a greater depth of understanding about the dynamics of interactions related to freshwater scarcity, they have extremely limited external validity. However, small-N case studies can also be used to verify or falsify theoretical frameworks that can support their development. As such, there was a broad consensus amongst our interviewees that an ideal research strategy to develop understanding would involve a coordinated approach of theory testing (large-N) and theory building (small-N).

In terms of the quantitative, large-N study design, the following suggestions were made. The study should:

- have a clear theoretical framework, and aim to test a specific causal mechanism;
- include a rich dataset of additional explanatory variables that can determine the outcome in order to control for them and interact with the explanatory variable (water scarcity);
- have a sound identification strategy that reduces endogeneity within the model such as using an exogenous variable (e.g. precipitation) or exploiting the panel dimension of the data by running fixed effect (by region) estimations. It is noted, however, that exogenous variables may be useful for limiting endogeneity; they are less useful for capturing the social dimensions of scarcity such as access;
- use detailed data on both the dependent and explanatory variable, and in the case of longitudinal studies, time varying dependent and explanatory variables. Poor variability in the explanatory variable will weaken the potential to identify the relationship;
- *w*hile progressive scarcity may vary in a slow and monotonic way, it may also be difficult to separate the impact of increased water scarcity from other trends in the region. As such for the study of progressive scarcity, a dataset with high temporal resolution and covering long periods of time (e.g. 30 years), may be necessary to identify any specific response to scarcity. Given this, from a methodological point of view, the study of shocks may be more suited to identifying causality. In reality, and as discussed in Chapter 1, the observed response to progressive scarcity and shocks may different due to confounding factors such as adaptation; and
- have variability across geographical areas. For example, cross-national studies should aim to capture a range of different hydro-climates, and should use spatially disaggregated, geo-referenced data.

[31] http://www.transboundarywaters.orst.edu/database/

In terms of, small-N study design, the following suggestions were made. The study should:

- have a clear theoretical framework, and aim to test a specific causal mechanism; and
- be comparative. Here, a number of case studies should be selected that compare comprehensively incidences where there is/was a) water scarcity + conflict; b) water scarcity + collaboration and c) water scarcity + harmony. The interviewee argued that this is necessary because environmental conflict and scarcity researchers are more often than not criticised for choosing their case studies in line with the occurrence of both environmental scarcity and also conflict, which leaves them biased from the start. While research into collaboration could be accused of the same mistake, it would be useful to compare cases where neither conflict nor collaboration ensued as a result of water scarcity. This would also address the inevitability question.

From this, and the discussions presented above and in Chapter 4, we identify a number of areas for future research. These are presented in the concluding chapter of this report.

5.3 Review limitations

While we originally set out to explore the qualitative case-study literature, we found the body of literature to be vast. Due to time limitations, we specifically focussed our efforts on developing an in depth map of the quantitative literature. But the findings of this review are useful for both quantitative and case study approaches. Particularly in relation to the definitional challenges related to conflict and collaboration and scarcity.

Second, this review has been limited by the heterogeneity of studies. The topic area is broad, and as discussed extensively in earlier sections of this chapter and Chapter 4, the research lacks firm definitions of conflict and collaboration or freshwater scarcity. Researchers also employ a variety of different theoretical frameworks and additional explanatory variables. This has precluded an assessment of the literature in a systematic way.

Third, due to time limitations and user-group priorities, we only looked at the relationship between water. However there are number of non-renewable resources that are also explored in the environmental security literature. These include *inter alia*, land, soil quality, fisheries, and forestry. Comparisons between the societal responses to multiple types of scarcity may also provide further insights into the circumstances under which conflict or collaboration emerges.

A final limitation, which was highlighted at the review phase of the protocol, relates to language. Foreign language searches were not carried out. The purpose of this review was to carry out a comprehensive search of the literature. Time constraints meant that to include other languages would have compromised the comprehensiveness of the search. This decision was supported by the review user group and methodological experts. As systematic reviews are evolving processes, we would welcome continuation of this work that focuses on languages other than English.

6. Reviewers' Conclusions

6.1 Implications for policy

Toset et al (2000) argued that while there appeared to be many alarming public statements relating to water scarcity and conflict, surprisingly limited relevant systematic research on the issue. A decade later, while there has been increase in quantitative research, this field is still formative. And, little is known about the mechanisms that tie scarcity to conflictive or collaborative interactions between states, different actors, communities and within communities.

Despite the growing number of studies in this field, there is, as yet, no sign of consensus on the expected societal responses to freshwater scarcity. Discrepancy between study designs is one key reason. This review has shown that studies vary significantly in research question, theoretical frameworks employed, definitions of conflict or collaboration and scarcity, and spatial scale. Furthermore, freshwater scarcity is rarely considered to be the sole driver of conflictive or collaborative interactions between two or more parties. Instead it is regarded as one of many factors influence social dynamics. While a set of common additional explanatory and control variables were identified, they are not used systematically, therefore increasing heterogeneity between studies.

There is a strong geographical bias in the literature with the majority of studies identified that focus on the national level or below conducting in African states, and in particular SSA. It is not clear, how transferable these findings are to other geographical regions.

So, while the quantitative research included in this review may appear to be at odds with the dire predictions cited in early empirical case studies, we caution such conclusions from being drawn from the evidence presented here, particularly when policy makers and researchers seek to identify the implications of this review. The small number studies identified and the heterogeneity between them means we are not in a position to confirm or refute this position. Furthermore, few studies identified were considered weighted as 'high' in our quality assessment framework.

However, overstating risks of water conflict or oversimplifying causal links may be detrimental to intended research objectives. For example it may direct resources away from development towards conflict prevention, or may reduce efficacy of measures. Although some have argued that these are two sides of the same coin (e.g. Conca and Dabelko, 2002) policy makers and other decision makers may feel that as long as violent conflict is avoided, they have been successful. This may also draw attention away from important proximate causes of conflict (Katz, 2011).

Observed and predicted trends in global environmental change, and particularly climate change, means there is an urgent need develop understanding of the multiple conditions possibility under which conflict and collaboration emerge when societies are exposed to environmental stress. The huge economic and social costs of violent conflict means that a systematic and coordinated research programme in this field would be worth the investment. At this stage, however, we do not feel that research is sufficiently developed to guide mitigating policy. Although, addressing lack of access to basic needs, such as potable water; mitigating against further impacts of climate change and enhancing adaptive capacity of communities to global environmental change would all have mitigating effects for the link between environmental scarcity and conflict, should one exist.

We also add a cautionary note regarding future projections based on retrospective analyses. Due to the complex interaction between global environmental change and economic, political and social factors, there are limitations to which studies of past conflictive or collaborative outcomes can be used to forecast future risks.

The curvilinear relationship observed across all three major spatial scales between scarcity and the likelihood of conflict and collaboration, for example, implies that the relationship may be non-linear. Global environmental change, specifically climate change coupled with the rapid economic development in many regions of the world will change the dynamics between patterns of demand and supply. Additionally, extreme weather events such as drought and flooding are expected to increase in frequency and amplitude over the next century. This will occur against a background of more progressive climate change. The cumulative effect of a number of hydrometeorological events occurring in close succession against a backdrop of longer-term progressive change in freshwater availability and other climate change impacts could impact the capacity to adapt or cope. Understanding how this translates into social interactions between and within states, therefore is a key research priority. And, uncertainty in social responses to scarcity should not be seen as evidence that it does not carry significant societal risks,

6.2 Implications for research

As concluded in the previous section, understanding how and why conflict or collaboration emergences under conditions of scarcity is a critical research question. However, this review suggests that the field is still formative. As such gaps in the literature and future research priorities are listed below.

- *Research strategy*: While the body of research is growing, development of understanding is still stymied by a number of factors. The majority of studies identified in this review were multivariate analyses. While this approach affords the opportunity to provide statistical evidence, they are insufficient for theory building and can often over generalise. As such they may fail to capture regional dynamics or historical contexts, thus reducing the internal validity of the research. While small-N case studies can provide a greater depth of understanding about the dynamics of interactions related to freshwater scarcity, they have extremely limited external validity. However, small-N case studies can also be used to verify or falsify theoretical frameworks that can support their development. An ideal research strategy to develop understanding would involve a coordinated approach of theory testing (large-N) and theory building (small-N).
- *Theory building*: The dominant theoretical framework within the literature is neo-Malthusian. However, there is limited support for this mechanism. The research strategy described above could support the development of new or refined theories.

  Three studies suggested the existence of a curvilinear relationship between the likelihood of collaboration and water scarcity in relation to transboundary river disputes. A similar relationship was also observed at the intrastate and micro-level. The consistency between different spatial scales implies this relationship warrants further examination. The curvilinear relationship posits a threshold between moderate scarcity and extreme scarcity may exist. Beyond this point, the likelihood of conflictive or less collaborative interactions increases. As climate change projections imply an amplification of hydroclimates (Fung et al 2011) this relationship may suggest more conflictive interactions are likely in the future, which are not captured by historical data.

  Several studies at the national level and below also found that abundance not scarcity was a significant predictor of conflictive outcomes. During wetter periods, violent conflict was more likely. This observation also warrants further investigation, as it runs counter to the expected outcome.
- *Monitoring and datasets, dependent variables*: As described in detail above, the continuum from harmony to conflict is multidimensional. There are three key ways how future research could be developed in this area.

- First, convergence on accepted definitions of collaborative and conflictive events could significantly improve research in this field by providing systematic framework for reporting and development of datasets.
- Second, while a number of datasets exist for violent conflict (UCDO/ PRIO, ICoW), there is a deficiency in systematically collected and reported low level violent conflict, non-violent conflict and collaborative interactions. The transboundary river basin literature has benefited from rich datasets of claims, treaties and conflict, developed over the past decade and spanning at least the last 100 years. If replicated for intrastate conflicts at multiple spatial scales, this would be of substantial value to future research.
- Third the development of metrics that measure the efficacy of transboundary river treaties could provide the basis for research into the sustainability of agreements under increases in resource stress. For example, although not included in this analysis as it did not explore freshwater scarcity, Bernauer and Sigfried (2008) developed a policy performance metric to explore effectiveness and compliance in international water agreements.

- *Monitoring and datasets, independent variables*: Rainfall as a proxy for water availability whilst a good identification strategy for econometric modelling does not necessarily capture actually experienced scarcity. Surface water availability is dependent on multiple other factors – physical, economic, political and social. Capturing all these into one indicator would be problematic, and would introduce issues of endogeneity. However it is worth noting that in order to understand the link between conflict and collaboration and water scarcity, the scarcity indicator needs to be measuring the phenomenon being tested. It is not a drought/ low water availability per capita that may necessarily be the cause of a conflict per se, but the limited access, or exclusion that communities or households may experience. Additionally, there is currently a lack of good data on community and political institutions that may mitigate conflict and promote collaboration as posited by Gizelis and Wooden (2010). The collection of more data on water policies, environmental management, foreign assistance, for example, particularly at the local level may improve the robustness of models considerably.
- *Groundwater aquifers*: As reported in Chapter 1, groundwater extraction and depletion has more than doubled since the 1960s.While one study reported a growth in claims over groundwater aquifers (De Stefano *et al*., 2010), we did not identify any study that specifically addressed this. Hamner (2009) argued that this is due to the limited monitoring and mapping of groundwater resources, and that they are, 'insufficiently mapped for large-scale tests.' This highlights a significant gap in the research.
- *Continued research into the differentiation between progressive and acute scarcity*: Exploring the impacts of shocks has advantages over that of long-term scarcity for studying conflicts of resource scarcity. This has four advantages.
  - First, progressive scarcity could have human causes and introduce endogeneity problems.
  - Second, due to limitations in data coverage, developments in understanding the scarcity-conflict/collaboration nexus may first come from studies that link shocks to social outcomes.
  - Third, progressive and acute scarcity may result in different outcomes, and may provide a more detailed understanding of the causal pathways of the societal response to scarcity.
  - Fourth, in the context of transboundary river basins, the study of shocks may also presents the opportunity to examine the resilience of treaties to future climatic changes or changing demand.

- *Additional exploratory variables*: There is a need for more research into additional social, economic, political, geographical and historical explanatory variables. Those used in the included studies are often derived from empirical research into civil conflict. However, Theisen & Brandsegg (2007) argue that non-state violence (and indeed collaborative interactions) may be influenced by other factors, and explanatory variables common to civil war research, may not necessarily be relevant.
- *Continued focus on methodologies that use spatially disaggregated and geo-referenced data*. Only a few studies have disaggregated below the national level. Some have argued that the state-centric approach overestimates the risk of conflict. Additionally, aggregated data can result in the loss of a huge amount of information, as assumes that homogeneous distributions of socio-economic indicators that may also be important predictors of conflict/collaboration.
- *An increase in micro-level research*: In relation for the previous point, the review revealed that micro-level analyses are limited. However, research at this level i.e. sub-national studies examining inter-community conflict or intra-community conflict offer the opportunity to examine the importance of cultural and historical context.
- *Geographical diversity*: The review has demonstrated there is a strong geographical bias in the literature. The majority of studies identified at the national level or below were conducted in African states, and in particular SSA. It is not clear, how transferable these findings are to other geographical regions.
- *Integrate perspectives from multiple disciplines*. Political science and economic analysis dominate the quantitative literature. However, future research could benefit from working closely with researchers from other disciplines. Additionally, there is a body of literature that explores behavioural change during disasters and other exogenous shocks. The disaster sociology literature may provide insights into causal mechanisms.
- *Future systematic reviews*: The purpose of this review was to carry out a comprehensive search of the literature. Time constraints mean that to include other languages may compromise the comprehensiveness of the search. As systematic reviews are evolving processes, we would welcome continuation of this work that focuses on languages other than English. Additionally, while the original research question posed by the user-group focused on all NRR, due to the volume of the literature and time constraints, our focus has been freshwater scarcity. Building on this review, further mapping of studies that explore other NRRs is recommended.

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8. Potential Conflicts of Interest and Sources of Support

No potential conflicts of interest are declared.

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Appendices

Appendix A – Köppen-Geiger Climate Classification

Arid, semiarid and dry subhumid hydroclimates (desert, savannahs and steppe ecosystems): These zones are characterised by extreme variability in rainfall such as few rainfall events, high-intensity storms, and high frequency of dry spells and droughts.
Error! Reference source not found.shows a world map of the Köppen-Geiger Climate Classification. As we were unable to source the raw data for this map, the image was enlarged to A3 size in order to resolve the grid. Countries wholly or partially falling within BWk, BWh, BSk or BSh were considered. Figure 6 shows nations that fell into this category.

Figure 6: World Map of the Köppen-Geiger Climate Classification (Kottek et al., 2006)

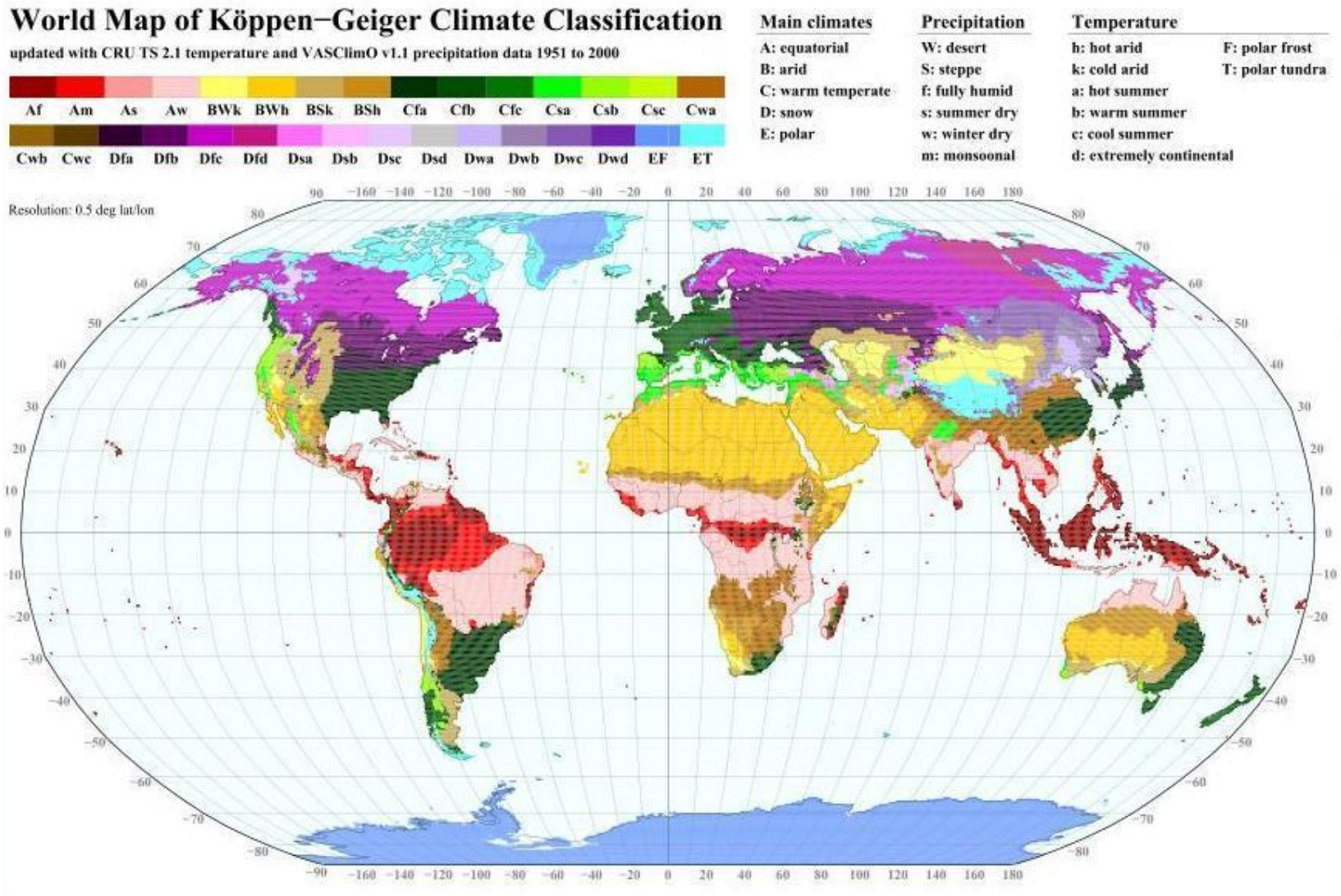
World Map of Köppen−Geiger Climate Classification
updated with CRU TS 2.1 temperature and VASClimO v1.1 precipitation data 1951 to 2000
Af Am As Aw BWk BWh BSk BSh Cfa Cfb Cfc Csa Csb Csc Cwa
Cwb Cwc Dfa Dfb Dfc Dfd Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd EF ET
Main climates
A: equatorial
B: arid
C: warm temperate
D: snow
E: polar
Precipitation
W: desert
S: steppe
f: fully humid
s: summer dry
w: winter dry
m: monsoonal
Temperature
h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
d: extremely continental
F: polar frost
T: polar tundra
Resolution: 0.5 deg lat/lon

Table 43: Nations wholly or partially classified as arid or semi-arid according to the World Map of the Köppen-Geiger Climate Classification (Kottek et al., 2006)

Algeria
Afghanistan
Angola
Argentina
Australia
Bolivia
Botswana
Brazil
Burkina Faso
Chad
China
Egypt
Ethiopia
Iran
Iraq
Israel
Jordan
Kazakhstan
Kenya
Kyrgyzstan
Lesotho
Libya
Mali
Mauritania
Mexico
Mongolia
Morocco
Mozambique
Namibia
Niger
Oman
Pakistan
Palestine
Peru
Saudi Arabia
Somalia
South Africa
Sudan
Swaziland
Syria
Tajikistan
Tanzania
Tunisia
Turkmenistan
United States (western half)
Uzbekistan
Western Sahara
Yemen
Zambia
Zimbabwe

Appendix B – Strategy for electronic databases

B.1 Search terms and first results

Preliminary searches were carried as part of a scoping exercise. These aimed to test the relevance of key terms and refine the search strategy. Exposure and outcome terms and their synonyms were identified from our scoping knowledge map and in discussion with the review team keywords and their synonyms identified from our knowledge map. These terms (see Table 44) were then tested using one of the largest databases: Web of Science (ISI Web of Knowledge).

Table 44: Initial search terms

	Search terms (searches were carried out using Boolean operators and wildcards)
Exposure terms	water*, riparian*, aquifer*, aqua*, dam, dams, hydrolog*, hydroelectric*, groundwater, drought*, river*, lake*, stream, streams, reservoir*, flood*, irrigat*, rain*, baseflow*, precipitation, fresh*, basin*, flow, drylands
Outcome terms	conflict*, dispute*, insurgen*, war*, violen*, securit*, terror*, strife, peace*, govern*, coercion, cooperat*, "co-operat*", collaborat*, collective, geopolitic*, "international relation*" allocat*, distribut*, shar*, mediat* governance, treaty, treaties, agreement*, manag*

The refining of the search terms was an iterative process. Each term was tested for its relevance and either rejected or refined. For example, "rain*" became three separate terms rather than a single one with wildcard. Exposure terms were checked first and outcome terms second. All searches were limited to articles published from 1990 onwards. Terms were searched in TOPIC (title, abstract – when available - and keywords) and the first 100 articles were screened to determine usefulness of the term (after sorting by relevance). The results of the trial are outlined in Table 45.

Table 45: Results of trial searches in Web of Science

Trial	**Number of articles**	**Term(s) tested**	**Search syntax and changes**	**Comments**
1	> 100,000	All terms	Complete initial search	Large number of unrelated articles and volume of hits too high.
2	604	Rain, rains, rainfall	Change rain* to rain, rains and rainfall: (rain OR rains or rainfall) AND (conflict* OR cooperat*)	A few relevant articles identified in the first 50 hits. Included in final search.
3	3	Baseflow*	baseflow* AND (cooperat* OR conflict*)	No relevant articles. Excluded from final search.
4	633	Precipitation	precipitation AND (cooperat* OR conflict*)	Large number of unrelated articles. Excluded from final search.
5	1,049	Basin	basin AND (cooperat* OR conflict*)	As above.
6	255	Flood	flood AND (cooperat* OR conflict*)	As above.
7	1,290	Fresh*	fresh*	As above.
8	5,151	Flow	flow	As above.
9	356	Hydrolog*	hydrolog*AND (cooperat* OR conflict*)	As above.
10	62	Hydroelectric*	hydroelectric* AND (cooperat* OR conflict*)	No relevant articles. Exclude from final search.
11	547	Irrigat*	irrigat* AND (cooperat* OR conflict*)	As above.
12	977	Stream, streams	(stream OR streams) AND (cooperat* OR conflict*)	As above.
13	785	Aqua*	aqua* AND (cooperat* OR conflict*)	As above.
14	182	Aquifer	aquifer AND (cooperat* OR conflict*)	As above.
15	353	Groundwater	groundwater AND (cooperat*	As above.

Trial	Number of articles	Term(s) tested	Search syntax and changes	Comments
			OR conflict*)	
16	777	Dry	dry AND (cooperat* OR conflict*)	As above.
17	38	Dryland	dryland AND (cooperat* OR conflict*)	As above.
18	274	Dam, dams	(dam OR dams) AND (cooperat* OR conflict*)	Relevant articles in the first 50 hits. Included in final search.
19	442	Reservoir*	reservoir* AND (cooperat* OR conflict*)	As above.
20	828	Lake*	lake AND (cooperat* OR conflict*)	As above.
21	10,935	Reduced list of exposure terms	(water* OR riparian* OR dam OR dams OR drought* OR river* OR lake* OR reservoir* OR rain OR rainfall OR rains) AND (cooperat* OR conflict*)	As above.
22	49	Coercion	coercion AND (newly reduced exposures)	No relevant articles. Excluded from final search.
23	123	Geopolitic*	geopolitic* AND (reduced exposures)	As above.
24	7,048	Rational*	rational* AND (reduced exposures)	As above.
25	763	Disput*	disput* AND (reduced exposures)	Relevant articles in the first 50 hits. Included in final search.
26	21	Insurgen*	insurgen* AND (reduced exposures)	As above.
27	2,797	Securit*	securit* AND (reduced exposures)	As above.
28	26	Strife	strife* AND (reduced exposures)	As above.
29	224	Terror*	terror* AND (reduced exposures)	As above.
30	19,121	Govern*	govern* AND (reduced exposures)	As above.
31	23,175	Collecti*	collecti* AND (reduced exposures)	As above.
32	54	"International relation*"	"International relation*" AND (reduced exposures)	As above.
33	40,760	Agreement*	agreement* AND (reduced exposures)	As above.
34	8,445	Allocat*	allocat* AND (reduced exposures)	As above.
35	>100,000	Distribut*	distribut* AND (reduced exposures)	High volume of hits and no relevant articles in the first 100 hits. Exclude the term in final search.
36	2,769	Collaborat*	collaborat* AND (reduced exposures)	As above.
37	2,317	Collaboration, collaborative	(collaboration OR collaborative) AND (reduced exposures)	Little difference with previous search. Still no relevant articles. Potentially relevant ones seem to focus on collaboration in industrialized countries and in planning policies and governance. Checked by doing a title search before excluding. Exclude the term in final search.
38	160	Collaborat*	collaborat* AND (reduced exposures) in TITLE	Little difference with previous search. Excluded from final search.
39	848	Violen*	violen* AND (reduced exposures)	No relevant articles. Excluded from final search.
40	24,117	Shar*	shar* AND (reduced exposures)	High volume of hits and no relevant articles in the first 100 hits. Checked with more specific terms such as share, shared, and sharing.

Trial	Number of articles	Term(s) tested	Search syntax and changes	Comments
41	9,341	Share, shared, sharing	(share OR shared OR sharing) AND (reduced exposures)	No relevant articles. Excluded from final search.
42	26,508	Mediat*	mediat* AND (reduced exposures)	As above.
43	357	Treaty, treaties	(treaty OR treaties) AND (reduced exposures)	Relevant articles in the first 50 hits. Included in final search.
44	820	Peace*	peace* AND (reduced exposures)	As above.
45	41,598	Agreement*	agreement* AND (reduced exposures)	High volume of hits, but relevant articles in the first 100 hits. A few relevant articles also include the word 'conflict'. Modify search to exclude 'conflict'.
46	41,117	Agreement*	agreement* AND (reduced exposures) NOT (conflict* OR cooperat*)	High volume of hits and no relevant articles in the first 100 hits. Checked with title only search.
47	80	Agreement*	agreement* AND (reduced exposures) (in title)	Relevant articles in the first 100 hits. Modified search to exclude 'conflict*', 'cooperat*' and 'peace'
48	73	Agreement*	agreement* AND (reduced exposures) NOT (conflict* OR cooperat* OR peace*) (in title)	Previously relevant articles no longer return because of exclusion of terms 'conflict', 'cooperat*', 'peace'. No relevant articles. Exclude from final search.
49	71,868	Manag*	manag* AND (reduced exposures)	High volume of hits, many related to water management for agriculture. Modified search to include specific types of management such as "water resource management"
50	8,964	Several types of management	("water management" OR "river management" OR "basin management" OR "water resource management" OR "watershed management") AND (reduced exposures)	High volume of hits. A few relevant articles which also include the terms 'conflict' or 'cooperation'. Modified search to exclude these terms.
51	8,580	Several types of management	("water management" OR "river management" OR "basin management" OR "water resource management" OR "watershed management") AND (reduced exposures) NOT (conflict* OR cooperat* OR peace*)	Many returns, with no relevant articles in first 100 hits. Modify search to find other types of management which might be relevant
52	55,445	Several types of management	management AND (reduced exposures) NOT ("water management" OR "river management" OR "basin management" OR "water resource management" OR "watershed management")	No relevant articles. Exclude 'management' and other composite terms from final search.
53	9	Hydro-political	hydro-political AND (reduced exposures)	No relevant articles. Exclude from final search.
54	20,159	All terms	(reduced exposures) AND (newly reduced outcomes)	Many relevant articles in first 100 articles, and manageable number of total returns.

The final trial produced a large but manageable number of articles for initial screening.

B.2 Retrieved citations

Search strategies were modified according to each search engine and database included in the review. Table 46 outlines the total number of articles returned from each database searched as well as modifications to the syntax imposed by the variations or limitations of each database.

Table 46: Retrieved citations

Database	Number of articles	Years covered by search	Search strategy used	Comments
Web of Science	20,159	1990-2010	(all outcomes) AND (all exposures)	
ScienceDirect	4,868	1990-2010	(all outcomes) AND (all exposures)	
African Journals Online	53	2003-2010	(all outcomes) AND (all exposures)	Database started in 2003. Title only search.
Directory of Open Access Journals	157	n/a	Conflict AND water (in abstract); cooperation AND water (in abstract)	Limited search capability. Searches were carried out by pairing one exposure with one outcome.
JSTOR	72	1990-2010	(all outcomes) AND (all exposures)	Full search capabilities. First 72 articles were imported. All others were not relevant.
SAGE	101	1990-2010	Conflict AND water (in abstract); cooperation AND water (in abstract)	Limited search capabilities with 'add row' function.
SCOPUS	512	1990-2010	(all outcomes) AND (all exposures)	Full search capabilities.
Adelphi	12	21	Conflict AND water (in abstract); cooperation AND water (in abstract)	Limited search capabilities.
EBSCO-Econlit	2000	n/a	(all outcomes) AND (all exposures)	Copied the first 2000 references to *Mendeley*. Remaining articles were found to be irrelevant.
Geobase	205	1990-2010	(all outcomes) AND (all exposures)	Full search capabilities.
International Bibliography Of the Social Sciences (IBSS)	1196	Earliest-Current	(all outcomes) AND (all exposures)	As above.
SciDev.net	118	n/a	Conflict AND water; cooperation AND water	Limited search capability. Searches in 'key documents'
Woodrow Wilson International Centre for Scholars	7	n/a	Conflict AND water; cooperation AND water	Limited search capability. Searches in 'Publications'
UNEP, ODI, World Bank	245	1990-2010	Water in TITLE AND all outcomes in TEXT	Used Google Scholar for UNEP documents. Limited search capabilities.
Web search	540	1990-2010	Conflict AND water; cooperation AND water	http://www.alltheweb.com http://www.scholar.google.com http://www.google.com http://www.dogpile.com
Pacific Institute's Water and Conflict Bibliography	31	n/a	Conflict AND water; cooperation AND water	
Eldis	118	n/a	Conflict AND water; cooperation AND water	

Appendix C – Coding Tool

Generic	
Identification of report	• Citation (author, date, title, editors (if book section), journal (volume, pages) or publisher (city: institution) • Contact • Hand search • Electronic database (e.g. Web of Knowledge) • Unknown
What kind of printed material does it concern?	• Book • Journal article • Report/working paper • Other (please specify)
What is the status of the report?	• Published • In press • Unpublished (including ongoing project, communication from author) • Conference presentation

Methodological	
What is the purpose of the research?	
What type of methods does this research study report using? (please specify)	

Review specific	
Time frame (please specify)	
Spatial scale	• **Interstate, transboundary rivers: n>2 -** Transboundary conflict involves more than 2 states • **Interstate, transboundary rivers: n=2 -** Transboundary conflict involving 2 states • **Interstate** (not transboundary rivers) • **National level** (country level analysis) • **Intracommunity** -Where social interactions of some aspect of water may occur over a very small area between members of the same community • **Intercommunity -** Representing a slightly larger scale, where all or most of the individuals within each community may present a united front in their interactions with a neighbouring community
Population focus (select all that apply)	• **Individuals** • **Households** • **Communities** *Of place* • **Local/ regional government** • **State** • **Private sector** *Please specify which sector(s)* • **Civil society** *civilians* • **Military**
Theoretical framework (please select all that apply)	• Neo-Malthusian • Cornucopian • Common Property Management • Realist • Neoliberal • Other (please specify) • **Unclear** • **None**
What country/countries were studied (Please select all that apply and specify which nations)	• **Global** • **Africa** • **Asia** • **Central America** • **Eastern Europe**

	• **European Union** • **Middle East** • **North America** • **Please specify (territory or state)** • **Oceania** • **Central America** • **South America** • **The Caribbean**
Dependent variable measured *Please specify measure used and how measured (e.g. from existing dataset; observation; participant views)*	• **Cooperation** *"A situation where there is currently an absence of conflicting interests between two actors, or else where they are regularly resolved through non-violent "mechanisms'* • **Non-violent conflict** *Demonstrations, strikes, claims (please specify)* • **Violent conflict** *'situations of tense confrontation between armed forces, engaging in threats and possible skirmishes, but without significant and sustained force' or 'conflicting interests are normally fought over through violent and coercive military means'* • **Other** *please specify*
Independent variable measure (freshwater) *Please select all the apply*	• **Meteorological variable** *Measures changes in variation in rainfall (specify dataset)* • **Anthropogenic** *River flow reduced due to daming, diversion, increased consumption etc(please specify)* • **Natural -changes to river flow** *Changes in river flow are due to natural causes (e.g. not due to daming or increased upstream withdrawals)* • **Water stress index** *Uses a water stress index that uses only physical parameters (e.g. does not include social parameters) please specify index and dataset name* • **Social water stress index** *Please specify index used and parameter* • **Threshold indicator** *e.g. Drought. Please specify dataset* • **Groundwater measure** • **Other** *Please specify*
Other explanatory variables *E.g. in addition to a freshwater scarcity measure. Please specify measure(s)*	*Please specify measure(s)*
Account of result	*Brief summary of conclusion < 50 words. Tick box to confirm completion*

Appendix D – Confidence Assessment of Included Studies

D.1 Interstate interactions, Transboundary Rivers

Study Identifier	Method description	Theoretical framework with a precise prediction to be tested	Clarity of reporting	Tests causality	Directly links freshwater issues to response variable	Basin disaggregation (transboundary rivers only)	Statistical significance of results clearly presented	Method rank	Overall rank
Brochmann & Gleditsch (2006a)	not done	done	done	done	done	not done	done	4 (7)	**Low (Moderate)**
Brochmann & Gleditsch (2006b)	partial	not done	done	done	not done	not done	done	4	**Low**
Brochmann & Hensel (2008)	done	done	done	done	done	done	done	4	**Low**
De Stefano (2010)	done	done	done	not done	done	done	not done	1	**Low**
Dinar (2009)	done	done	not done	not done	done	done	done	2	**Low**
Dinar *et al.* (2010)	done	done	done	done	done	done	done	7	**Very high**
Dinar *et al.* (2007)	done	done	not done	done	done	done	done	7	**High**
Furlong *et al.* (2006)	done	done	done	done	not done	done	done	5	**High**
Gleditsch *et al.*(2006)	done	done	done	done	not done	done	done	4	**Low**
Hamner (2009)	done	done	done	done	done	done	done	7	**Very high**
Hensel & Brochmann (2008)	done	done	done	done	done	not done	done	7	**High**

Study Identifier	Method description	Theoretical framework with a precise prediction to be tested	Clarity of reporting	Tests causality	Directly links freshwater issues to response variable	Basin disaggregation (transboundary rivers only)	Statistical significance of results clearly presented	Method rank	Overall rank
Hensel *et al.* (2006)	done	done	done	done	done	not done	done	7	**High**
Spector (2000)	done	done	done	not done	done	done	not done	1	**Low**
Stinnett & Tir (2009)	done	done	done	done	done	done	done	7	**Very high**
Tir & Ackerman (2009)	done	done	done	done	done	not done	done	7	**High**
Toset *et al.* (2000)	done	done	done	done	not done	not done	done	6	**Moderate**
Wolf (1998)	not done	done	done	not done	done	not done	not done	1	**Low**
Yoffe *et al.* (2003)	done	done	partial	not done	done	done	done	3	**Low**

D.2 Interstate interactions, excluding Transboundary Rivers

Study Identifier	Method description	Theoretical framework with a precise prediction to be tested	Clarity of reporting	Tests causality	Directly links freshwater issues to response variable	Statistical significance of results clearly presented	Method rank	Overall rank
Stalley (2003)	**done**	**done**	**done**	**done**	**not done**	**done**	**7**	**High**

D.3 Intrastate interactions, national level

Study Identifier	Method description	Theoretical framework with a precise prediction to be tested	Clarity of reporting	Tests causality	Spatial disaggregation (independent variable)	Spatial disaggregation (dependent variable)	Statistical significance of results clearly presented	Method rank	Overall rank
Bernauer et al (2010)	partial	done	not done	done	not done	not done	done	7	**Low**
Buhaug (2010)*	partial	done	partial	done	not done	not done	done	7	**Low**
Buhaug & Theisen (2010)	done	done	not done	done	not done	not done	done	7	**Low**
Burke et al (2009)*	done	not done	done	done	not done	not done	done	7	**Low**
Burke et al (2010)*	done	not done	done	done	not done	not done	done	7	**Low**
Couttenier and Soubeyran (2010)	done	not done	done	done	not done	not done	done	7	**Low**
Gizelis & Wooden (2011)	done	done	done	done	not done	not done	done	7	**Moderate**

Hauge & Ellingsen (1998)	done	done	done	done	not done	not done	done	7	**Moderate**
Hendrix & Glaser (2007)	done	done	done	done	not done	not done	done	7	**Moderate**
Hendrix & Salehyan (2010)	done	done	done	done	not done	not done	done	7	**Moderate**
Kevane & Gray (2008)	done	done	not done	not done	not done	not done	not done	1	**Low**
Levy et al (2005)	partial	done	not done	done	done	done	not done	7	**Low**
Raleigh & Ural (2007)	done	done	done	done	done	done	done	7	**Very high**
Theisen (2008)	done	not done	done	done	not done	not done	done	7	**Low**
Theisen *et al* (2010)	done	done	done	done	done	done	done	7	**Very high**

D.4 Intrastate: Micro-level

Study Identifier	Method description	Theoretical framework with a precise prediction to be tested	Clarity of reporting	Tests causality	Statistical significance of results clearly presented	Method rank	Overall rank
Araral (2009)	done	done	done	done	done		**Low**
Bardhan (2000)	done	partial	done	done	done	4	**Low**
Dayton-Johnson (2000)	done	done	partial	done	not done	3	**Low**
Fayankinnu (2005)	partial	not done	partial	not done	not done	1	**Low**
Funder *et al* (2010)	partial	not done	partial	not done	not done	1	**Low**
Hendrix & Salehyan (2010)	done	done	done	done	done	7	**Very high**
Raleigh and Kniveton (2010)	done	Not done	done	not done	done	2	**Low**
Meinzen-Dick *et al* (2005)	done	done	done	done	done	3	**Low**

Makepe (2005)	done	done	done	done	done	4	**Low**
Meier *et al* (2007)	done	done	done	done	done	3	**Low**
Theisen (2010)	done	done	done	done	done	7	**Very high**
Theisen & Brandsegg (2007)	done	done	done	done	done	6	**Very high**
Witsenberg & Roba (2003)	done	not done	done	not done	done	2	**Low**
					not done	1	**Low**

Appendix E - Systematic map

E.1 Generic details of 48 included studies

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Araral (2009)	EBSCO	**Journal article**	**Published**	Econometric cross-sectional analysis (2002) of the factors that influence collective action in the commons for 1,958 irrigation associations in the Philippines. The author ground truths 13 of the 196 irrigation systems to check for systematic biases in the data.	Multivariate data set from 2002; ground-truthing observations 2003-2005	**Statistical associations** *OLS, Logit regression.*
Bardhan (2000)	Web search	**Journal article**	**Published**	Quantitatively analyses the physical, institutional and socioeconomic determinants of cooperation in irrigation communities in the South Indian state, Tamil Nadu.	Not specified	**Statistical associations** *Logit regression*
Bernauer *et al*. (2010)	Contact	**Working Paper/ Report**	**Published**	Uses rainfall/ temperature as IV, by first examining relationship between rainfall and economic growth in a longitudinal econometric model o examine the link between climate conditions, economic growth and armed conflict at the country level for a global sample. Also carry out a separate analysis for African states.	1950-2004	**Statistical associations** *2SLS, time series.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Brochmann and Gleditsch (2006a)	Electronic dataset: Web search	**Working Paper/ report**	**Published**	Explores the conditions under which a water treaty seems to exist in a dyad, and the relationship between water related events and the signing of treaties.	1820-2002	**Statistical associations** *Econometric, logit regression, dyad-year is unit of analysis*
Brochmann & Gleditsch (2006b)	Electronic dataset: Web search	**Working Paper/ Report**	**Published**	Longitudinal (1975-2000) econometric analysis to examine the impact of drought, region and regime type on cooperation (dyadic trade and joint dyad membership of international organisations) for a global sample.	1880-2000 & 1975-2000	**Statistical associations** *Multivariate analysis. Gravity model is used as a baseline and additional control variables are included from an earlier study of shared rivers and conflict.*
Brochmann & Hensel (2008)	Electronic dataset: Web search	**Working Paper/ Report**	**Published**	Examine the management of internationally shared rivers to explore the conditions states are most likely to try and solve ongoing river disputes. Dyad-year is the unit of analysis.	1900-2001	**Statistical associations**: *Multivariate analyses (Heckman probit analysis). Control for relative capabilities (CINC, from ICoW).*
Buhaug & Theisen (2010)	Contact	**Book**	**Published**	Uses a longitudinal econometric analysis to examine the impact of interannual rainfall variability on the onset of civil war in African states.	1960-2004	**Statistical associations** *Regression, time series*
Buhaug (2009)	Contact	**Journal article**	**Published**	Uses a longitudinal econometric analysis to examine the impact of interannual precipitation and temperature variability on the onset of civil war in African states over the period.	1982-2002	**Statistical associations** *multivariate regression models*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Burke *et al* (2009)	**Electronic dataset**: *Web of Knowledge*	**Journal article**	**Published**	Uses an longitudinal econometric analysis to examine the relationship between interannual temperature and precipitation variability in African states.	1981-2002	**Statistical associations** *Regression, time series.*
Burke *et al* (2010)	**Contact**	**Working Paper/ Report**	**Published**	Explores the incidence of civil war to country specific deviations from long-term trends temperature and precipitation. Re-examining an earlier paper that linked historical variation of climate to incidence of African conflict.	1981-2002	**Statistical associations** *Regression, time series.*
Couttenier and Soubeyran (2010)	**Contact**	**Working Paper/ Report**	**Published**	Uses a longitudinal econometric analysis to examine the relationship between drought and civil war in Sub-Saharan Africa	1960-2000	**Statistical associations** *Regression, time series*
Dayton-Johnson (2000)	**Electronic dataset**: *ScienceDirect*	**Journal article**	**Published**	Theoretical model verified by field work to explore the determinants of cooperation in Mexican irrigation societies.	1995-1996	**Statistical associations** *Logit, Cross-sectional* **Qualitative methods** *Ethnography*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
De Stefano *et al* (2010)	**Electronic dataset**: *Web of Knowledge*	**Journal article**	**Published**	Surveys hydro political relations over the period 1948-1999 and compares to 2000-2008.	1948-2008	**Collects numerical measures** *International basins (from the Transboundary Freshwater Dispute Database and Atlas of International Freshwater Agreements) scanned for new events. International Water Events listed from year 1999 culled for news sources and keywords. Incidents ranked by intensity along a conflict-cooperation scale used in the International Water Events Database of COPDAB.* **Examines relationships** *Relationship between water-related events and level of conflict/cooperation in 1948-1999 compared to 2000-2008*
Dinar (2009)	**Electronic dataset**: *Web search*	**Journal article**	**Published**	Using an ANOVA study, examines the difference between treaty existence/number of treaties and dyads that are likely to cooperate (both riparians have moderate scarcity or just one dyad has moderate or high scarcity) and those that aren't (both dyads have low or high levels of water scarcity.	Does not specify	**Statistical associations** *ANOVA*
Dinar *et al* (2010)	**Electronic dataset**: *DOAJ*	**Journal article**	**Published**	Uses s longitudinal econometric analysis to examine the impact of water supply variability on 'treaty cooperation' between dyads for a global sample.	Un-specified	**Statistical associations** *Logit, time series.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Dinar *et al.* (2007)	**Electronic dataset**: *EBSCO*	**Working Paper/ Report**	**Published**	Uses a longitudinal econometric analysis to examine the impact of water scarcity in leading to cooperation between dyads for a global sample.	1850-2002	**Statistical associations** *OLS, time series.*
Fayankinnu (2005)	**Electronic dataset**: *DOAJ*	**Journal article**	**Published**	Examines the form/patterns of social conflict generated as a result of water shortage in Akungba-Akoko of Ondo State.	no indication	**Structured surveys and/or validated measures** **Collects numerical measures** **Qualitative methods** *semi-structured interviews, in-depth interviews*
Funder *et al.* (2010)	**Electronic dataset**: *Web of Knowledge*	**Journal article**	**Published**	Explores water conflict and cooperation events in Namwala District of Zambia reported over the period 1995-2007 by collective quantitative data from interviews with current and former government officials, local authorities and line agencies, the police and courts and civil society associations.	1995-2007	**Examines relationship** **Qualitative methods** *Focus group, semi-structured interviews, 3 in-depth case studies*
Furlong (2006)	**Electronic dataset**: *Web search*	**Journal article**	**Published**	Uses a longitudinal econometric analysis to explore the relationship between contiguous territories with shared rivers, water scarcity and conflict.	1880-1992	**Statistical associations** *Logit, time series.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Gizelis & Wooden (2011)	**Electronic dataset**: *ScienceDirect*	**Journal article**	**In press**	Conducts a longitudinal econometric analysis to examine the direct and indirect impact of water scarcity on conflict by systematically exploring how intervening factors, such as political institutions might influence the impact of water scarcity on the probability of conflict.	1981-2000	**Statistical associations** *Simultaneous equations model, time series.*
Gleditsch *et al*. (2006)	**Electronic dataset**: *IBSS*	**Journal article**	**Published**	Uses a longitudinal econometric analysis to examine the relationship between shared rivers and interstate conflict for a global sample.	1880-2001	**Statistical associations** *Logit, time series.*
Hamner (2009)	**Electronic dataset**: *Web search*	**Working Paper/ Report**	**Published**	Uses a longitudinal econometric analysis to examine the impact of drought and long-term drought on the likelihood of water treaty formation between 2 countries for a global sample.	1948-2001	**Statistical associations**: *Cox regression, time series.*
Hauge & Ellingsden (1998)	**Electronic dataset**: *Web search*	**Journal article**	**Published**	Use an econometric, longitudinal analysis to examine the effects of land degradation, freshwater scarcity, population density and deforestation on interstate conflict at the country level for a global level sample.	1980-1992	**Statistical associations** *Logit; time series, cross-sectional data to verify results.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Hendrix & Glaser (2007)	**Hand search**	**Journal article**	**Published**	Use a longitudinal econometric analysis to examine the impact of both long-term trends and short-term shocks in water availability on the onset of civil war in Sub-Saharan Africa.	1981-2002	**Statistical associations** *Logit, time-series.*
Hendrix & Salehyan (2010)	**Electronic dataset**: *Eldis*	**Working Paper/ Report**	**Conference presentation**	Use a econometric, longitudinal analysis to examine the impact of hydro-meteorological disasters (droughts and floods), on civil conflict as well as on civil unrest in Africa.	1990-2009	**Statistical associations** *logistic regression, time series*
Hensel & Brochmann (2007)	**Electronic dataset**: *Web search*	**Working Paper/ Report**	**Conference presentation**	Explores the management of shared rivers to examine the conditions under which outbreak of explicit disagreements (river claims) and which of these disagreements are most likely to lead to militarisation.	1990-2001	**Statistical associations** *ReLogit (Rate Event Logistic Regression)*
Hensel *et al* (2006)	**Electronic dataset**: *IBSS*	**Journal article**	**Published**	Explores link between resource scarcity (water in this case) and interstate conflict.	1900-2001	**Statistical associations** *Logit, time series.*
Kevane & Leslie (2008)	**Electronic dataset:** *Web of Knowledge*	**Journal article**	**Published**	Examines the relationship between civil conflict in Darfur, Sudan and other nations in sub-Saharan Africa and structural breaks in rainfall (interannual variability) between 1971 and 2006.	1971-2006	**Examines relationships** *Time series analysis of rainfall data and compares to outbreaks of violence (viz. Darfur, 2003).*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Levy *et al* (2005)	**Contact**	**Working Paper/ Report**	**Published**	Longitudinal econometric analysis to examine the link between water availability (surface freshwater availability and interannual rainfall variability) and low and height intensity internal war outbreak.	1980-2002	**Statistical associations** *Logistical regression model*
Makepe (2005)	**Electronic dataset**: *EBSCO*	**Journal article**	**Published**	Econometric cross-sectional analysis to examine determinants of collective action in the Kgatleng Distring of Botswana. In particular examined the relationship between water shortages during the dry season and alternative water sources to bore hole syndicates during the wet season and collective action.	2002	**Structured surveys and/or validated measures** *3 members from each of the 73 borehole syndicates. Collected information on the: structure; function; use and maintenance or water and range resources; range degradation and improvements; causes and extent of disputes over resource use; market accessibility.* **Statistical associations** *Regression* **Qualitative methods** *semi-structured interviews*
Meier *et al* (2007)	**Electronic dataset**: *Web search*	**Working Paper/ Report**	**Published**	Econometric, longitudinal analysis to examine the relationship between rainfall deficiency and violence in the border areas between Uganda, Kenya and Ethiopia.	January 2004 - December 2005	**Statistical associations** *OLS, times series.*
Meinzen-Dick *et al.* (2005)	**Electronic dataset**: *Eldis*	**Working Paper/ Report**	**Published**	Examines links between physical and socioeconomic environment and the strength of farmer involvement to identify conditions under which farmers are most likely to participate in irrigation systems in Rajasthan and Karnataka, India.	Not specified	**Statistical associations** *Logit* **Qualitative methods** *Ethnography*: *Ethnographic information relating to study villages and their history.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Raleigh & Urdal (2007)	**Electronic dataset**: *Web search*	**Journal article**	**Published**	Using geo-referenced data for the sub-national level uses an econometric, cross-sectional analysis to examine the relationship between local resource scarcity and conflict (land degradation and freshwater availability) for a global sample.	1990-2004	**Statistical associations** *Logit, cross-sectional.*
Raleigh & Kniveton (2010)	**Electronic dataset** *Web search*	**Working Paper/ Report**	**Unpublished**	Spatially and temporally examines communal violence, and explores whether areas have overall differences in conflict event occurrence, normalised by area, population and over time; if communal violence patterns exhibit unique spatial and temporal tendencies that are different from political ethnic violence or civil war; or if patterns of violence correlated to environmental shifts, such as rainfall spatial and temporal variation.	2003-2010	**Statistical associations** *Correlations*
Spector (2000)	**Hand search**	**Journal article**	**Published**	Examines the types of environmental, social and economic indicators that create suitable conditions for negotiating cooperative water resource agreements	Does not specify	**Examines relationships**
Stalley (2003)	**Unknown**	**Working Paper/ Report**	**Published**	Uses a cross-national, longitudinal econometric analysis to examine the relationship between resource scarcity and interstate militarised conflict.	1980-1992	**Statistical associations** *Logit, time series.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Stinnett & Tir (2009)	**Hand search**	**Journal article**	**Published**	Uses a longitudinal econometric analysis to examine the impact of water scarcity and other factors on the institutional cooperation of rivers for a global sample.	1950-2002	**Statistical associations** *Probit, time series.*
Theisen (2008)	**Contact**	**Working Paper/ Report**	**Unpublished**	Using an econometric longitudinal analysis, examines the relationship between resource scarcity and civil conflict (including freshwater scarcity and drought) at the country level for a global sample.	1979-2001	**Statistical associations** *Logit; time series.*
Theisen *et al*. (2010)	**Electronic dataset**: *Eldis*	**Working Paper/ Report**	**Published**	Use a longitudinal econometric analysis and a high resolution gridded dataset of Africa between 1960-2004, that combines geo-referenced and annualised precipitation data with new data on the point location of civil war onset and the location-specific drought measures and allow for both direct and conditional relationships, where the effect of drought is contingent on various socio-political characteristics at the local as well as the national level.	1960-2004	**Statistical associations** *Relogit, Logit, time series.*
Theisen (2010)	**Contact**	**Working Paper/ Report**	**Conference presentation**	Longitudinal econometric analysis to examine the link between various indicators of interannual precipitation variability and violent conflict using spatially disaggregated data for both dependent and independent variables.	1989-2004	**Statistical associations** *Relogit, time series.*

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Theisen & Brandsegg (2007)	**Electronic dataset**: *SAGE*	**Journal article**	**Published**	Explores the relationship between resource scarcity and internal armed conflict on smaller-scale internal conflicts with no direct state involvement, so called non-state conflicts for Sub-Saharan Africa.	2002-2005	**Statistical associations** *Logit, cross-sectional.*
Tir & Ackerman (2009)	**Electronic dataset**: *Web search*	**Journal article**	**Published**	Uses a longitudinal econometric analysis to examine factors that hinder the emergence of formalised river cooperation in a global sample.	1948-2000	**Statistical associations** *Cox regression, time series.*
Toset (2000)	**Hand search**	**Working Paper/ Report**	**Conference presentation**	Uses a longitudinal bivariate and econometric analysis to examine how the supply of water may be associated with violent conflict between states, on its own or interaction with other factors for a global sample.	1880-1992	**Statistical associations** *Logit, time series.*
Witsenburg & Roba (2002)	**Hand search**	**Journal article**	**Published**	Explores the link between violent conflicts and scarcity of water in Marsabit District, northern Kenya.	1997-2000	**Statistical associations** *Correlation between armed incidents and killings and rainfall / rainfall 1-year time lag.* **Qualitative methods** *Semi-structured interviews* *Ethnography*: *Historical records.*
Wolf (1998)	**Electronic dataset**: *Web of Knowledge*	**Journal article**	**Published**	Relies on event data time series to identify historical incidence of international freshwater conflict and cooperation.	1948-1999	**Examines relationships**

Study	Identification of report	Type of publication	Status of report	Study purpose	Time-frame	Research methods
Wutich (2009)	**Contact**	**Journal article**	**Published**	Using field observations, and significant testing methodologies (t-test, ANOVA) , examines how an urban Andean (Cochabamba) common pool water resource institutions in a squatter settlement (Villa Israel) perform during periods of water scarcity in 2004, 2005 and 2008.	2003-2008	**Examines relationships** *Tabulates the relationship between use of tapstand system (distributes groundwater) and community membership (collaboration).* **Qualitative methods** *Semi-structured interviews*: *household interviews with community and non-community members.*
Yoffe (2003)	**Contact**	**Journal article**	**Published**	Explores the impact of a number of factors, including water stress on conflict/cooperative interactions in international river basins.	1948-1999	**Statistical associations** *Regression, time series, two-sample t-tests.*

E.2 Review specific details by scale of analysis

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Araral (2009)	**Intracommunity**	**Asia**: *Philippines*	Common resource management theory: Collective action outcomes are shaped by the incentive structure faced by the players which is in turn affected by the context they face. The context is defined by the physical characteristic of the resource, the attributes of the players and the internal and external institutional context.	**Other** *Cropping intensity as a proxy for water scarcity (inverse relationship), continuous captures wet and dry season.*	Distance to market; age of irrigation association; group size; origin of IA - irrigation association (self-organised/ government assistance); gender (% women in IA); farm size (proxy for wealth); governance structure of IA	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Collective action measured by two proxies: free riding in the payment of irrigation feed; free riding in terms of labour contribution towards maintenance of irrigation system.*
Bardhan (2000)	**Intracommunity**	**Asia** *6 districts in Tamil Nadu*	Common property management: no clear hypothesis, but expect that in conditions of extreme scarcity, arrangements of cooperation may break down, whilst during times of abundance, there is a greater incentive to cooperate	**Other** *Number of months there is access to irrigation; whether irrigation channel is lined; whether topographical nature of the area precludes equal access to water for all the farmers.*	Number of beneficiary households per acre of *ayacut* area; number of beneficiary households using irrigation source; Gini coefficient of land-holding of beneficiary households in *ayacut*; at least 75% of sampled farmers are members of the same caste group; the system is partially or fully lined; if *ayacut* is in a canal system; if PWD makes all decisions on allocation; if village is situated at the tail end of the irrigation system; index of connection with urban areas; measure of extent to which farmers are market orientated; estimated fraction of total irrigated land held by sampled farmers outside the *ayacut*; irrigation organisation has been there for 20 years or more.	**Other** *Water allocation rules frequently violated by at least one group; no conflict over water within village in the past 5 year; index of quality of maintenance of distributaries and field channels.*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Bernauer et al (2010)	**Aggregate national level**	**Global** **Africa**	Rainfall and temperature indirectly lead to conflict through changes in economic growth. Uses rainfall/ temperature as IV, by first examining relationship between rainfall and economic growth in an econometric model.	**Meteorological variable** *Precipitation using various measures: Standardized Precipitation Index (SPI 6); yearly moving average of precipitation (difference between the current year's precipitation level and the average of the previous 30 years) (GPCC, CRU).*	Yearly moving average of temperature (CRUTEM3); political institutions (Polity IV). Control variables: GDP per capita (Penn World Tables); population; population growth; ethnolinguistic fractionalisation (Fearon & Laitin, 2003); mountainous terrain (Fearon & Laitin, 2003); oil exporting countries (Fearon & Laitin, 2003); regional dummy variable.	**Crisis/ violent conflict** *25 battle-related deaths (Uppsala / PRIO)* **Other** *Economic growth (first equation) (Penn World Tables).*
Brochmann & Gleditsch (2006a)	**International** *n=2*	**Global**	No model or hypothesis.	**Threshold indicator** *Drought: when one or both states have experienced a drought at any time during the past five years (CRED).*	Peace history (number of years since the last MID in the dyad since the younger of the two countries gained independence), regime type (Polity IV); proximity (distance between capitals and contiguity, ICoW), major power (ICoW) economic strength (GDP) % of basin in the upstream state; alliances (dyad pair part of entente or defence pact, ICoW); joint memberships of IGOs (ICoW); regional differences (SSA and MENA).	**Other** *Treaty existence and treaty signing from Transboundary Freshwater Dispute Database.* *Water events variable from International Water Events Database (water event registered in the dyad the previous year).* *Two dichotomous variables from the 15 point Basins at Risk scale (Yoffe et al 2003). Cooperative event (1-7) and Conflictive event (-1 -7).*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Brochmann & Gleditsch (2006b)	**International** *n=2*	**Global**	Cornucopian framework Shared rivers are likely to promote cooperation as well as conflict.	**Threshold indicator** *Drought: whether one or both countries have experience a drought at any time during the past five years (CRED)*	Shared basin (Transboundary River Basin Registry) Critical regions (SSA and MENA)	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Dyadic trade (US$, 1996); Joint memberships in international organisations are used as indicators of cooperation (ICoW, Pevehouse et al, 2004).*
Brochmann & Hensel (2008)	**International** *n=2*	**Central America; European Union:** ***Western Europe*** **Middle East; North America; South America**	Neo-liberal: expect claims most likely to occur when water is scarce, the river is long (proxy for river salience), river crosses international boundary rather than acts as a border but likely to experience peaceful settlements. River claims are less likely to begin when river treaties already exist.	**Physical water stress index** *Water supply: Water discharge and water runoff; Water supply: water demand (population density of river basin) (TFDD)*	Length of river (ICoW), river claim salience (ICoW), existence of river treaties (TFDD), shared IGO membership, trade interdependence between dyads (ICoW), Polity IV.	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Peaceful negotiations (ICoW)* **Non-violent conflict** *River claim between dyads (ICoW)*
Buhaug & Theisen (2010)	**Aggregate national level**	**Africa**	Neo-Malthusian Expect drier years to be associated with higher civil war risk	**Meteorological variable** *Interannual and long-term precipitation deviations (GPCP).* **Threshold indicator** *Intra-annual rainfall variability (0.5 x 0.5 Standardized Precipitation Index), coded drought as three consecutive months with at least 1 SD below normal, or two consecutive months with at least 1.5 SD below normal.*	Ethnopolitical exclusion (EPR database); democratic institutions (Polity IV); IMR; population size; decay function for time since last conflict (UCDP/PRIO).	**Crisis/ violent conflict** *Onset of civil war - 25 battle deaths/ year (UCDP/PRIO)*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Buhaug (2009)	**Aggregate national level**	**Africa** *SSA*	Based on neo-Malthusian framework, but no model or hypothesis.	**Meteorological variable** *Precipitation (Global Precipitation Climatology Centre).*	Ethnopolitical exclusion; economic level of development; conflict history; post-cold war period.	**Crisis/ violent conflict** *Civil conflict (>25 deaths) Uppsala Conflict Data Program/PRIO*
Burke *et al* (2009)	**Aggregate national level**	**Africa** *SSA*	No clear model but, broadly neo-Malthusian/ eco-violence framework. Expect variability in temperature and precipitation in highly dependent rain-fed areas leads to conflict due to reductions in agriculture performance.	**Meteorological variable** *Country level variations in precipitation (CRU).*	Country level variations in temperature (CRU), per capita income, democracy (Polity IV).	**Crisis/ violent conflict** *Civil war - 1000 battle related deaths (Uppsala/PRIO)*
Burke *et al* (2010)	**Aggregate national level**	**Africa**: *SSA*	Neo-Malthusian, no clear hypothesis	**Meteorological variable** *Deviation in precipitation (CRU)*	Deviations in temperature (CRU); country fixed effects and country-specific time trends (although these are not specified).	**Crisis/ violent conflict** *Civil war - 1000 and 25 battle deaths/year analysed separately (Uppsala/PRIO conflict data)*
Couttenier & Soubeyran (2010)	**Aggregate national level**	**Africa** *SSA*	Neo-Malthusian	**Threshold indicator** *PDSI*	GDP growth; population; peace years; Polity 2; mountainous terrain; former UK colony; former French colony; oil producer	**Crisis/ violent conflict** *incidence and onset of civil war ≥ 1000 battle deaths, Uppsala/ PRIO*
Dayton-Johnson (2000)	**Intracommunity**	**Central America** *Mexico, Guanajuato*	Common property management: Expects irrigation supply to be positively associated with a proxy of collective action (irrigation canal maintenance).	**Other** *Irrigation supply ($1000sm^3$): water available in the reservoir at the beginning of the irrigation season*	Group size, economic inequality (Gini coefficient of landholding), social heterogeneity (number of different villages from which the users are drawn), local wages (proxy unit for cooperation due to opportunity cost), government constructed system.	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Collective maintenance is a proxy for cooperation and includes three variable: maintenance of canal slopes; condition of field intakes; filtration.*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
De Stefano *et al* (2010)	**International** *n=2, n>2*	**Global**	None provided	**Other** *Water quantity, water quantity and other events listed in the International Water Events Database.*	None	**Other** *Water event intensity scale (modified from Yoffe et al., 2003)*
Dinar (2009)	**International** *n=2*	**Global**	Expect cooperation to be most likely during moderate scarcity, and decreases during low scarcity and high-levels of scarcity - termed 'Scarperation'. As such the relationship between scarcity and the likelihood of cooperation follows a curvilinear trend.	**Water stress index with social parameters** *Water Poverty Index (WPI) (Lawrence, Meigh, and Sullivan 2002)*	None	**Other** *Water treaties (treaty/no treaty)*
Dinar *et al* (2010)	**International** *n=2*	**Global**	Expect cooperation to be most likely during moderate levels of water supply variability and decreases during low and high levels of water supply variability - termed 'Scarperation'. As such the relationship between scarcity and the likelihood of cooperation follows a curvilinear trend.	**Meteorological variabl**e *Water variability measured using: runoff data (Global Runoff Data Centre); precipitation data (Climate Research Unit from CGIAR)*	Democracy and governance ; trade interdependence; diplomatic relations (ICOW); GDP and GDP per capita (proxy for power asymmetries); river geography (e.g. cross-boundary); existing treaties (TFDD).	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Treaty data (226 country dyad observations)*
Dinar *et al* (2007)	**International** *n=2*	**Global**	Expect long-term water supply variability will lead to enduring cooperation between river riparians	**Physical water stress index** *Water availability per capita (Population Action International)*	Governance (Corruption Perception Index); trade interdependence, geography of river (e.g. cross border).	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Cooperation between two riparian states measured as existence of a treaty.*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Fayankinnu (2005)	**Intracommunity**	**Africa** *Nigeria*	Neo-Malthusian	**Meteorological variable** *Dry season.* **Other** *Number of boreholes.*	None	**Other** *Social conflict defined as physical violence, the use of charms, verbal assault, breaking of water containers.*
Funder *et al* (2010)	**Intracommunity**	**Africa** *Namwala district, Zambia*	Observational study, no theoretical framework presented.	**Meteorological variable** *Wet and dry seasons*	None	**Other** *Inventory of all formally reported public water events, defined as "actions (or set of actions) that seek to secure one or more parties' access to water by: challenging other parties' access; confirming own or other parties' access; collaborating with other parties to secure access." Conflictive: one or more parties challenge other parties access to a particular water resource; Cooperative: one or more parties engage in jointly coordinated actions with other actors to secure shared water access or acknowledge other parties access to water.*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Furlong (2006)	**International** *n=2*	**Global**	Neo-Malthusian: expect, ceteris paribus, countries with water scarcity are more likely to exhibit dyadic conflict. And, water scarcity increases the extent to which river sharing is associated with dyadic conflict behaviour	**Physical water stress index** *Freshwater availability (Hauge and Ellingsen, 1998). Country with less than 10,000 m3 per capita per year is coded as water-scarce.*	Shared rivers, alliances (ICoW), regime type (Polity III), major power status (ICoW), peace history, energy consumption (proxy for economic development), boundary length.	**Crisis/ violent conflict** *onset of MID with minimum one fatality (ICoW).*
Gizelis & Wooden (2011)	**Aggregate national level**	**Global**	Neo-Malthusian: expect water resource scarcity to increase the probability of intrastate wars; and water resource scarcity to contribute to the emergence of autocratic regimes.	**Meteorological variable** *Controls: precipitation every 5 years (FAO); water dependency ration (FAO).* **Physical water stress index** *Internally renewable freshwater resources per capita (IRFWR, FAO Aquastat, 2001) at intervals of 5 years.*	Governance proxy (institutionalised democracy, Policy IV); Index of democracy; urbanisation; crop production index ; rural population density; GDP per capita. Control for total population and occurrence of conflict during the study period, number of consecutive peace years since the study period.	**Crisis/ violent conflict** *25 battle-related deaths/ year (UCDP 2008).*
Gleditsch *et al*. (2006)	**International** *n=2*	**Global**	Neo-Malthusian: expect dyads with an unequal distribution of shared water resources to have more conflict; dyads sharing a river basin have more conflict if one or both of the countries in the dyads have low rainfall; dyads sharing a river basin have more conflict if one or both of the countries in the dyad have recently experienced drought.	**Meteorological variable** *Average rainfall.* **Threshold indicator** *Drought in last 5 years.*	Shared basin; river boundary; cross boundary river; basin size; upstream basin; percent upstream.; regime type (Polity IV); level of development (per capita energy consumption); population size of dyad; major power; alliance; distance; boundary length.	**Crisis/ violent conflict** *onset of MID (ICoW), minimum one fatality.*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Hamner (2009)	**Aggregate national level**	**Global**	Prospect: Expects a state experiencing a period of acute scarcity to experience an increase in the likelihood of the formation of a treaty addressing water issues with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.	**Drought** *PDSI: current year; past year; three-year moving average; shared drought (PDSI of -1 to -4).*	Trade; development (natural log of GDP per capita in $US); military capabilities (ICoW); dyad democracy (Polity IV).	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Treaty formation, specifically addressing water as a resource (TFDD). Disaggregate between treaties relating to hydropower/navigation; treaties that address freshwater quality/quantity; treaties that specifically allocate freshwater.*
Hauge & Ellingsden (1998)	**Aggregate national level**	**Africa** *SSA*	Neo-Malthusian: expect countries with a low freshwater availability per capita to be more likely to experience domestic armed conflict than countries with a high freshwater availability per capita	**Meteorological variable** *% change in annual rainfall from previous year; dummy variable for SD > 1/2 from mean (30 year normal) (GPCP)* **Physical water stress index** *Per capita renewable water resources (FAO).*	Static land degradation (FAO); climate suitability for Eurasian climate (Köppen-Geiger classification) Control variables: per capita GDP, oil producer, % mountainous terrain, and GDP growth.	**War** *Civil war (PRIO/Uppsala)*
Hendrix & Glaser (2007)	**Aggregate national level**	**Africa**	Neo-Malthusian: Expects that higher levels of rainfall relative to previous years will be associated with higher returns to agriculture and therefore lower risk of conflict.	**Meteorological variable** *Interannual rainfall variability (GPCP);* **Physical water stress index** *Climate suitability for agriculture (typical of Eurasian continent); total renewable water resources per capita.*	GDP per capita; GDP growth; population; mountainous regions; oil producer; total percentage of land degraded.	**Crisis/ violent conflict** *Civil conflict onset (25+ annual battle deaths)*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Hendrix & Salehyan (2010)	**Aggregate national level; Intercommunity**	**Africa**	Does not provide a formal model, but discusses five plausible mechanisms. Hydro-meteorological disasters may lead to: conflict between consumers due to water salience or desertification; price disputes between rural producers and urban consumers and food price inflation; migration from stressed areas may lead to competition for resources, employment and cultural tensions; strains on government revenues due to the reduction of the tax base and increase demands for services and assistance from disasters ; negative macroeconomic impacts may lead to civil conflict and social disorder.	**Meteorological variable** *Hydro-meteorological disasters: annual standardised rainfall deviation from the long-term (1979-2008) panel mean of rainfall (Global Precipitation Climatology Project).* **Threshold indicator** *Drought and flood events using CRED dataset.*[32]	Polity II; population; population growth; GDP per capita; GDP growth.	**Crisis/ violent conflict** *Civil conflict onset (25+ annual battle deaths), low level violence and non-violent events e.g. riots, demonstrations (Social Conflict in Africa Database, SCAD).*
Hensel & Brochmann (2007)	**International** *n=2*	**Global**	High levels of water scarcity increase the frequency of explicit claims over water, increase chances of militarized conflict, and make it more difficult for conflict management institutions to be effectively created.	**Physical water stress index** *renewable water resources per capita; annual water use per capita; annual water use as a % of renewable water.*	River specific institutions, general conflict management institutions. Control for: joint democracy (Polity IV); river claims salience (ICoW); power asymmetry (Material Capabilities, ICoW); history of recent conflict.	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Bilateral and third party effort to manage conflict.* **Crisis/ violent conflict** *MID over given river claim* **Other** *Effectiveness of peaceful conflict management.*

[32] Events meet the CRED definition of disaster if one or more of the following criteria are met: 1) 10 or more people were reported killed; 2) 100 people were reported affected; 3) declaration of a state emergency; and/or 4) it led to calls for international assistance see http://www.emdat.be/criteria-and-definition).

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Hensel *et al* (2006)	**International** *n=2*	**Africa; Asia; Central America; Eastern Europe; Middle East; South America**	Variant of neo-Malthusian arguments of scarcity leading to conflict due to weak institutional capacity, deprivation and grievance.	**Meteorological variable** *Rainfall deviations from normal (using Weighted Anomaly Standardized Precipitation Index - WASP), lagged by 1 year; ean annual locally-derived runoff (using a Water Balance and Transport Model)*	Control for relative IMR and trade openness compared to global mean; democratic institutions (Polity) and population.	**Crisis/ violent conflict** *Low and high-level civil conflict (PRIO/Uppsala Conflict Database).*
Kevane & Leslie (2008)	**Aggregate national level**	**Africa** *Sudan, Darfur; Sahelian/ West Africa*	None provided	**Meteorological variable** *Rainfall (CRU, & GPCP)*	None	**Crisis/ violent conflict** *years of war (PRIO0; civil conflict in 1980s and 1990s (PRIO); years of war (Collier)*
Levy *et al* (2005)	**Aggregate national level**	**Global**	Expect regions with low levels of baseline water availability to be more prone to conflict than other regions; contiguous or near-contiguous regions that exhibit significant disparities in baseline levels of water availability are more prone to conflict than other regions; regions with high levels of variability on available water are more prone to conflict than other regions; deviations from baseline water availability that result in significant disparities across regions will experience more conflict than other regions.	**Physical water stress index** *Renewable water availability (mean annual locally-derived runoff); average water availability per capita* **Meteorological variable** *Interannual precipitation variability.*	Population; Polity -5 to -7; IMR; trade openness.	**Crisis/ violent conflict** *Violent conflict (low and high intensity), Uppsala / PRIO*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Makepe (2005)	**Intracommunity**	**Africa** *Botswana*	Common Property Management. Specifically: water shortages during the dry season has a positive impact on collective actions (since reliance on borehole during this period raises the stakes for members to act collectively to ensure that water is available on a permanent basis).	**Water stress index with social parameter** *Water shortage during the dry season.* **Other** *Source of water during the wet season.*	Number of households who are members of syndicates; heterogeneity in cattle ownership; average herd size per member; total distance to major market where cattle are sold; membership in other village organisations; age of syndicate; years of schooling of the chairman; presence of hirers; percentage of women members; turnover ratio of membership.	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Index of collective action including 5 variables: disputes; number of meetings; percentage of attendance; non-payment of fees; and punishment.*
Meier *et al* (2007)	**Intercommunity**	**Africa** *Uganda, Ethiopia, Kenya*	Neo-Malthusian: Expect that environmental variability drives pastoral migration and competition over dwindling resources critical to livelihoods, which in turn may lead to the use of violence to secure these resources.	**Meteorological variable** *Spatially disaggregated monthly precipitation (NOAA)*	Vegetation (NOAA, AVHRR), forage (LEWS), peace indicator scores from CEWARN (alliances, exchanges, mitigation, initiatives), conflict indicator scores (aggravators, pressure, provocation).	**Crisis/ violent conflict** *Pastoral conflict (human deaths, livestock losses, organised raids), from CEWARN.*
Meinzen-Dick *et al.* (2005)	**Intracommunity**	**Asia** *Rajasthan and Karnataka, India.*	Common resource management: Expect a curvilinear relationship between scarcity (location along irrigation canal) and cooperation and less cooperation where farmers are less reliant on irrigation canals (i.e. in wetter regions)	**Other** *Location along irrigation canals, density of wells*	None	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Cooperation (Water User Associations, collective representation, maintenance of minor irrigation canal)*
Raleigh & Urdal (2007)	**Aggregate national level**	**Global**	Neo-Malthusian: expect areas with high freshwater scarcity are more likely to experience armed conflict the greater the population growth.	**Physical water stress index** *Easily available freshwater (TERRASTAT)*	Soil degradation (ISRIC); population growth and density (CIESIN); regime type (Polity IV); political change (Polity IV); annual GDP (proxy for state capacity; state adaptability).	**Crisis/ violent conflict** *Civil conflicts (Uppsala/PRIO data).*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Raleigh & Kniveton (2010)	**Intercommunity**	**Africa**	Unclear / implicitly eco-violence: Expect communal violence may become more common as the adverse effects of direct climate change may be disproportionately felt amongst the smaller, economically and politically marginalised across arid and semi-arid lands.	**Meteorological variable** *Interannual rainfall*	n/a	**Crisis/ violent conflict** *Communal violence (Armed Conflict Location and Event Dataset)*
Spector (2000)	**International** *n=2*	**Global**	None	**Water stress index with social parameters** *Water inequality indicator between riparian states*	None	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Cooperation (treaty existence)*
Stalley (2003)	**International** *n=2*	**Global**	States experiencing environmental scarcity are more likely to be involved in international conflict.	**Physical water stress index** *Per capita freshwater availability (WRI)*	Fish stocks (WRI), Soil degradation (GLASOD); population density (Demographic Yearbook); environmental scarcity (aggregate environmental scarcity score); vulnerability: PCA generated factor of inequality, number of subsistence farmers, land burden, fuel wood as a percent of energy consumption; and proxy measures land burden and number of subsistence farmers (all from State Failure Task Force). Control for: regime type (Polity III), economic development (per capita real GDP), economic interdependence (trade as a % of GDP), military capability, geographic opportunity (number of borders), peace history.	**War** *Militarised International Dispute (ICoW)*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Stinnett & Tir (2009)	**International** *n=2; n>2*	**Global**	Neoliberal theoretical framework. Institutionalisation of river treaties depend on the urgency (degree of scarcity) to cooperate and contextual political factors. High levels of institutionalisation will be difficult to achieve in the absence of factors that make it desirable.	**Physical water stress index** *Per capita renewable water (FAO Aquastat)*	Per capita GDP; trade interdependence (ratio of trade between all agreement members to the total trade members engage with the world); regime type (Polity IV). Control variables: military alliances, history of MID in previous five years, power concentration (ICoW Material Capabilities composite index).	**Other** *Additive index of institutional features contained in each agreement: monitoring, enforcement, conflict resolution, international organisation from IFTD*
Theisen (2008)	**Aggregate national level**	**Global**	Neo-Malthusian: Expect environmental scarcity to limit capacity to cope with environmental stressors and increases the risk of civil war and armed conflicts.	**Physical water stress index** *Water per capita* **Threshold indicator** *Drought*	Land degradation (GLASOD); ongoing conflict in country.	**Crisis/ violent conflict** *> 25 battle-deaths per year, only if new onset is preceded by two or more years of peace.*
Theisen *et al*. (2010)	**Aggregate national level**	**Africa**	Neo-Malthusian: Expect drought to increase the local risk of civil war and expected to be a 'threat-multiplying' shock to already conflict-prone societies (i.e. ethno-political exclusion)	**Threshold indicator** *Drought: proportional change in rainfall from the previous years, % deviation from annual average (GPCC), binary drought indicator from UNEP, Standard Precipitation Index measuring negative deviations from normal rainfall during the previous 6 months (CRED, CRED).*	Political marginalisation of ethnic groups (Geo-Referencing of Ethnic Groups, Ethnic Power Relations) with a one-year lag to control for reverse causality. Control for population; distance to nearest international border, dummy variable for cells that contain a capital city; democracy (Polity IV); IMR; conflict history.	**Crisis/ violent conflict** *At least 25 battle-deaths /year (UCDP/PRIO)*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Theisen (2010)	**Intercommunity**	**Africa** *Kenya*	Neo-Malthusian: Expects both that drier years are more violent than wetter years. But, based on earlier research also expects drier years to be less violent than wetter years.	**Meteorological variable** *Spatial rainfall shortage using (GPCC): 1) percentage change in precipitation from t-1 to t; 2) deviation from mean rainfall in the cell.*	Population density (CIESIN Gridded Population of the World dataset), temperature (CRU TS 3.0), ethnicity (GREG), election year, non-monetary measure of poverty (1999 Population and Housing Census), dummy variable to capture whether the cell has one or more district national boundary or not.	**Crisis/ violent conflict** *Spatial data of non-state and one-sided violence that generated at least 25 deaths for a year. Dataset generated from reporting in Kenyan daily newspaper.*
Theisen & Brandsegg (2007)	**Intercommunity**	**Africa** *SSA*	Neo-Malthusian	**Meteorological variable** *5-year average precipitation, % change in precipitation for 2001-2005; standard deviation of precipitation within 2001-20005 (CPC, 2006).*	Population density and population change (CIESIN); infant mortality (CIESIN); state capacity (distance to national capital from centre of each grid). Controls: for spill-over effects; size of country in km2; democracy (Polity IV); time since last regime change.	**Crisis/ violent conflict** *Non-state conflict: "the use of armed force between two organised groups, neither of which is the government of a state, which results in at least 25 battle-related deaths" (Uppsala)*
Tir & Ackerman (2009)	**International** n=2	**Global**	Draws on realist, neoliberal neo-Malthusian theories.	**Physical water stress index** *Per capita freshwater availability (Engelman 2002)*	Alliances; strength of militarised threat; power distribution (material capabilities, ICoW); regime type (Polity IV); economic interdependence.	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Water quality and quantity treaties (IFTD, Wolf 2007).*
Toset (2000)	**International** *n=2*	**Global**	Neo-Malthusian: expect ceteris paribus, two contiguous nations with water are more likely to have conflictive behaviour.	**Threshold indicator** *<10,000m^3 per capita freshwater availability (surface and groundwater).*	Control for: regime type (Polity III); economic development (per capita energy consumption); major power; alliances (ICoW).	**Crisis/ violent conflict** *MID onset (ICoW).*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Witsenburg & Roba (2002)	**Intercommunity**	**Africa** *Kenya, Marsabit*	Neo-Malthusian	**Meteorological variable** *Annual rainfall* **Water stress index with social parameters** *Use and management of wells: ownership and access rights, allocation of water.* **Threshold indicator** *Drought during 2000*	None	**Crisis/ violent conflict** *Livestock raiding, armed attack, murder.*
Wolf (1998)	**International** n>2	Global	No model.	**Other** *Water events*	None	**Durable peace/ stable peace/ no significant conflict/ cooperation** *Signing of treaties.* **Crisis/ violent conflict** *Disputes (International Crisis Behaviour dataset, ICB) over scarce water resources. Disputes which were considered to be international crises defined as (1) basic national values are threatened (e.g. territory, influence, or existence), (2) time for making decisions is limited, and (3) the probability for military hostilities is high.*
Wutich (2009)	**Intracommunity**	**South America** *Bolivia, squatter settlement in Cochabamba.*	Common property management	**Meteorological variable** *Dry season.*	Home ownership; social relationships.	**Other** *Cooperative behaviour: percentage of respondents attending Neighbourhood Council meetings over five seasonal periods.*

Study	Spatial Scale	Country/ countries studied	Conceptual framework/ pathway	Independent variable measure (freshwater)	Other independent variables	Dependent variable measured
Yoffe (2003)	**International** *n=2; n>2*	**Global**	None	**Meteorological variable** *Precipitation.* **Physical water stress index** *Volume of freshwater availability per capita (WSI).* **Water stress index with social parameters** *Social Water Stress Index (WSI weighted by adaptive capacity HDI).*	GDP, GDP/capita, population density, overall relations, relative power, rate of population growth, no. of dams, dam density, basin area, no. basin countries, HDI, agriculture as a % of GDP, % labour force, hydropower.	**Other** *Water events (BAR scale).*

E.3 Assessment of study quality by scale of analysis

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Araral (2009)	**Intracommunity**	**Individuals** *Farmers within irrigation associations*	**Asia** *Philippines*	Collective action is associated with water scarcity, proximity to markets, group size, wealth and governance structures. Specifically, monetary free riding (lack of collective action) is associated with cropping intensity (water scarcity). Water scarcity has a curvilinear effect on monetary free riding - collective action is more difficult when water is either abundant or extremely scarce. IAs controlled by farmers are associated with lower levels of free-riding and mediates the effects of other variables (e.g. water scarcity and age of IA).	**Low**
Bardhan (2000)	**Intracommunity**	**Communities**: *Water users' organisations*	**Asia** *6 districts in Tamil Nadu*	Number of months in a year when there is access to water is positively and significantly related to the quality of the maintenance of distributaries and field channels. When there is more access to irrigation (for more time during the year) the return to investing effort in maintenance of field channels is higher and people are more likely to behave cooperatively and help maintain the channels.	**Low**
Bernauer et al (2010)	**Aggregate national level**	**State** **Civil society**	**Global** **Africa**	While there are some negative impacts of climate variables on the likelihood of conflict, the effect is not significant. Non-democratic nations are more likely to experience armed conflict when economic conditions deteriorate.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Brochmann & Gleditsch (2006a)	**International** *n=2*	**State**	**Global**	Drought has a positive impact on dependent variable. Dyads where one or both countries have been affected by drought are more likely to have a treaty. Higher probability of treaty existing if dyad has a history of peaceful relations and other kinds of cooperation measured (alliances [not significant] and memberships in IGOs). Probability of treaty existing in dyad increases with economic strength. Larger the % of basin in an upstream state, the greater the chances of a treaty being present. Neighbouring countries have more treaties. Conflictive as well as cooperative events tend to stimulate treaties, and treaties in turn contribute to water cooperation. Treaties also result from conflictive events. Treaties do not seem to inhibit future water conflictive events. A treaty signed two years prior to present may catalyse a conflictive event (although caution because of selection effect).	**Low (Moderate, for panel analysis)**
Brochmann & Gleditsch (2006b)	**International** *n=2*	**State**	**Global**	Dyads that share a basin where at least one of the countries have experienced drought during the past five years seem to trade more, but join less IGOs than other dyads. Sharing of a river is positively related to two general measures of interstate cooperation, trade and joint memberships of international organisations. These results are not strong. Conclude: scarcity, region and regime type matters. Additional factors not included may also be important (e.g. salience). Neo-Malthusian and cornucopian conceptual frameworks could both be correct. The two are not mutually exclusive. Previous conflict can contribute to later cooperation and vice versa. Conflict and cooperation can even come about at the same time.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Brochmann & Hensel (2008)	**International** n=2	**State**	**Central America; European Union** *Western Europe***; Middle East; North America; South America**	The availability of water is the most important factor when considering river interaction. Scarcity, higher demands on water, longer rivers, and cross-border rivers all increase the likelihood that riparian states will come into diplomatic conflict over a shared river. Scarcity and longer rivers increase the likelihood that states involved in such disagreements will negotiate to try to manage or settle the issues. Concludes: little evidence to support the water wars hypothesis and supports theory that states will seek to cooperate when an issue is considered vital. Relationship between democracy implies that negotiations may be hampered by lack of trust and insufficient information sharing.	**Low**
Buhaug & Theisen (2010)	**Aggregate national level**	**State** **Civil society**	**Africa**	None of the precipitation variables have a significant impact on conflict. But, weak evidence that drought two years before increased the risk of conflict. Population size has the most significant impact on conflict risk. Ethnopolitical exclusion is positively correlated to conflict risk. IMR and democracy are also positively correlated to the risk of civil war onset, but are not significant.	**Low**
Buhaug (2010)	**International** *n=2*	**State**	**Africa** *SSA*	No robust correlation between climate variability and civil war. The only model that produces a significant relationship is one that shows that major civil wars (years with at least 1,000 battle deaths) are more frequent in years following unusually wet periods, thus contradicting the scarcity-conflict hypothesis.	**Low**
Burke *et al* (2009)	**Aggregate national level**	**State; Civil society**	**Africa** *SSA*	Temperature change is significantly related to the likelihood of civil war. There is a weak relationship between precipitation and conflict. Argues temperature may be a better predictor of civil war.	**Low**
Burke *et al* (2010)	**Aggregate national level**	**State; Civil society**	**Africa** *SSA*	Robust relationship between climate change (both temperature and precipitation) and civil war, though this relationship has weakened recently (possibly due to economic and political changes), and the relationship is stronger for temperature than precipitation.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Couttenier and Soubeyran (2010)	**Aggregate national level**	**State; Civil Society**	**Africa** *SSA*	Find drought has a positive effect on the incidence of civil war over the period 1945-2005. The risk of civil war increases by more than 42% from a "normal" climate to an "extremely drought" climate. Only 2.5% of this effect is channelled through economic growth.	**Low**
Dayton-Johnson (2000)	**Intracommunity**	**Households** *members of water users association*	**Central America** *Mexico, Guanajuato*	Irrigation has a negative (though non-significant) effect on side-slope maintenance (one measure of cooperation). Social heterogeneity and landholding inequality however are significantly associated with lower maintenance in all measures of cooperation.	**Low**
De Stefano *et al* (2010)	**International** *n=2, n>2*	**State**	**Global**	International cooperation over transboundary river basins are more prevalent than conflict. However, dataset limited to English-language and therefore biased, particularly in relation to South America.Comparison between 1948-1999 and 2000-2008 suggests recent move towards less cooperative interactions between some countries, but this is not detected in the MENA region. Jordan, Tigris-Euphrates/Shatt al Arab, Danube and Ganges-Brahmamaputra-Meghna have reported an increase in positive events. Mekong has also reported an increase in event, but these have been cooperative. North America has experienced an increase in mild conflicts (legal) relating to water rights or treaties. However, infrastructure and water quality are consistently the most conflictive. Flood control, joint management and technical aspects, however have become increasingly cooperative. There has been an increase in groundwater disputes Almost all negative events reported between 2000-2008 were mild verbal expressions of discord through diplomatic-economic hostile actions. Nor was there any evidence of the extremes of the BAR scale.	**Low**
Dinar (2009)	**International** *n=2*	**State**	**Global**	Relationship between water scarcity and cooperation is an inverted U-shaped curve. At low levels of scarcity, cooperation (measured by international water agreements) is less likely. As scarcity rises, cooperation begins, but cooperation decreases again as the resource becomes scarce.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Dinar *et al* (2010)	**International** *n=2*	**State**	**Global**	Basin precipitation runoff variability explains the variance in the level of treaty cooperation across the analyzed basins: confirming the suggestions of an inverted U-shape of relationship between water variability and treaty cooperation. Diplomatic, trade relations support cooperation, while uneven economic power inhibits cooperation.	**Very High**
Dinar *et al* (2007)	**International** *n=2*	**State**	**Global**	Scarcity and cooperation have an inverted U curve relationship. Trade and governance are both significant in explaining cooperation.	**High**
Fayankinnu (2005)	**Intracommunity**	**Individuals**	**Africa** *Nigeria*	Water scarcity generates social conflict between "indigenes" and students in Akungba-Akoko	**Low**
Funder *et al* (2010)	**Intracommunity**	**Communities**	**Africa** *Namwala district, Zambia*	Local water competition situations often involve both conflictive and cooperative events often in a dynamic succession to one another (conflict leads to cooperation and vice versa). The majority of water events are conflictive and often take place at the intracommunity level between different types of water users rather than the same users (viz. pastoralists vs. crop-orientated livelihoods; gender; state-hydropower vs. pastoralists). Most conflictive events were low level oral disagreements or voicing protest Of the 183 recorded events, only one involved rioting and physical violence. Third party involvement tends to be primary local institutions such as Headmen.	**Low**
Furlong (2006)	**International** *n=2*	**State**	**Global**	Significant relationship between conflict and one or more shared rivers, and between water scarcity and conflict. No significant (weakly positive) relationship between boundary length and the risk of conflict. The presence of one or two major powers and peace history are negative correlated with conflict. No significance found for economic development or regime type.	**High**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Gizelis & Wooden (2011)	**Aggregate national level**	**State**	**Global**	Level of water scarcity does not have a significant impact on the probability of conflict. But institutions appear to influence the capacity of states to adapt to their freshwater needs by mitigating potential conflicts of interest that could escalate to intrastate wars. Water scarcity may also affect the nature and effectiveness of domestic institutions.	**Moderate**
Gleditsch *et al*. (2006)	**International** *n=2*	**State**	**Global**	There is no clear relationship between scarcity and MID. However, a shared basin (cross-boundary) is positively and significantly related to conflict; a river boundary is not (forms part of the state boundary). Most significant results are found the river salience. Argue that this may be due to the multiple benefits of river systems - good communications, hydropower, abundant fish and irrigation.	**Low**
Hamner (2009)	**International** *n=2 n>2*	**State**	**Global**	States are less likely to enter into water treaties (navigation/hydropower) during times of water stress. States more likely to enter into water treaty (water quality, quantity) or water sharing treaty when drought occurs/ remains below PDSI of -1. Bilateral treaties are more likely to come into being during drought shared by both signatory states. Concludes: water-specific cooperation more likely under conditions of water scarcity. Contradicts realist and Malthusian arguments.	**Very High**
Hauge & Ellingsden (1998)	**Aggregate national level**	**State**	**Global**	Low freshwater availability per capita, soil degradation, population density and deforestation are positively associated with incidence of civil war/armed conflict. Some evidence that environmental degradation is more important for the risk of armed conflicts rather than civil war. Countries suffering from environmental degradation are more prone to civil conflict. But, economic factors are more important in predicting domestic armed conflict than environmental factors.	**Moderate**
Hendrix & Glaser (2007)	**Aggregate national level**	**Civil society**	**Africa** *SSA*	Interannual variability of rainfall more significant determinant of conflict than climate, land degradation and water scarcity. Land degradation and climatic zone has no effect, long-term water scarcity decreases risk.	

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Hendrix & Salehyan (2010)	**Aggregate national level;** **Intercommunity**	**Communities** **Local/ regional government** **State** **Private sector** **Civil society** **Military**	**Africa** Africa-wide. Every country in Africa, including North Africa is coded.	More deviation from average rainfall, the greater the probability of violent events. But low rainfall increases probability of non-violent and government targeted events, while high rainfall leads to violent and non-government targeted events. Extremes (positive and negative) in rainfall have large effects on all types of political conflict. The relationship is strongest for violent conflict, which is more responsive to abundant than scarce rainfall. Argue this may be due to tactical considerations of rebel groups. Insurgents may be less likely to launch violent campaigns when there are severe water shortages. Supportive of hypothesis that discrete hydro-meteorological disasters are robustly associated with civil conflict or social conflict.	**Moderate (High, for Intercommunity level)**
Hensel & Brochmann (2007)	**International** n=2	**State**	**European Union:** *Western Europe* **Middle East** **North America** **South America**	Greater levels of water scarcity and greater demands on water increase risk of both claim onset and militarisation. Navigation claims, especially prone to lead to militarised conflict. River treaties significantly reduce militarisation. But, water allocation treaties significantly increase the risk of river claims over water quantity. Whereas water quality and navigation treaties 'almost perfectly' prevent the onset of river claims over their general subject matter. Claim militarisation is more likely over cross-border rivers and over claims that are more salient to the riparian states. Every militarised dispute over rivers in authors dataset involved a cross-border river. Democracies are better able to avoid river claims, but the effect was not significant for claim militarisation. Stronger upstream state is positively associated with increased risk of a claim onset. Conclusion: water availability and demand are crucial for the outbreak and militarisation of claims and river treaties have mixed effects.	**High**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Hensel *et al* (2006)	**International** n=2	**State**	**Global**	Greater water scarcity increases the likelihood of MID and peaceful third party settlement attempts. Argue MID more likely in water scarce regions where there is a high degree of salience, but less likely if contending states share membership in general or river-specific institutions. River-specific institutions reduce likelihood of MID and increase the effectiveness of peaceful settlement attempts.	**High**
Kevane & Leslie (2008)	**Aggregate national level**	**State** **Civil society**	**Africa** *Sudan, Darfur; Sahelian/ West Africa*	Rainfall in Darfur did not decline significantly in the years prior to the eruption of major conflict in 2003; rainfall exhibited a flat trend in the thirty years preceding the conflict (1972-2002). Preliminary analysis suggests little merit to the proposition that a structural break several decades earlier is a reasonable predictor of violence in Darfur.	**Low**
Levy *et al* (2005)	**Aggregate national level**	**State** **Civil society**	**Africa; Asia; Central America; Eastern Europe; Middle East; South America**	When rainfall was significantly below normal, the likelihood of conflict outbreak was higher the subsequent year. Regions with low levels of baseline water availability or high levels of variability are more likely to have conflicts than other regions. Strong relationship between rainfall deviations below normal and the likelihood of high-intensity conflict. No such correlation for low-intensity conflict.	**Low**
Makepe (2005)	**Intracommunity**	**Communities** *Members of 'borehole syndicates'.*	**Africa** *Botswana*	Water shortage during dry season has a positive and significant effect on aspects of cooperative behaviour (greater activity in meetings and number of meetings).	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Meier *et al* (2007)	**Intercommunity**	**Civil society**	**Africa** *Uganda, Ethiopia, Kenya*	No statistical significance between deaths and livestock losses and the independent variables, but was found for organised raids. Vegetation is positively correlated to the incidence of organised raids. There is no statistically significant relationship between rainfall and conflict. Argue that rainfall may be a too indirect measure of water availability. Conclude: aggravating behaviour along with a reduction in peace initiatives and reciprocal exchanges is associated with an escalation in pastoral conflict, especially when coupled with an increase in vegetation (cover and stronger livestock) for organised raids.	**Low**
Meinzen-Dick *et al.* (2005)	**Intracommunity**	**Communities**	**Asia** *Rajasthan and Karnataka, India*	No significant relationship is observed between any of the proxies for cooperation and water scarcity, although there is a significant and negative relationship between abundance and cooperation (collective representation proxy only).	**Low**
Raleigh & Urdal (2007)	**Aggregate national level**	**Civil society** **State**	**Global**	Population growth and density, associated with increased risk, effects of land degradation and water scarcity are weak, negligible or insignificant. The results indicate that the effects of political and economic factors far outweigh those between local level demographic/environmental factors and conflict.	**Very High**
Raleigh & Kniveton (2010)	**Intercommunity**	**Communities**	**Africa**	Increases in rainfall are significantly correlated to higher communal violence.	**Low**
Spector (2000)	**International** n=2	**State**	**Global**	The greater the difference in access to safe water between riparian states, the greater the incidence of treaty existence.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Stalley (2003)	**International** *n=2*	**State**	**Global**	Water is statistically insignificant - although does not use dyadic model. Regime type, not statistically significant. All state vulnerability to environmental scarcity indicators generate statistically insignificant result. Soil degradation one of more influential variables. Even when environmental factors controlled, population density significantly increases the likelihood of conflict. No support for fish stocks and MID. Concludes: States suffering from environmental conflict more likely to be involved in MID.	**Moderate**
Stinnett & Tir (2009)	**International** n=2; n>2	**State**	**Global**	Institutionalisation of river treaties is associated with water scarcity and trade interdependence and to a lesser extent flow pattern of shared rivers (upstream/downstream) and level of economic development.	**Very High**
Theisen (2008)	**Aggregate national level**	**State** **Civil society**	**Global**	Unable to replicate Hauge and Ellingsen (1998). Little evidence for water scarcity and drought-conflict connection, and relationship is close to insignificant. High level of soil degradation, have significant relationship with risk of conflict. Population density and growth have no effect. Level of development, population size, instability and dependence on oil exports significantly related to civil conflict. Level of democracy, ethno-linguistic fractionalisation not significant.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Theisen *et al*. (2010)	**Intercommunity**	**State** **Civil society**	**Africa**	Find virtually no relationship between 15 operationalisations of drought and civil conflict onset as well as several interactions with socio-political variables. Slightly reduced risk of conflict in areas with drought. No correlation between acute water shortage and increased risk of conflict. Location of civil war in Africa is best explained by: political, socioeconomic, geographic factors (population density, size of marginalized population), and breaks out disproportionately in politically marginalised areas. Conclusion: drought is unrelated to the short-term risk of civil war.	**Very High**
Theisen (2010)	**Intercommunity**	**Communities** **State**	**Africa** *Kenya*	In support of climatic influence on the risk of conflict incidence. Wetter years are less safe than drier ones. Some effect of higher temperatures increasing conflict risk. More densely populated areas run a higher risk of conflict - but this is restricted to election years when conflicts occur more frequently in central areas. Multiethnic areas and less developed areas are more at risk of conflict incidence.	**Very High**
Theisen & Brandsegg (2007)	**Intercommunity**	**Civil society**	**Africa** *SSA*	Higher levels in rainfall coincide with a higher risk of conflict onset. Marginalized regions also run a higher risk. No substantive evidence to suggest that that changes in levels rather than changes in pressure on renewable resources are more related to conflict. Regions worse off in material terms are not affected harder by scarcities than other regions. Tentatively conclude that the risk of non-state conflicts is somewhat heightened by decreasing access to renewable resources.	**Very High**
Tir & Ackerman (2009)	**International** n=2	**State**	**Global**	Water scarcity, power distributions, economic interdependence, democratic governance all increase the likelihood that states will sign river treaties. Upstream/downstream relationships are insignificant. However, conclude that results imply that developing nations may be more at risk from conflict.	**High**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Toset *et al*. (2000)	I**nternational** *n=2*	**State**	**Global**	A joint rivers increase the probability of a militarised and armed conflict. Dyads with water scarcity are estimated to have roughly 4 times higher risk of conflict than dyads without. Water scarcity is positively related to conflict, particularly when a river is shared across rather than along a border - the upstream/downstream relationship appears to be the form of shared water most frequently associated with conflict. The results are not particularly significant, however.	**Moderate**
Witsenburg & Roba (2002)	**Intercommunity**	**Individuals Households Communities**	**Africa** *Kenya, Marsabit*	Do not find a relationship between conflicts and increasing scarcity of water. There is less violence in drought years than wet years. Although this may indicate a strategic or lagged response. People do not engage in violent conflict over access to water resources. During drought years, cooperation is more likely to the extent that when a drought is expected, warring communities often reconcile in order to share water and pasture. Suggest that during wet years, when more conflicts are observed, may indicate opportunism (livestock are better fed, raiding is easier due to vegetation to hide in and surface water for trekking with livestock), and labour surplus means young men are free to raid. Raiding often occurs at wells, but because they are profitable places ot raid, but not due to access.	**Low**
Wolf (1998)	**International** *n>2*	**State**	**Global**	Even minor skirmishes are found in this century; no war has ever been fought over water. In contrast, 145 water-related treaties were signed in the same period. Cooperation over water, including signing of treaties, outweighed conflict over water and violent conflict in particular.	**Low**
Wutich (2009)	**Intracommunity**	**Individuals**	**South America** *Bolivia, squatter settlement in Cochabamba.*	Community operated according to principles of CPR management institutions. Flexibility in rules for water allotment allowed CPR to be managed adaptively during dry seasons but this did not undermine fairness, equity and subsistence ethic. Findings suggest that indicates that well-organized community common pool resource institutions have ability to remain ecologically and socially sustainable during periods of water stress.	**Low**

Study	Spatial Scale	Population focus	Country/ countries studied	Account of result	Overall study assessment
Yoffe (2003)	**International** *n=2; n>2*	**State**	**Global**	International relations over water are overwhelming cooperative. Where acute conflict is reported, it is related to infrastructure or water quantity, but these instances only involved bilateral interactions. No single indicator - water stress, climate, government type, dependence over water for agricultural or energy needs can explain conflict/cooperation in a basin. Arid regions, not found to be substantially less cooperative than other climatic zones. Most cooperative years were those where rainfall was close to average. Very dry years marginally more cooperative than wet or very wet years. Suggest that may not be overall climate or average precipitation that provides an indicator of conflict, but the occurrence of extremes (physical or institutional changes) or level of uncertainty concerning available water resources in the basin. International relations over freshwater resources were overwhelmingly cooperative and covered a wide range of issues, including water quantity; water quality, joint management, and hydropower. Conflictive relations tended to centre on quantity and infrastructure. No single indicator explained conflict/cooperation over water. Even indicators showing a significant correlation with water conflict, such as high population density, low per capita GDP, and overall unfriendly international relations, explained only a small percentage of data variability. The most promising sets of indicators for water conflict were those associated with rapid or extreme physical or institutional change within a basin and the key role of institutional mechanisms, such as freshwater treaties, in mitigating such conflict.	**Low**

E.4 Study by scale of analysis, region, conceptual framework, outcome and total confidence assessment score

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Araral (2009)	**Intracommunity**	**Asia** *Philippines*	Common resource management: Collective action outcomes are shaped by the incentive structure faced by the players which is in turn affected by the context they face. The context is defined by the physical characteristic of the resource, the attributes of the players and the internal and external institutional context.	Find that collective action is associated with water scarcity, proximity to markets, group size, farm size and governance structure. The author finds that water scarcity has a curvilinear effect on collective action and is mediated by the governance structure.	**Low**
Bardhan (2000)	**Intracommunity**	**Asia** *6 districts in Tamil Nadu*	Common property management: no clear hypothesis, but expect that in conditions of extreme scarcity, arrangements of cooperation may break down, whilst during times of abundance, there is a greater incentive to cooperate	Number of months in a year when there is access to water is positively and significantly related to the quality of the maintenance of distributaries and field channels. When there is more access to irrigation (for more time during the year) the return to investing effort in maintenance of field channels is higher and people are more likely to behave cooperatively and help maintain the channels.	**Low**
Bernauer *et a*.l (2010)	**Aggregate national level**	**Global** **Africa**	Rainfall and temperature indirectly lead to conflict through changes in economic growth. Uses rainfall/ temperature as IV, by first examining relationship between rainfall and economic growth in an econometric model.	Rainfall and temperature indirectly lead to conflict through changes in economic growth.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Brochmann and Gleditsch (2006a)	**International** *n=2*	**Global**	No model or hypothesis.	Drought has a positive impact on the dependent variable. Dyads where one or both countries have been affected by drought are more likely to have a treaty. There is a higher probability of treaty existence if the dyad has a history of peaceful relations and other proxies of cooperation. The probability of treaty existing in the dyad increases with economic strength. Larger	**Low (Moderate, for panel analysis)**
Brochmann & Gleditsch (2006b)	**International** *n=2*	**Global**	Cornucopian framework: Shared rivers are likely to promote cooperation as well as conflict.	Find that sharing a river is related to general measures of positive interstate interaction (trade, alliances and joint membership in international organisations) as well as low-level conflict.	**Low**
Brochmann & Hensel (2008)	**International** n=2	**Central America; European Union** *Western Europe***; Middle East; North America; South America**	Neo-liberal: expect claims most likely to occur when water is scarce, the river is long (proxy for river salience), river crosses international boundary rather than acts as a border but likely to experience peaceful settlements. River claims are less likely to begin when river treaties already exist.	The availability of water is the most important factor when considering river interaction. Scarcity, higher demands on water, longer rivers, and cross-border rivers all increase the likelihood that riparian states will come into diplomatic conflict over a shared river. Scarcity and longer rivers increase the likelihood that states involved in such disagreements will negotiate to try to manage or settle the issues. States will seek to cooperate when an issue is considered vital. The relationship between democracy implies that negotiations may be hampered by lack of trust and insufficient information sharing.	**Low**
Buhaug & Theisen (2010)	**Aggregate national level**	**Africa**	Neo-Malthusian: Expect drier years to be associated with higher civil war risk	None of the precipitation variables have a significant impact on conflict. But, weak evidence that drought two years before increased the risk of conflict. Population size has the most significant impact on conflict risk. Ethnopolitical exclusion is positively correlated to conflict risk. IMR and democracy are also positively correlated to the risk of civil war onset, but are not significant.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Buhaug (2009)	**Aggregate national level**	**Africa** *SSA*	Based on neo-Malthusian framework, but no model or hypothesis.	No robust correlation between climate variability and civil war. The only model that produces a significant relationship is one that shows that major civil wars (years with at least 1,000 battle deaths) are more frequent in years following unusually wet periods, thus contradicting the scarcity-conflict hypothesis.	**Low**
Burke *et al* (2009)	**Aggregate national level**	Africa: *SSA*	No clear model but, broadly neo-Malthusian/ eco-violence framework. Expect variability in temperature and precipitation in highly dependent rain-fed areas leads to conflict due to reductions in agriculture performance.	Temperature change is significantly related to the likelihood of civil war. There is a weak relationship between precipitation and conflict. Argues temperature may be a better predictor of civil war.	**Low**
Burke *et al* (2010)	**Intracommunity**	Africa: *SSA*	Neo-Malthusian, no clear hypothesis	Robust relationship between climate change (both temperature and precipitation) and civil war, though this relationship has weakened recently (possibly due to economic and political changes), and the relationship is stronger for temperature than precipitation.	**Low**
Couttenier and Soubeyran (2010)	**Aggregate national level**	**Africa** *SSA*	Neo-Malthusian, no clear hypothesis	Find drought has a positive effect on the incidence of civil war over the period 1945-2005. The risk of civil war increases by more than 42% from a "normal" climate to an "extremely drought" climate. Only 2.5% of this effect is channelled through economic growth.	**Low**
Dayton-Johnson (2000)	**Intracommunity**	**Central America** *Mexico, Guanajuato*	Common property management: Expects irrigation supply to be positively associated with a proxy of collective action (irrigation canal maintenance).	Irrigation has a negative (though non-significant) effect on side-slope maintenance (one measure of cooperation). Social heterogeneity and landholding inequality however are significantly associated with lower maintenance in all measures of cooperation.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
De Stefano *et al* (2010)	**International** *n=2*	Global	n/a	Water quantity and infrastructure were the most controversial water events, but comparison of 1948-1999 hydro political relations to 2000-2008 shows cooperation is dominant outcome from reported water events, including those in the MENA region.	**Low**
Dinar (2009)	**International** *n=2*	**Global**	Scarperation: Expect cooperation to be most likely during moderate scarcity, and decreases during low scarcity and high-levels of scarcity - termed 'Scarperation'. As such the relationship between scarcity and the likelihood of cooperation follows a curvilinear trend.	Relationship between water scarcity and cooperation is an inverted U-shaped curve. At low levels of scarcity, cooperation (measured by international water agreements) is less likely. As scarcity rises, cooperation begins, but cooperation decreases again as the resource becomes scarce.	**Low**
Dinar *et al* (2010)	**International** *n=2*	**Global**	Scarperation: Expect cooperation to be most likely during moderate levels of water supply variability and decreases during low and high levels of water supply variability - termed 'Scarperation'. As such the relationship between scarcity and the likelihood of cooperation follows a curvilinear trend.	Basin precipitation runoff variability explains the variance in the level of treaty cooperation across the analyzed basins: confirming the suggestions of an inverted U-shape of relationship between water variability and treaty cooperation. Diplomatic, trade relations support cooperation, while uneven economic power inhibits cooperation.	**Very High**
Dinar *et al* (2007)	**International** *n=2*	**Global**	Scarperation: Expect long-term water supply variability will lead to enduring cooperation between river riparians	Scarcity and cooperation have an inverted U curve relationship. Trade and governance are both significant in explaining cooperation.	**High**
Fayankinnu (2005)	**Intracommunity**	**Africa** *Nigeria*	Neo-Malthusian	Water scarcity generates social conflict between "indigenes" and students in Akungba-Akoko	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Funder *et al* (2010)	**Intracommunity**	**Africa** *Namwala district, Zambia*	Observational study, no theoretical framework presented.	Water-related conflict and cooperation takes place in response to situations of actual or potential competition (situations in which two or more parties seek access to the same water resources). At times, such conflict or cooperation is latent, while at other times it is expressed as "water events".	**Low**
Furlong (2006)	**International** *n=2*	**Global**	Neo-Malthusian: expect, ceteris paribus, countries with water scarcity are more likely to exhibit dyadic conflict. And, water scarcity increases the extent to which river sharing is associated with dyadic conflict behaviour	Significant relationship between conflict and one or more shared rivers, and between water scarcity and conflict. No significant (weakly positive) relationship between boundary length and the risk of conflict. The presence of one or two major powers and peace history are negative correlated with conflict. No significance found for economic development or regime type.	**High**
Gizelis & Wooden (2011)	**Aggregate national level**	**Global**	Neo-Malthusian: expect water resource scarcity to increase the probability of intrastate wars; and water resource scarcity to contribute to the emergence of autocratic regimes.	Level of water scarcity does not have a significant impact on the probability of conflict. But institutions appear to influence the capacity of states to adapt to their freshwater needs by mitigating potential conflicts of interest that could escalate to intrastate wars. Water scarcity may also affect the nature and effectiveness of domestic institutions.	**Moderate**
Gleditsch *et al*. (2006)	**International** *n=2*	**Global**	Neo-Malthusian: expect dyads with an unequal distribution of shared water resources to have more conflict; dyads sharing a river basin have more conflict if one or both of the countries in the dyads have low rainfall; dyads sharing a river basin have more conflict if one or both of the countries in the dyad have recently experienced drought.	There is no clear relationship between scarcity and MID. However, a shared basin (cross-boundary) is positively and significantly related to conflict; a river boundary is not (forms part of the state boundary). Most significant results are found the river salience. Argue that this may be due to the multiple benefits of river systems - good communications, hydropower, abundant fish and irrigation.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Hamner (2009)	**Aggregate national level**	**Global**	Prospect: Expects a state experiencing a period of acute scarcity to experience an increase in the likelihood of the formation of a treaty addressing water issues with an adjacent state, compared to a state sharing a water resource that is not experiencing acute scarcity.	States are less likely to enter into water treaties (navigation/hydropower) during times of water stress. States more likely to enter into water treaty (water quality, quantity) or water sharing treaty when drought occurs/ remains below PDSI of -1. Bilateral treaties are more likely to come into being during drought shared by both signatory states. Concludes: water-specific cooperation more likely under conditions of water scarcity. Contradicts realist and Malthusian arguments.	**Very High**
Hauge & Ellingsden (1998)	**Aggregate national level**	**Africa** *SSA*	Neo-Malthusian: expect countries with a low freshwater availability per capita to be more likely to experience domestic armed conflict than countries with a high freshwater availability per capita	Low freshwater availability per capita, soil degradation, population density and deforestation are positively associated with incidence of civil war/armed conflict. Some evidence that environmental degradation is more important for the risk of armed conflicts rather than civil war. Countries suffering from environmental degradation are more prone to civil conflict. But, economic factors are more important in predicting domestic armed conflict than environmental factors.	**Moderate**
Hendrix & Glaser (2007)	**Aggregate national level**	**Africa**	Neo-Malthusian: Expects that higher levels of rainfall relative to previous years will be associated with higher returns to agriculture and therefore lower risk of conflict.	Interannual variability of rainfall more significant determinant of conflict than climate, land degradation and water scarcity. Land degradation and climatic zone has no effect, long-term water scarcity decreases risk.	**Moderate**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Hendrix & Salehyan (2010)	**Aggregate national level; Intercommunity**	**Africa**	Does not provide a formal model, but discusses five plausible mechanisms. Hydro-meteorological disasters may lead to: conflict between consumers due to water salience or desertification; price disputes between rural producers and urban consumers and food price inflation; migration from stressed areas may lead to competition for resources, employment and cultural tensions; strains on government revenues due to the reduction of the tax base and increase demands for services and assistance from disasters ; negative macroeconomic impacts may lead to civil conflict and social disorder.	The greater the deviation from average rainfall, the greater the probability of violent events. But low rainfall increases probability of non-violent and government targeted events, while high rainfall leads to violent and non-government targeted events. Extremes (positive and negative) in rainfall have large effects on all types of political conflict. The relationship is strongest for violent conflict, which is more responsive to abundant than scarce rainfall. Argue this may be due to tactical considerations of rebel groups. Insurgents may be less likely to launch violent campaigns when there are severe water shortages.	**Moderate (High, for Intercommunity level)**
Hensel & Brochmann (2007)	**International** *n=2*	**Global**	High levels of water scarcity increase the frequency of explicit claims over water, increase chances of militarized conflict, and make it more difficult for conflict management institutions to be effectively created.	Greater levels of water scarcity and greater demands on water increase risk of both claim onset and militarisation. Navigation claims, especially prone to lead to militarised conflict. River treaties significantly reduce militarisation. But, water allocation treaties significantly increase the risk of river claims over water quantity. Whereas water quality and navigation treaties 'almost perfectly' prevent the onset of river claims over their general subject matter. Claim militarisation is more likely over cross-border rivers and over claims that are more salient to the riparian states. Every militarised dispute over rivers in authors dataset involved a cross-border river. Democracies are better able to avoid river claims, but the effect was not significant for claim militarisation. Stronger upstream state is positively associated with increased risk of a claim onset.	**High**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Hensel *et al* (2006)	**International** *n=2*	**Africa; Asia; Central America; Eastern Europe; Middle East; South America**	Variant of neo-Malthusian arguments of scarcity leading to conflict due to weak institutional capacity, deprivation and grievance.	Greater water scarcity increases the likelihood of MID and peaceful third party settlement attempts. Argue MID more likely in water scarce regions where there is a high degree of salience, but less likely if contending states share membership in general or river-specific institutions. River-specific institutions reduce likelihood of MID and increase the effectiveness of peaceful settlement attempts.	**High**
Kevane & Leslie (2008)	**Aggregate national level**	**Africa** *Sudan, Darfur; Sahelian/ West Africa*	None provided	Rainfall in Darfur did not decline significantly in the years prior to the eruption of major conflict in 2003; rainfall exhibited a flat trend in the thirty years preceding the conflict (1972-2002). Preliminary analysis suggests little merit to the proposition that a structural break several decades earlier is a reasonable predictor of violence in Darfur.	**Low**
Levy *et al* (2005)	**Aggregate national level**	**Global**	Expect regions with low levels of baseline water availability to be more prone to conflict than other regions; contiguous or near-contiguous regions that exhibit significant disparities in baseline levels of water availability are more prone to conflict than other regions; regions with high levels of variability on available water are more prone to conflict than other regions; deviations from baseline water availability that result in significant disparities across regions will experience more conflict than other regions.	When rainfall was significantly below normal, the likelihood of conflict outbreak was higher the subsequent year. Regions with low levels of baseline water availability or high levels of variability are more likely to have conflicts than other regions. Strong relationship between rainfall deviations below normal and the likelihood of high-intensity conflict. No such correlation for low-intensity conflict.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Makepe (2005)	**Intracommunity**	**Africa** *Botswana*	Common Property Management. Specifically: water shortages during the dry season have a positive impact on collective actions (since reliance on borehole during this period raises the stakes for members to act collectively to ensure that water is available on a permanent basis).	Water shortage during dry season has a positive and significant effect on aspects of cooperative behaviour (greater activity in meetings and number of meetings).	**Low**
Meier *et al* (2007)	**Intercommunity**	**Africa** *Uganda, Ethiopia, Kenya*	Neo-Malthusian: Expect that environmental variability drives pastoral migration and competition over dwindling resources critical to livelihoods, which in turn may lead to the use of violence to secure these resources.	No statistical significance between deaths and livestock losses and the independent variables, but was found for organised raids. Vegetation is positively correlated to the incidence of organised raids. There is no statistically significant relationship between rainfall and conflict. Argue that rainfall may be a too indirect measure of water availability. Conclude: aggravating behaviour along with a reduction in peace initiatives and reciprocal exchanges is associated with an escalation in pastoral conflict, especially when coupled with an increase in vegetation (cover and stronger livestock) for organised raids.	**Low**
Meinzen-Dick *et al.* (2005)	**Intracommunity**	**Asia** *Rajasthan and Karnataka, India.*	Common resource management: Expect a curvilinear relationship between scarcity (location along irrigation canal) and cooperation and less cooperation where farmers are less reliant on irrigation canals (i.e. in wetter regions)	No significant relationship is observed between any of the proxies for cooperation and water scarcity, although there is a significant and negative relationship between abundance and cooperation (collective representation proxy only).	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Raleigh & Urdal (2007)	**Aggregate national level**	**Global**	Neo-Malthusian: expect areas with high freshwater scarcity are more likely to experience armed conflict the greater the population growth.	Population growth and density, associated with increased risk, effects of land degradation and water scarcity are weak, negligible or insignificant. The results indicate that the effects of political and economic factors far outweigh those between local level demographic/environmental factors and conflict.	**Very High**
Raleigh & Kniveton (2010)	**Intercommunity**	**Africa** *Kenya*	Unclear / implicitly eco-violence: Expect communal violence may become more common as the adverse effects of direct climate change may be disproportionately felt amongst the smaller, economically and politically marginalised across arid and semi-arid lands.	Find a relationship between high rainfall patterns and conflict.	**Low**
Spector (2000)	**International** *n=2; n>2*	**Global**	Unclear, but hypothesises: situational factors that point to joint utilisation of the water resource are likely to push parties towards a negotiated state	Results suggest that inequality among riparian states across a wide range of physical, economic and social dimensions increases the incidence of international and regional agreements	**Low**
Stalley (2003)	**International** *n=2*	**Global**	States experiencing environmental scarcity are more likely to be involved in international conflict.	Water is statistically insignificant - although does not use dyadic model. Regime type, not statistically significant. All state vulnerability to environmental scarcity indicators generate statistically insignificant result. Soil degradation one of more influential variables. Even when environmental factors controlled, population density significantly increases the likelihood of conflict. No support for fish stocks and MID. Concludes: States suffering from environmental conflict more likely to be involved in MID.	**Moderate**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Stinnett & Tir (2009)	**International** *n=2; n>2*	**Global**	Neoliberal theoretical framework. Institutionalisation of river treaties depend on the urgency (degree of scarcity) to cooperate and contextual political factors. High levels of institutionalisation will be difficult to achieve in the absence of factors that make it desirable.	Institutionalisation of river treaties is associated with water scarcity and trade interdependence and to a lesser extent flow pattern of shared rivers (upstream/downstream) and level of economic development.	**Very High**
Theisen (2008)	**Aggregate national level**	**Global**	Neo-Malthusian: Expect environmental scarcity to limit capacity to cope with environmental stressors and increases the risk of civil war and armed conflicts.	Unable to replicate Hauge and Ellingsen (1998). Little evidence for water scarcity and drought-conflict connection, and relationship is close to insignificant. High level of soil degradation, have significant relationship with risk of conflict. Population density and growth have no effect. Level of development, population size, instability and dependence on oil exports significantly related to civil conflict. Level of democracy, ethno-linguistic fractionalisation not significant.	**Low**
Theisen *et al*. (2010)	**Aggregate national level**	**Africa**	Neo-Malthusian: Expect drought to increase the local risk of civil war and expected to be a 'threat-multiplying' shock to already conflict-prone societies (i.e. ethno-political exclusion)	Find virtually no relationship between 15 operationalisations of drought and civil conflict onset as well as several interactions with socio-political variables. Slightly reduced risk of conflict in areas with drought. No correlation between acute water shortage and increased risk of conflict. Location of civil war in Africa is best explained by: political, socioeconomic, geographic factors (population density, size of marginalized population), and breaks out disproportionately in politically marginalised areas. Conclusion: drought is unrelated to the short-term risk of civil war.	**Very High**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Theisen (2010)	**Intercommunity**	**Africa** *Kenya*	Neo-Malthusian: Expects both that drier years are more violent than wetter years. But, based on earlier research also expects drier years to be less violent than wetter years.	In support of climatic influence on the risk of conflict incidence. Wetter years are less safe than drier ones. Some effect of higher temperatures increasing conflict risk. More densely populated areas run a higher risk of conflict - but this is restricted to election years when conflicts occur more frequently in central areas. Multiethnic areas and less developed areas are more at risk of conflict incidence.	**Very High**
Theisen & Brandsegg (2007)	**Intercommunity**	**Africa** *SSA*	Neo-Malthusian	Higher levels in rainfall coincide with a higher risk of conflict onset. Marginalized regions also run a higher risk. No substantive evidence to suggest that that changes in levels rather than changes in pressure on renewable resources are more related to conflict. Regions worse off in material terms are not affected harder by scarcities than other regions. Tentatively conclude that the risk of non-state conflicts is somewhat heightened by decreasing access to renewable resources.	**Very High**
Tir & Ackerman (2009)	**International** n=2	**Global**	Draws on realist, neoliberal neo-Malthusian theories.	Water scarcity, power distributions, economic interdependence, democratic governance all increase the likelihood that states will sign river treaties. Upstream/downstream relationships are insignificant. However, conclude that results imply that developing nations may be more at risk from conflict.	**High**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Toset (2000)	**International** *n=2*	**Global**	Neo-Malthusian: expect ceteris paribus, two contiguous nations with water are more likely to have conflictive behaviour.	A joint rivers increase the probability of a militarised and armed conflict. Dyads with water scarcity are estimated to have roughly 4 times higher risk of conflict than dyads without. Water scarcity is positively related to conflict, particularly when a river is shared across rather than along a border - the upstream/downstream relationship appears to be the form of shared water most frequently associated with conflict. The results are not particularly significant, however.	**Moderate**
Witsenburg & Roba (2002)	**Intercommunity**	**Africa** *Kenya, Marsabit*	Neo-Malthusian	Do not find a relationship between conflicts and increasing scarcity of water. There is less violence in drought years than wet years. Although this may indicate a strategic or lagged response. People do not engage in violent conflict over access to water resources. During drought years, cooperation is more likely to the extent that when a drought is expected, warring communities often reconcile in order to share water and pasture. Suggest that during wet years, when more conflicts are observed, may indicate opportunism (livestock are better fed, raiding is easier due to vegetation to hide in and surface water for trekking with livestock), and labour surplus means young men are free to raid. Raiding often occurs at wells, but because they are profitable places ot raid, but not due to access.	**Low**
Wolf (1998)	**International** n>2	Global	No model.	Even minor skirmishes are found in this century; no war has ever been fought over water. In contrast, 145 water-related treaties were signed in the same period. Cooperation over water, including signing of treaties, outweighed conflict over water and violent conflict in particular.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Wutich (2009)	**Intracommunity**	**South America** *Bolivia, squatter settlement in Cochabamba.*	Common property management	Community operated according to principles of CPR management institutions. Flexibility in rules for water allotment allowed CPR to be managed adaptively during dry seasons but this did not undermine fairness, equity and subsistence ethic. Findings suggest that indicates that well-organized community common pool resource institutions have ability to remain ecologically and socially sustainable during periods of water stress.	**Low**

Study	Spatial Scale	What country/ countries were studied	Theoretical framework/ pathway	Outcome	Overall study assessment
Yoffe (2003)	**International** *n=2; n>2*	**Global**	None	International relations over water are overwhelming cooperative. Where acute conflict is reported, it is related to infrastructure or water quantity, but these instances only involved bilateral interactions. No single indicator - water stress, climate, government type, dependence over water for agricultural or energy needs can explain conflict/cooperation in a basin. No single indicator explained conflict/cooperation over water. Even indicators showing a significant correlation with water conflict, such as high population density, low per capita GDP, and overall unfriendly international relations, explained only a small percentage of data variability. Arid regions, not found to be substantially less cooperative than other climatic zones. Most cooperative years were those where rainfall was close to average. Very dry years marginally more cooperative than wet or very wet years. Suggest that may not be overall climate or average precipitation that provides an indicator of conflict, but the occurrence of extremes (physical or institutional changes) or level of uncertainty concerning available water resources in the basin. The most promising sets of indicators for water conflict were those associated with rapid or extreme physical or institutional change within a basin and the key role of institutional mechanisms, such as freshwater treaties, in mitigating such conflict.	**Low**

Appendix F – Full references of included documents

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Appendix G – Full references of studies excluded as unable to source at full text

For all studies published in 2005 onwards, we contacted the author to request a copy of the study.

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